EMERGENCY DEPARTMENT CROWDING AND ITS IMPACT ON THE CLINICAL CARE AND MORTALITY OUTCOMES OF STROKE PATIENTS AT THE TEMA GENERAL HOSPITAL IN GHANA

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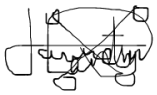
DECLARATION

This is to certify that the copy of my thesis, which I have presented for consideration for my postgraduate degree embodies solely the results of my own course of study and research. It has been composed entirely by me and has been granted the appropriate level of ethics approval. This thesis has not been submitted for any other degree or professional qualification. Except where it states otherwise by reference or acknowledgement, the thesis presented is entirely my own.



08 January 2024

LIST OF ABBREVIATIONS

ACEP……..American College of Emergency Physicians

ACEM…….Australasian College for Emergency Medicine

AF…….Atrial Fibrillation

AI……. Artificial Intelligence

AOR……Adjusted Odds Ratio

APVU……Alert Voice Pain Unresponsiveness

BE-FAST……...Balance, Eyes, Face, Arm, Speech Time

BP.....Blood Pressure

BI……Barthel Index

BMI……...Body Mass Index

CAEP……Canadian Association of Emergency Physicians

CEDOCS..... Community Emergency Department Overcrowding Study

CI……..……Confidence Interval

COPD.....Chronic Obstructive Pulmonary Diseases

CPSS……Cincinnati Prehospital Stroke Scale

CT .....Computerised Tomography

CTA…….Computer Tomography Angiograph

CTP…….....Computer Tomography Perfusion

CVA…….Cerebrovascular Accident

CVD ..... Cardiovascular Disease

CXR……...……..Chest X-Ray

DALYs…….……Disability Adjusted Life Years

DBP……...…Diastolic Blood Pressure

DCTC…….Door to Computer Tomography Completion Time

DET……..…..……...……Data Extraction Tool

DHMIS……District Health Management Information System

DTA……..…….Decision to Assessment Time

DWI……..…Diffused Weighted Imaging

ECG……..…….…….…….……Electrocardiograph

e-DET…….…… ……...……Electronic Data Extraction Tool

ED .....Emergency Department

ED LOS……..Emergency Department Length of Stay

EDWIN .....Emergency Department Work Index

EPV .....Events Per Variable

ESI…….…….……Emergency Severity Index

FAST……...…… Face Arm Speech Time

GBD…….……...…..……Global Burden of Disease

GCS..... Glasgow Coma Score

GDHS…….……..Ghana Demographic Health Survey

GEMC……..Ghana Emergency Medicine Collaborative

GenHAT……...Genetic of Hypertension Associated Treatments

GGT……..…….……...Gamma-glutamyl Transferase

GHS.....Ghana Health Service

HIC……...…….……...High Income countries

HIV…….……...……...Human Immunodeficiency Virus

HS…….……..……....Haemorrhagic Stroke

ICD……...……International Classification of Disease

ICH……...……Intracerebral Haemorrhage

IFEM……..International Federation for Emergency Medicine

IS……..……...……...Ischaemic Stroke

KBTH……...……..…..…Korle Bu Teaching Hospital

K-MBI……Korean Modified Barthel Index

LIC…….…….……Low Income Country

LMIC.....Lower Middle Income Country

LOS……...…Length of Stay

Med PACS……..……Medic Prehospital Assessment for Code Stroke

MCCOD……..……..Medical Certificate Cause of Death

MOH ..... Ministry of Health

MPH.....Master of Public Health

MRI…….…….…….……Magnetic Resonance Imaging

mRS.....Modified Rankin Scale

NCD……Non-Communicable Disease

NEDOCS…….…...National Emergency Department Overcrowding Score

NECT……Non-contrast Enhanced Computer Tomography

NICE……..….National Institute of Health Care Excellence

NIH…….……...…….…...National Institute of Health

NHIS……..……National Health Insurance Scheme

NIHSS…….……..National Institute of Health Stroke Scale

OR…….……..…Odds Ratio

PreHAST……..PreHospital Ambulance Stroke Test

RCEM……...…….……..…Royal College of Emergency Medicine

READI ..... Real-time Emergency Analysis of Demand Indicators

REGARDS……Reasons for Geographic and Racial Differences in Stroke

rTPA…….....Recombinant Tissue Plasminogen Activator

TBI……...Traumatic Brain Injury

TIA……Transient Ischaemic Attack

SAH…….Subarachnoid Haemorrhage

tPA…….……Tissue Plasminogen Activator

SATS..... South African Triage Scale

SBP…….Systolic Blood Pressure

SPSS……...Statistical Package for the Social Sciences

SSNIT……..……...…...Social Security and National Insurance Trust

SIREN……..…Stroke Investigation Research and Educational Network

SONET..... Severely Overcrowded-Overcrowded-Not Overcrowded Estimation Tool

SSA…….……...…….…....Sub-Saharan Africa

TBI……...Traumatic Brain Injury

TGH .....Tema General Hospital

TEWS.....Triage Early Warning Score

TIA..... Transient Ischaemic Attack

UK…….United Kingdom

UI…….……Uncertainty interval

UN.....United Nations

UMIC…….……Upper Middle-Income Country

UoS……..……..University of Salford

USA…….…….United States of America

WHO ..... World Health Organization

YLDs…….....……..……Years of Healthy Life lost due to Disability

YLLs……..…...Years of Life Lost due to premature mortality

GLOSSARY OF TERMS

Term	Description
Active member of the national health insurance scheme (NHIS)	A member of the NHIS who has fulfilled all financial obligations to enable access to health care
Age adjusted rates	They are rates that would have existed if the population under study had the same age distribution as the "standard" population. A standard population distribution is used to adjust the deaths rates
All-cause mortality rate	The number of deaths due to all conditions by the mid-year population
Cause	A single disease or injury or an aggregation of diseases and injuries that causes death or disability
Cause-specific mortality rate	The number of deaths due to cause divided by the mid-year population
Case fatality	The proportion of people who die from a specified disease among all individuals diagnosed with the disease over a certain period of time
Crude rates	Calculated as the number of events (numerator) divided by the population at risk (denominator). It gives an idea of the total burden of a health outcome to a community or specified population
Deaths	Deaths occurring in a population during a certain period
Disability-adjusted life years (DALYs)	The sum of years lost due to premature death (YLLs) and years lived with disability (YLDs). DALYs are also defined as years of healthy life lost
Expected value (life expectancy, deaths, YLLs, YLDs, DALYs)	The value of a specified measure (life expectancy, deaths, YLLs, YLDs, or DALYs) that is expected for a particular GBD location and year, given its socio-demographic development status as measured by SDI
Hemiplegia	Weakness of one entire side of the body
House officer	Medical doctor freshly graduated from medical school and undertaking internship in the first year

Incidence	Refers to the occurrence of new cases of disease or injury in a population over a specified period of time
Life expectancy	The number of years a person is expected to live at a given age assuming he or she will experience the age-specific mortality rate observed in a given year throughout his or her lifetime. For GBD, the life expectancy associated with an age group (example, 50- to 54-year-olds) is life expectancy at the starting year of the age group
Lipid profile	A panel of blood test used to find abnormalities in lipids such as cholesterol and triglycerides
Medical Officer	A senior house officer who has complete two years of intension and practicing as a medical doctor
Measure	he indicator for which estimates are produced
Metric (Units)	The unit by which a measure is expressed. For example, number, percent, and rate
National Health Insurance Scheme (NHIS)	A health insurance package that grants financial access to health care in Ghana for active members
National Emergency Department Overcrowding Score (NEDOCS)	It is a calculated and graded score used to assess and evaluate the severity of emergency department crowding status
No Bed Syndrome	A situation where a patient visits a hospital in Ghana and there is no available bed to admit the patient and hence turned away or advised to visit a different hospital
Odds ratio (OR)	Measures the association between exposure and outcome. The odds of an event occurring in one group to the odds of the same event occurring in another group
Out of pocket payment	The direct payment of money that may or may not be later reimbursed from a third-party source. This is expenses for medical care that are not reimbursed by insurance
Prevalence	Proportion of persons in a population who have a particular disease, injury or sequela or attribute at a specified point in time or over a specified period of time

Population attributable fraction	Proportional reduction in population disease or mortality would occur if exposure to a risk factor were reduced to an alternative ideal exposure scenario
Population at risk	All those to whom an event could have happened, where it did or not. This denominator is mostly applied to the total population of interest
Proportion	The number of cases with a certain characteristic in a population (example, the proportion of HIV that is due to sexual transmission or the proportion of households using solid fuels for cooking)
Risk (Risk factor)	An attribute, behaviour, exposure, or other factor which is causally associated with an increased (or decreased) probability of a disease or injury. If the probability decreased, the risk is a protective factor.
Senior House Officer	A house officer in the second year of internship
Sex	Male, female or both sexes combined
Standard Treatment Guideline	A reference and guidance manual to guide clinicians in the provision of health care to patients in all health facilities in Ghana
Sub-Saharan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Democratic Republic, Congo, Republic, Cote d'Ivoire, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe
Year	The period of 365 days (or 366 days in leap years) in the Gregorian calendar divided into 12 months beginning with January and ending with December
Years lived with disability (YLDs)	Years lived with any short-term or long-term health loss weighted for severity by the disability weights
Years of life lost (YLL)	Years of life lost is a measure of premature mortality that considers both the frequency of deaths and the age at which it occurs. YLLs are the multiplication of deaths and a standard life expectancy at the

	age of death. The standard life expectancy is derived from a life table that contains the lowest observed mortality rate at each age that has been observed in any population greater than 5 million

ABSTRACT

EMERGENCY DEPARTMENT CROWDING AND ITS IMPACT ON THE CLINICAL CARE AND MORTALITY OUTCOMES OF STROKE PATIENTS AT THE TEMA GENERAL HOSPITAL IN GHANA

LAWRENCE LARTEY

Thesis under the supervision of Prof Penny Cook and Dr Deborah Robertson

Stroke is a cardiovascular related disease that commonly presents at the emergency department (ED) with high mortality rates and lifelong disability. At the ED, overcrowding is a reported challenge that has impact on the outcome of patient care. The overall aim of the study was to evaluate the levels of overcrowding and predictors of mortality outcomes among stroke patients at the ED of Tema General Hospital (TGH) in the Greater Accra Region of Ghana, a lower-middle income country (LMIC) in sub-Saharan Africa (SSA). The study aimed to evaluate the crowding status of the ED, stroke specific case fatality, stroke specific mortality by stroke subtype, association between CT scan use and stroke mortality, association between admission BP levels and mortality, and to evaluate ED overcrowding and other predictors of stroke specific mortality.

This was a facility-based retrospective study of prospectively collected secondary data already documented in the patients' clinical records between October 2019 and March 2020. Participants were all patients aged 18 years and above who presented at the ED with any focal neurologic deficit suggestive of acute stroke (ischaemic, haemorrhagic, and transient ischaemic attack). The National Emergency Department Overcrowding Scale (NEDOCS) was the standard metric used to assess the levels of crowding. The analysis was evaluated at the 95% confidence interval and a p-value of <0.05 was considered significant. The outcome variable of interest was stroke mortality.

A total of 175 (89 males and 86 females) stroke patients visited the ED during the period of data collection. Only 70 (40.0%) stroke patients had a computer tomography (CT) scan done during admission at the ED. The ED was always overcrowded with the NEDOCS greater than 100. There were 139 deaths representing a stroke specific mortality rate of 79.4%. Overall, there were 104 (59.4%) ischaemic strokes of which 78 (75.0%) died, and there were 71 (40.6%) haemorrhagic strokes of which 61 (85.7%) died at the ED. There were three statistically

significant stroke predictors; average NEDOCS (AOR = 1.033; 95% C1: 1.003 – 1.064; p = 0.033), type of stroke (haemorrhagic stroke) (AOR = 3.834; 95% CI: 1.184 – 12.416; p = 0.025) and a medical history of diabetes mellitus (AOR = 3.001; 95% CI: 1.006 – 8.951; p = 0.049).

In conclusion, in-patient stroke case fatality was extremely high and stroke mortality were higher among younger patients and patients with haemorrhagic stroke. There is an urgent need to establish comprehensive stroke care systems at the ED to reduce stroke mortality, and practical measures to improve the crowding situation at the ED are required.

Keywords: stroke, stroke burden, stroke care, stroke risk factors, stroke deaths, clinical outcomes, mortality outcomes, emergency department crowding, emergency department crowding measurement.

University of Salford **08 January 2024**

COVID-19 IMPACT STATEMENT

Prior to the COVID-19 pandemic, I was an emergency department physician in Tema General Hospital, conducting my PhD study using routine data collected from stroke patients admitted to the department. On the 12 March 2020, Ghana recorded its first cases of COVID-19. Following this a few decisions were taken by the Government of Ghana and the management of the Tema General Hospital that affected my study especially with data collection:

1. There was a lockdown where all movements to and from houses were totally ceased.
2. All non-COVID-19 admissions to the Tema General Hospital emergency department were halted.
3. Only dire emergencies were allowed admission after careful administrative vetting.
4. The emergency department of the Tema General Hospital was closed to non-COVID-19 patients.
5. All ancillary services in the hospital including laboratories, pharmacies among others were not fully operational.
6. All other health facilities and diagnostic centres including CT scan operators were also not fully operational in the Greater Accra Region.
7. The Tema General Hospital was declared as a treatment centre for the management of COVID-19 patients.
8. All emergency department staff were asked to stay home until a determination of their return to work was made.
9. All research including human related research were halted indefinitely.
10. All patients admitted to the ED were systematically and judiciously discharged home during this period.
11. All research assistants were made to go home and not to return until a determination was made for them to return to the hospital and continue data collection.
12. As a result of the experience, I had gained studying for a PhD at the University of Salford, I was reassigned to the national headquarters of the Ghana Health Service to assist in the early detection and surveillance of COVID-19 patients
13. I was made the head of Port Health and directly in-charge of the Kotoka International Airport with regards to the enforcement of the COVID-19 health protocols
14. I was made to be in charge of the National Public Health Emergency Operating Center responsible for the COVID-19 response in Ghana.

15. I was made a member of the National Technical Coordination Committee, a COVID-19 inter-ministerial committee headed by the Minister of Health
16. I was made a member of the President COVID-19 Task Force headed by the President of the Republic of Ghana
17. I contracted COVID-19 five time in my line of duty.
18. The University of Salford asked for all human related research to be halted.
19. The University granted a 6-month interruption

All these events impacted on my study in the following way:

1. My inability to collect more data on stroke patients.
2. At the time I had data on 175 stroke patients.
3. My supervisors contacted a statistician from the UoS who advised in a session that the sample I had was adequate for the study using the 'event per variable' rule of thumb for rare events.
4. I was taken away from the hospital and further observations of events at the ED became impossible.
5. The initiative of the electronic patient tracking system that I had started halted in the process as I was not available later when restrictions were lifted.
6. I had additional responsibilities of caring for my wife, a laboratory scientist who went down with COVID-19 on three occasions.
7. I have elderly patients and in-laws whom I had added responsibility of ensuring that they were in good health.

Through the methods, it was the expectation to collect data from a minimum of 200 stroke patients who would have experienced mortality. That was not to be the case because of the advent of COVID-19 and the disruption of data collection.

The patient electronic data management system was gaining traction as the ED staff were becoming familiar with the operations of the new system that had been set up as a result of this study. Unfortunately, this was curtailed with the impact of COVID-19 on service delivery at the ED. I was also moved out of the hospital to assume higher duties at the headquarters of the Ghana Health Service. The research assistants were also stopped from coming to the emergency department in a bid to safeguard their lives. Because of the disruption in data collection, the volume of data points which were not reached could have potentially affected the analysis and the outcome of the results.

It was also assumed that I would have made a trip to the UK to have an experience that would have helped strengthen the outputs of my thesis, which did not happen.

I was undertaking a training program to augment my analytical skills and professional development at the Ghana College of Physician and Surgeons when COVID-19 struck in Ghana. The college went on a break for several months. This indirectly affected the flow of my thesis. However, with the help of my supervisors I was able to catch up over a period of time.

Summarily, a few decisions and actions were taken to mitigate for the impact of the COVID-19 on the research. There were proportionally more stroke deaths than survivors and additional data was presumed not to alter the analysis much. Secondly, it was noted that the emergency department was always crowded and that meant that there were not going to be non-crowded moment for comparison. Hence, the advice was that the data collected was adequate enough to do a meaningful analysis. Regular supervision meetings during this period kept me focused on the research and go through the entire rudiment of a PhD.

During my PhD journey at the University of Salford, I gained great experiences including logical reasoning, critical thinking, solving complex problems, deep analytical skills and large dataset analysis, use of SPSS, work ethics, systematic appraisal, review of documents, time management, working under pressure, meeting tight deadlines and above all professionalism. These professional skills and positive personal character traits that I developed during my journey helped me play a leading role in the COVID-19 emergency preparedness and response in Ghana at the highest level.

Chapter 1 INTRODUCTION

1.1 Background to this study

The dreaded disease called stroke, in simple terms, occurs when someone with high blood pressure develops a brain clot that prevents blood circulation in the brain or has raptured brain vessels with bleeding into the brain matter. The manifestation of stroke to the lay person is the sudden onset of weakness on one side of the body with restricted movement, difficulty in talking, swallowing and inability to control the passing of urine and faeces. This could result in a painful death. Stroke presents in two forms, one that is severe and often deadly, referred to as haemorrhagic stroke (HS) where blood vessels burst and bleed into the brain cells. This type of stroke accounts for 15% of all the stroke cases in the United Kingdom (UK) (Stroke Association - UK, 2021). The second type is known as ischaemic stroke (IS), where a clot in the brain stops blood flow and circulation to some parts of the brain and this accounts for 85% of all stroke cases (Stroke Association - UK, 2021). There is also a related condition, known as transient ischaemic attack (TIA), where the blood supply to the brain is temporarily interrupted by clot(s). This causes what is known as a mini stroke. It can last minutes or persist up to 24 hours.

This introduction aims to provide an overview of the importance and rationale for the study, but also gives the story of the research journey. This journey starts with a personal story, in Autumn of 2016, whilst on night duty at the emergency department (ED) of Tema General Hospital (TGH). I received a distress call at about 11:00 pm from a neighbour anxiously explaining that his 80-year-old father had experienced a “spiritual knock” on the forehead and had subsequently suffered “spiritual weakness” on the right side of the body, to the extent that he was unable to move, walk nor respond to verbal conversations. I simply responded, “kindly rush him to the ED immediately.” Upon arrival at the ED at about 1:00 am in an ambulance, we swiftly examined an elderly man who was unable to move parts of his body. He was nodding his head involuntarily, with saliva drooling down his chin and copious brownish vomitus had soaked and stained his shirt.

The examination took place on the trolley that was stationed within the ambulance that brought him to the hospital, due to the unavailability of admission beds at the ED. His trousers were drenched in urine and watery stool which he had passed when he had the “attack.” Struggling

for his life, he was unconscious and in respiratory distress (oxygen saturation of 50-60%) with extremely laboured and noisy breathing (respiratory rate was between 50-60 cycles per minute) and his abdomen rhythmically moved with every breathing effort he made. His systolic blood pressure (BP) was 280 mmHg, and his diastolic BP was 180 mmHg. His random blood sugar was 20.0 mmol/l with no urine ketones after a urinalysis was conducted. He was said to have a history of hypertension and diabetes mellitus but had defaulted his medications for well over six months prior to presenting at the ED. He also had a history of heavy consumption of alcohol, and he was not known to be a tobacco smoker.

A provisional diagnosis of acute haemorrhagic stroke with right hemiplegia secondary to life threatening high blood pressure was made. Medical treatment was started for clinical 'haemorrhagic stroke' without confirmatory CT scan as one was unavailable at the hospital. After over two weeks he partially recovered, albeit with sustained motor weakness on the right side of his body and he was unable to walk unaided. He had previously denied the medical diagnosis of hypertension and resorted to alternative health care by visiting the herbalist and the spiritualist occasionally. He was a farmer by profession and had seven children. The family members insisted perspicaciously that he had experienced a "spiritual attack" that was amenable to "spiritual cure." From the narrative of the family members, his wife had unfortunately passed away three weeks prior to the medical emergency he sustained. According to their custom, he was to stay indoors and not go to the farm until his deceased wife was duly buried. On the said day of his "attack" he went to the farm unceremoniously, and the supposed "spirit of the wife" gave him a "knock on the forehead as a way of punishment." This according to the family was the cause of his experience that day.

Later laboratory investigations and imaging studies conducted outside the hospital revealed that he had a brain blood clot in his middle cerebral artery, which had also bled into the left hemisphere of his brain. This confirmed our initial suspicion of a haemorrhagic stroke in a known hypertensive and a diabetic who had defaulted treatment. The family later sent their father for "spiritual cleansing and healing" and refused to visit the hospital for further follow-up and clinical care per the schedule he was given. After 2 months, I had a distress call from my neighbour again, this time wailing uncontrollably on the phone because their father had died that evening.

For every physician, the ED is a good place to fulfil a life's dream and wish to help save lives. To contextualise the triangulation between emergency health care delivery in a low resource

setting together with the philosophical underpinnings of patients/relatives and their understanding of medical conditions and the duty of care placed on the physician who swore the Hippocratic Oath, the narrative above is necessitated. As a physician in the ED and from years of practice, this is but one example of such cases which highlight the challenges of medical care in a low resource setting with varied understanding of medical conditions coupled with diagnostic constraints, bed unavailability, blinded medical treatment and superstitious believes among patients and family members. This combination of factors, tragically leads to increased likelihood of patient death. For instance, in Tanzania, a study found that, a combination of sociocultural factors like delays at home, in transportation and inaccessibility to health care were associated with higher risk of mortality among inpatients in a tertiary referral hospital (Snavely et al., 2018).

1.2 General overview of non-communicable diseases (NCDs)

Stroke is a is an important non-communicable disease (NCD) described as “worse than death” (Go et al., 2014; Samsa et al., 1998) by people who experienced it. Referred to as “4 x 4”, NCDs are made up of four group of diseases: cardiovascular diseases (CVDs), diabetes mellitus, chronic obstructive pulmonary disease (COPD) and cancer (Schwartz et al., 2021; World Health Organization, 2021). NCDs are chronic in nature and often result in significant disability and undermines socioeconomic growth directly or indirectly (Azzollini et al., 2021; Grefkes & Fink, 2020; Kernan et al., 2021) irrespective of income status (Mokdad, 2016; Naghavi et al., 2017). NCDs accounts for 74% (41 million deaths each year) of all-deaths globally (World Health Organization, 2022) and in sub-Saharan Africa, 35% (2.6 million) of all deaths (Yuyun et al., 2020). CVDs account for the most NCD deaths globally (19 million deaths yearly) (World Health Organization, 2021) and it causes 13% of all deaths in sub-Saharan Africa (Yuyun et al., 2020).

One out of every two American deaths was caused by CVDs in the 1940s (Kannel, 1990) and as reported, President Franklin D. Rosevelt of the USA died from an undetected and untreated cardiovascular disease (Howard, 1970). His death lead to the establishment of the phenotypic transgenerational Framingham heart study in 1948 that investigated the epidemiology and risk factors for CVDs (Mahmood et l., 2014; Anderson et al., 2021). Over several decades the Framingham heart study has highlighted and published the important roles of high blood pressure, atrial fibrillation and genetic predisposition as important stroke risk factors (Romero

& Wolf, 2013). Significantly, the study also developed the widely used clinical Framingham heart stroke risk score to estimate the 10-years stroke risk (Orfanoudaki et al., 2020). Because of the defined population of the study subjects, the validation of its findings in other jurisdictions has been questioned (Hermansson & Kahan, 2018).

1.3 The burden of non-communicable diseases in Ghana

The highest burden of NCDs is among younger people in low income countries (LICs) and lower middle income countries (LMICs) compared to high income countries (HICs) (Boutayeb, 2010; Fogarty International Center, 2019; Supakul et al., 2019; Terzic et al., 2011). According to the 2018 World Health Organisation (WHO) country estimates, NCDs accounted for 43% of all-cause deaths in Ghana (19% were due to cardiovascular diseases, 5%, 3% and 2% due to cancers, diabetes mellitus, COPD respectively and 13% from other NCDs). In 2019, stroke recorded the third highest mortality (49.88 deaths per 100,000 population) for both sexes in Ghana with the first being neonatal conditions (56.53 deaths per 100,000 population) (World Health Organization, 2020). Stroke is therefore a significant disease in Ghana**.** The Figure 1.1 below gives a breakdown of the top 10 causes of death in Ghana.

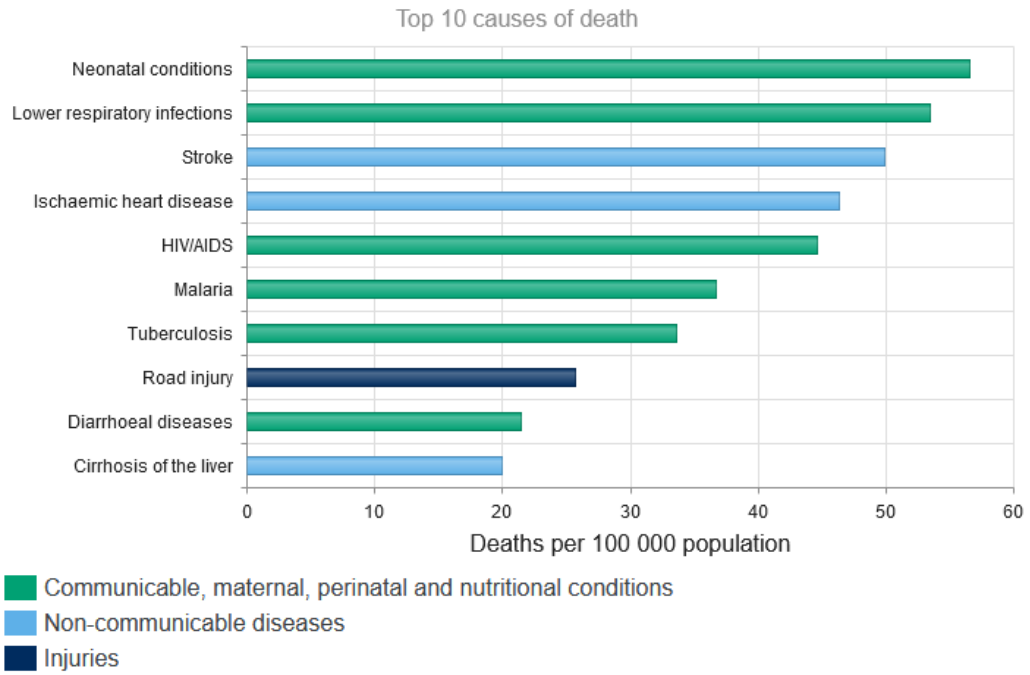


Figure 1.1 Top 10 causes of death for both sexes of all age groups in Ghana for 2019 (World Health Organization, 2020)

1.4 Global burden and epidemiology of stroke

Since 1990, the Global Burden of Disease (GBD) platform has been recognized for its evidence-based reporting on the global and country specific incidence, prevalence, mortality, disability adjusted life-years (DALYs), and the population attributable fraction on DALYs associated with 19 identified risk factors for stroke (GBD 2019 Stroke Collaborators, 2021). There has been various publications and analysis of finding from the GBD which indicates its relevance within the body of knowledge (Krishnamurthi et al., 2020; Johnson et al., 2019; Feigin et al., 2018; Feigin et al., 2017; Naghavi et al., 2017; Thrift et al., 2017; Vos et al., 2017; Hay et al., 2017; Feigin et al., 2014; Murray et al., 2012). The next few paragraphs synthesise epidemiological evidence of the heightened burden of stroke.

1.4.1 Incidence, prevalence, and stroke mortality distribution

In 2019, the absolute number of global incident strokes were 12.2 million and prevalent strokes were 101 million (GBD 2019 Stroke Collaborators, 2021). There was an increase in the absolute number of incident strokes by 70% from 1990 to 2019 and increase in prevalent stroke by 85% (GBD 2019 Stroke Collaborators, 2021). Implicitly, one in four people over the age of 25 years will have a stroke in their life time and over 62% of all strokes will occur in people under 70 years, whilst 16% in people 15 – 49 years of age (World Stroke Organisation, 2022). In 2019, the global point incidence (6.44 million) and prevalence (56.4 million) for females were higher than males (point incidence of 5.79 million and prevalence of 45 million) implying that 56% of people living with stroke at the time were women and 44% were men (World Stroke Organisation, 2022). Stroke is the second leading Level 3 cause of death globally after ischaemic heart disease (GBD 2019 Stroke Collaborators, 2021). There were 6.55 million stroke related deaths globally with 51% occurring in men and 49% in women (World Stroke Organization, 2022). The absolute number of stroke deaths increased by 43% from 1990 to 2019 though the stroke case fatality declined within the same period (GBD 2019 Stroke Collaborators, 2021).

The burden of stroke has been reported to be highest in sub-Saharan Africa (GBD 2019 Stroke Collaborators, 2021; Kengne & Mayosi, 2018; Owolabi et al., 2015; Sarfo et al., 2016; Walker et al., 2010). Indeed, 80% of all incident strokes, 77% of stroke survivors, 89% of stroke-related DALYs and 86.% of all stroke-related deaths in 2019 occurred in LICs, LMICs and upper-

middle income countries (UMICs) (GBD 2019 Stroke Collaborators, 2021). Age standardized stroke-related death rates in LICs were 3.6 times higher than that of HICs (GBD 2019 Stroke Collaborators, 2021). These LICs and LMICs rates are within the highest incidence rates (Walker et al., 2010), prevalence (Ezejimofor et al., 2017) and mortality rates (Sarfo et al., 2016; Walker et al., 2011) of all strokes in the world.

These worrying trends in low resource settings have been attributed to several factors. They include among others: limited access to diagnostic and time dependent intervention services, absence of stroke units and challenges with patient retention during post-stroke rehabilitation (Akinyemi & Adeniji, 2018); poor management of metabolic risk factors like blood pressure and blood sugar, delayed stroke recognition, difficulties in accessing early post-stroke care, population growth and ageing (Adeloye, 2014; Adoukonou et al., 2021; Kaduka et al., 2018; Okeng'o et al., 2017; Walker et al., 2011).

1.4.2 Stroke burden in Ghana

According to the 2019 NCD Prevention and Control program (responsible for the prevention and control on NCDs in Ghana) annual report, the regions in the southern parts of Ghana had the highest stroke rates with more than 100 reported stroke cases per 100,000 population compared to 10 stroke cases per 100,00 population in the northern part of Ghana (NCD Control Program, 2020). The attributable factors are yet to be studied. The regional distribution of stroke as captured by the district health information system 2 (DHIS2) is represented in Figure 1.2 below.

Sarfo et al. (2015), evaluated a 30-years (1983 – 2013) trend in stroke admissions and mortality rates in Ghana. They analysed 12,233 stroke admissions and the 28 days mortality rate was found to be 41.1% (Sarfo et al., 2015).This is comparatively high compared to findings from studies in Iran (6.7%) (Foroozanfar et al., 2020), Singapore (6.7%) (National Registry of Diseases Office, 2021), Sweden (11.1%) (Aked et al., 2018), Malasia (22% in women and 19.4% in men) (Hwong et al., 2021) and Southern Ethiopia (29.3%) (Fekadu et al., 2020). This current study seeks to bring to perspective the under 24 hours and within 7 days stroke mortality rates and further generate evidence of the impact of crowding on these outcomes which bothers on the quality of care. The next few paragraphs will focus on the historical perspective and clinical understanding of stroke, its definition, pathophysiology, and risk factors.

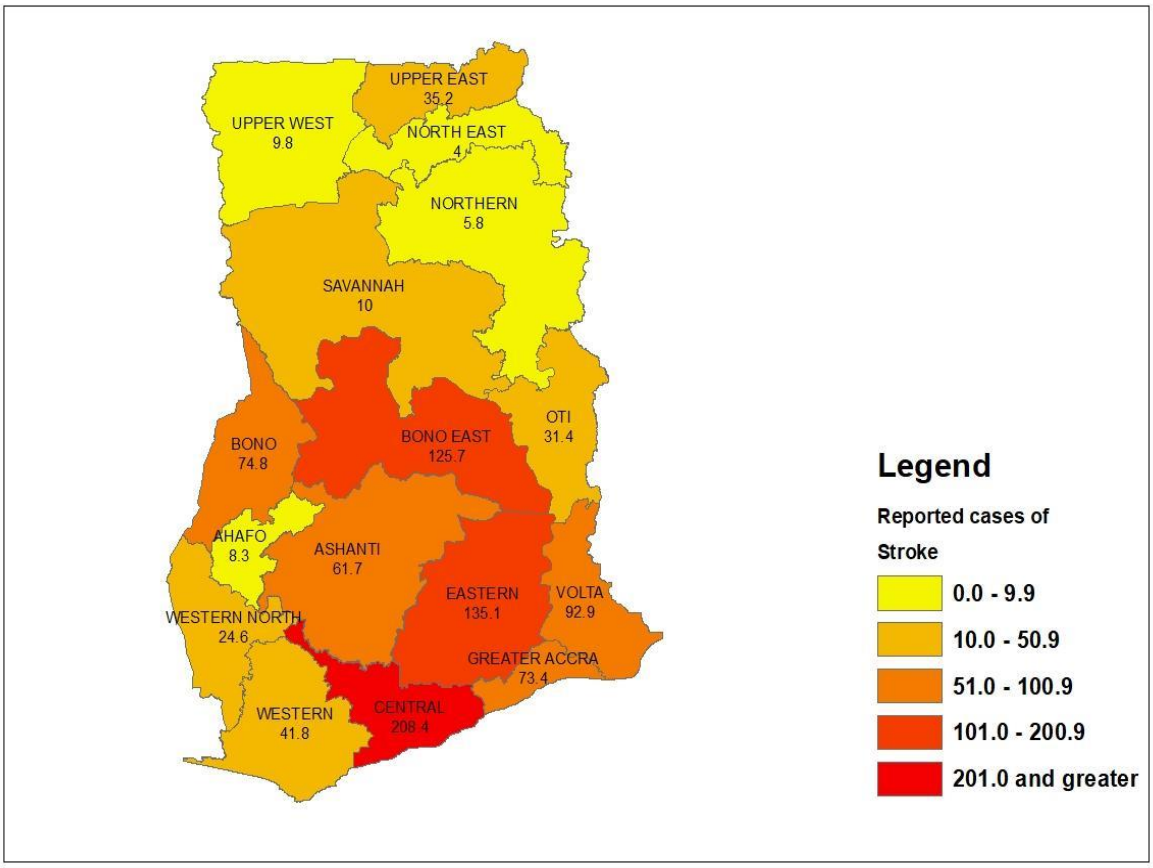


Figure 1.2 Reported cases of Stroke per 100,000 population, 2019: Source: *District Health Information System (DHIS2), downloaded on February 13, 2020

1.5 General overview and historical understanding of stroke

Stroke is an important medical emergency and a public health challenge of global proportions (Emmrich et al., 2021; Feigin et al., 2017; Gorelick, 2019) with worse impact in LMICs (Mendis et al., 2015; Owolabi et al., 2018; Pandian et al., 2020; Rahbar et al., 2022). It was first described by Hippocrates (460-370 BC) as 'apoplexy' from a Greek word meaning struck down with violence which occurred when a person suddenly falls, without consciousness or motion, retaining pulse or respiration (Clarke, 1963; Cooke, 1820; Pound et al., 1997).

In 1824, Cooke wrote that "The term apoplexy was employed and is still used, to denote a dise: patient falls to the ground, often suddenly and lies without sense or voluntary motion. Person instantaneously thus affected, as if struck by lightning, were, by the ancients, denominated, *attoniti syderati*" (Cooke, 1984, p. 75). "This term come from *'attonitus,'* the Latin for thunder-struck or stupefied, and '*sideror*,' to be planet-struck" (Pound et al., 1997, p. 332). Most scholars at the time of Cooke postulated that apoplexy occurred in three phases: "*fortissimo*, in

which a person falls suddenly to the ground as if struck by lightning and instantly dies: the *fortis*, in which sense and voluntary motion are suspended: and the *debili,* in which the power of motion wholly or partially lost, that of sense in some degree remaining" (Cooke, 1984, p. 119). As Hippocrates said in an aphorism "It is impossible to cure a severe attack of apoplexy, and difficult to cure a mild one" (Coupland et al., 2017, p. 1). To date, stroke is still a complex phenomenon.

Records available indicate that the word stroke has been in existence for over five centuries though it was not a popular term among clinicians (Pound et al., 1997). The word stroke was first used in English literature in 1599 in a phrase that read, "an excellent Cinnamome water for the stroke of Gods hande" (Pound et al., 1997, p. 331; Simpson et al., 1989). Evolution of the word reveals that, Cole (1635-1716) first introduced the word "stroke" to denote apoplexy in 1689 in a letter to a physician titled "A physio-medical essay concerning the late frequency of apoplexies together with a general method of their prevention and cure" (Cole, 1689). Excerpts from the letter written by Cole in 1689 from Oxford in the language at the time read:

> "this evident that the stroke is impressed on the animal faculty in general, by the immediate cessation of its functions, the vital (so called) continuing, for the most part, entire for some time, which must argue the cause to reside about the original of it, the Brain, since from thence only that faileur can so generally be effected. But when it begins with less violence, so that there is any interval betwixt its invasion, and the total defection of the animal functions, they generally complain of, either a vertigo, or a great oppression and pain in the head; upon which presently follow stupidness, somnolency, dazling of the eyes, a relaxation of all parts of the body, and the like: all which are so evidently deducible from the consideration of the nerves affected at their original, that were time lost farther to prove it" (Cole, 1689, p. 8).

With the advent of autopsies in the 18th century (Burton, 2005), the term apoplexy that had been used to describe what we now know as stroke lost its generic meaning (Engelhardt, 2017). It was only in the 19th century that the word stroke became popular among clinicians. Some historical figures like Alzheimer, Binswanger, Cohnheim, Laborde, Virchow, Durand-Fadel, Dechambre, Rostan, Blackall, Morgagni, Wepfer, Biumi, Galen, Rouchoux among others contributed to the science, literature, knowledge and understanding of the phenomenon of stroke during their generation rightly or wrongly (Engelhardt, 2017; Karenberg, 2020; Pound et al., 1997). Stroke (cerebrovascular) first appeared in the 9th revision of international classification of diseases (ICD-9) published in 1968 (Engelhardt, 2017). Stroke definitions has undergone modifications based on existing knowledge. This is further discussed in the next sections. But first a cursory appreciation of the pathophysiology of stroke.

1.6 Basic understanding of the pathophysiology of stroke

The circle of Willis plexus formed anteriorly by two internal carotid arteries and posteriorly by two vertebral arteries manage blood flow to the brain. A short supply of blood and oxygen to the brain leads to ischaemic stroke and a bleeding or leaky vessels in the brain leads to haemorrhagic stroke. Cellular brain injury, a result of cascaded set of neuroinflammatory events occur when blood and oxygen supply to the brain is truncated and this leads to reperfusion injury (from autoregulation and restoration of blood supply) and severe brain damage (Wu et al., 2020). This directly or indirectly lead to cerebral oedema, apoptosis, cell death and subsequent neurological deficits (Lin et al., 2016; Manzanero et al., 2013; Orellana-Urzúa et al., 2020; Xiong et al., 2018).

Plasminogen activators like tissue plasminogen activator (tPA) and urokinase plasminogen activator are released and they promotes plasmin-induced lysis of occluding clots (Thiebaut et al., 2018). Plasminogen activators are important in the treatment of acute ischaemic strokes. Using tPA for its fibrinolytic and thrombolytic effect usually within 4.5 hours from the onset of attack have been found to be effective in the management of ischaemic stroke (Jeanneret et al., 2016; Thiebaut et al., 2018). Interestingly tPAs are not often used in hospitals in Ghana during stroke care.

1.7 Evolution of the modern definition of stroke and transient ischaemic attack

The WHO in 1970 defined stroke as “rapidly developed clinical signs of focal (or global) disturbance of cerebral function, lasting more than 24 hours or leading to death, with no apparent cause other than vascular origin” (Aho et al., 1980, p. 114). Most cases of stroke include subarachnoid haemorrhage (SAH), intracerebral haemorrhage (ICH) and cerebral infarction (CI) (Aho et al., 1980). Transient ischaemic attack which differs from stroke was defined in 1975 by the National Institutes of Health (NIH) in the USA. TIA occurs as “episodes of temporary and focal cerebral (including retinal) dysfunction of vascular origin, rapid in onset which commonly last 2 – 15 minutes but occasionally up to a day (24 hours)” where “resolution is swift and leaves no permanent clinical neurologic deficit” (Abbott et al., 2017, p. 2). Empirically, two broad definitions of stroke and TIA exist. The time-based and tissue-based definition. The distinctions are relevant as it highlights scientific advancement in basic

sciences, pathophysiology, and neuroimaging in accurately and correctly diagnosing stroke and TIA.

1.8 Time-based and tissue-based definition of stroke and transient ischaemic attack

According to the 1970s time-based definitions, stroke last for more than 24 hours with permanent brain damage whereas TIA (which affects the brain and eye) last under 24 hours with no permanent brain damage (Fisher, 1958; Mohr, 2004; National Institute of Neurological and Communicative Disorders and Stroke & Health, 1975). With advancement in science and neuroimaging, evidence of diffusion (indicating brain injury) has been found on magnetic resonance imaging (MRI) within the 24-hour threshold of TIA, hither to this had not been discovered. Between 30 – 50% of classically defined TIA showed brain injury on diffused weighted MRI (Easton et al., 2009). Because TIA is a precursor to stroke (Abbott et al., 2017), its prompt diagnosis is important. In an earlier Manhattan stroke study, approximately 9% of patients who presented with first ischaemic stroke had experienced TIA (Sacco, 2004).

Other population-based stroke studies in the UK, USA and parts of Europe found that up to 17% of patients who experienced stroke had TIA on the day of the stroke and another 43% within 7 days before the stroke (Rothwell & Warlow, 2005). These and other findings informed the current and updated definition of TIA at the 2013 global consultative conference on stroke making it tissue-based (Norrving et al., 2013). TIA is now defined as a transient episode of neurological dysfunction caused by focal brain, spinal cord, or retinal ischaemia, without acute infarction. The new definition includes the spinal cord and excludes the earlier 24 hours threshold.

The implication of the new definitions has in a way impacted the incident increases in the diagnosis of stroke and TIA (Morgenstern et al., 2021). Where for example MRI used in tissue diagnosis positivity was found to be associated with an increased long-term risk of recurrent stroke after suffering a TIA and a minor stroke with a significant hazard ratio of 2.66 (Hurford et al., 2019). It is therefore imperative that patients with symptoms of stroke or TIA undergo neuroimaging preferably diffusion sequence MRI involving the cervical vessels (Easton et al., 2009). Summary stroke subtypes tissue-based definitions and highlighted in the appendices. Due to high stroke mortality, prevention is a preferred choice.

1.9 Important risk factors for stroke

There are 19 recognized attributable risk factors (modifiable or non-modifiable) for stroke (Boehme et al., 2017, 2018; GBD 2019 Stroke Collaborators, 2021). Traditionally, the common non-modifiable risks found for stroke include age, race, ethnic group, low birth weight, family history of stroke especially among first-degree relatives, genetic predisposition to myocardial infarction, to stroke and or to TIA.

1.9.1 Non-modifiable risk factors for stroke

The genome-wide association study (GWAS), the largest study of its kind has provided genetic evidence associated with traits and pathophysiology of stroke (Malik et al., 2018). As part of the GWAS, the multiancestry MEGASTROKE study worked on 521,612 (67,162 stroke cases and 454,450 controls) subjects of European, East Asian, South Asian, mixed Asian, African, and Latin American ancestry. Over the years, this particular study have identified 32 genetic loci associated with stroke and 18 individual loci associated with vascular traits of blood pressure, cardiac issues and venous thromboembolism (Malik et al., 2018). Additionally, there exist genetic predispositions to stroke with 11 new susceptibility loci (ANK2, CDK6, KCNK3, LINC01492, LRCH1, NKX2-5, PDE3A, PRPF8, RGS7, TM4SF4–TM4SF1, and WNT2B) identified to be involved in the stroke pathophysiology. Such large-scale genetic studies are yet to be conducted in the Africa region.

A meta-analysis study found a causal effect of type 2 diabetes mellitus liability and lipid traits on ischaemic risk in African ancestry individuals, with the mendelian randomization estimates similar to those obtained in European ancestry individuals (Fatumo et al., 2021). Among 10,700 African Americans treated for hypertension from the Genetics of Hypertension Associated Treatments (GenHAT) and Reasons for Geographic and Racial Differences in Stroke (REGARDS) studies, 10 significant genetic variants associated with the incidence of stroke among African Americans with hypertension have been found (Armstrong et al., 2021).

Sex variations and stroke outcomes have been demonstrated in past studies. In the USA and parts of Europe, stroke mortality and lifetime risk have been found to be higher among women compared to men (Rexrode et al., 2022; Virani et al., 2021; Phan et al., 2017). Stroke severity have also been found to be higher among women than men in studies in Australia (Phan et al., 2019), UK (Peters et al., 2020) and Ghana (Edzie et al., 2021). Other studies in Cameroon

(Mapoure et al., 2017), Ghana and Nigeria (Akpalu et al., 2019) have recorded high incidence of stroke and stroke severity among men than women. These variations have been explained to be the results of genetic predisposition, differentiations in life expectancy among other factors (Bushnell et al., 2018; Howard et al., 2019).

1.9.2 Modifiable risk factors for stroke

Modifiable risk factors can either be behavioural or clinical. Common behavioural modifiable risk factors for stroke include tobacco smoking, alcohol consumption, diet, physical inactivity, overweight and obesity. Clinically related modifiable risk factors include: hypertension, diabetes mellitus, hyperlipidaemia, asymptomatic carotid stenosis, metabolic syndrome, peripheral vascular disease, atrial fibrillation, post-menopausal hormone therapy, oral contraceptive therapy etc. (Alloubani et al., 2018; Arboix, 2015; Girijala et al., 2017; Hisham & Bayraktutan, 2013; LaRosa et al., 2006; Pandian et al., 2018; Zhang et al., 2017).

The top five modifiable stroke risk factors globally in 2019 were: high blood pressure (contributed 55.5% of total stroke DALYs), high body mass index (BMI) (contributed 20.2% of all stroke DALYs), high fasting plasma glucose (contributed 20.2%) of all strokes DALYs), ambient particulate matter pollution (contributed 20.1% of all stroke DALYs) and smoking (contributed 17.6% of all stroke DALYs) (GBD 2019 Stroke Collaborators, 2021). There are population level studies that have generated evidence about modifiable stroke risk factors.

The INTERSTROKE study (2007 – 2015) which highlights stroke risk factors (acute stroke within 5 days of the symptoms onset and 72 hours of hospital admission) is the largest case control study on stroke conducted in 32 countries within the regions of Asia, America, Europe, Australia, the Middle East, and Africa. There were 13,447 cases (ischaemic stroke – 10,388 and 3,059 intracerebral haemorrhage) and 13,472 controls (O'Donnell et al., 2016). The INTERSTROKE study concluded that hypertension had increased association with intracerebral haemorrhage compared to ischaemic stroke and current smoking, diabetes mellitus, apolipoproteins, and cardiac causes were more associated with ischaemic stroke than haemorrhagic stroke (O'Donnell et al., 2016). However, the causal association between the risk factor and stroke could not be proved in this case control study.

The single largest Africanised version modelled after the INTERSTROKE study to detail for the first time the epidemiology of stroke in Africa was the Stroke Investigative Research and

Education Network (SIREN) study which was conducted at 15 health facilities across Ghana and Nigeria (Owolabi et al., 2018). It involved 2,118 CT or MRI confirmed stroke case and 2,118 controls marched for sex, age, and ethnicity. The SIREN study found associations between stroke and 11 independent potentially modifiable risk factors. In descending order of odd ratio: hypertension, dyslipidaemia, regular meat consumption, elevated waist to hip ratio, diabetes mellitus, low green leafy consumption, stress, added salt at the table, cardiac disease, physical inactivity and current cigarette smoking (Owolabi et al., 2018). These findings were consistent with that of the INTERSTROKE and highlights the significant of modifiable risk factors associated with stroke though it could not establish causality. A few of these factors and how they contribute to stroke and other cardiovascular diseases are presented below.

1.9.2.1 Tobacco usage as a modifiable risk factor for stroke

Tobacco use (smoked, second-hand, and chewing) is responsible for more than 21.4% of global deaths among all men (approximately 6.56 million deaths among men) with higher prevalence in HICs, among men and in rural communities according to the 2019 GBD report. Tobacco smoking produces toxic chemical substances like carbon monoxide, polycyclic aromatic carbons, nicotine, heavy metal and their oxides (Roy et al., 2017). This chemicals induces atherogenesis, atherosclerosis and atherothrombosis through complex pathways of inflammation, endothelial dysfunction, prothrombosis, altered lipid metabolism, insulin resistance, which results in myocardial oxygen and blood demand-supply mismatch (Roy et al., 2017). Coupled with the increased release of catecholamines, cardiovascular manifestations like increased heart rate, vasoconstriction and increased cardiac output occurs. All these cardiovascular events can result in myocardial infarction, aortic dissection and stroke (Roy et al., 2017).

1.9.2.2 Alcohol consumption as a modifiable risk factor for stroke

Globally, alcohol is linked to over 200 health conditions including stroke and its yearly use has been estimated at 64 million litres with the highest rates of consumption in the European region (Zenu et al., 2021). Higher economic wealth has been found to be associated with higher alcohol consumption (World Health Organization, 2018). The global status report for 2018 estimated that, harmful alcohol consumption caused 3 million deaths globally (responsible for 5.1% of the global burden of disease expressed in DALYs) which was higher than the

cumulative deaths caused by tuberculosis, HIV/AIDS and diabetes mellitus (World Health Organization, 2018).

1.9.2.3 Unhealthy diet as a modifiable risk factor for stroke

The leading dietary risk factors for death globally are high intake of sodium, sugar, trans and saturated fat, low intake of whole grains and fruits (Grosso, 2019; Nguyen et al., 2016; Stanaway et al., 2018). High salt intake was the leading risk factor for mortality (accounting for 3.2 million deaths) and most people consume between 9-12 grams of salt daily which was twice the recommended daily intake (Zenu et al., 2021). A WHO STEPwise approach to NCD risk factor surveillance survey in 8 pacific Island countries and territories between 2002 and 2019 (involving 21,433 adults) revealed that 88% of the survey respondents did not consume the recommended amounts of fruits and vegetables (Reeve et al., 2022). Unhealthy diet can predispose people to obesity, hypertension, diabetes and subsequently stroke and other NCDs (Murray, et al., 2020; Global Burden of Disease obesity collaborators 2015, 2017, 2019; Anand et al., 2016).

1.9.2.4 Physical inactivity as a modifiable risk factor for stroke

Physical activity has been described as a "best buy" for public health (Physical Activity Guidelines Advisory Committee, 2018). Physically active persons sleep, feel and function better. In a prospective study, long sleep duration was found to be associated with increased risk of ischaemic stroke whereas short sleep was linked to increased risk of intracerebral haemorrhage (Titova et al., 2020). Physical inactivity registers as the fourth leading cause of global mortality, accounting for 7.2% and 7.6% of all cause and CVD deaths respectively and attributable for 1.6% of hypertension and 8.1% for dementia (Katzmarzyk et al., 2022; Zenu et al., 2021). HICs was found to have the highest relative burden of physical inactivity with the greatest number of absolute people affected in middle-upper income countries (Katzmarzyk et al., 2022).

1.9.2.5 Atrial fibrillation as a modifiable risk factor for stroke

Atrial fibrillation (AF) is the commonest cardiac arrhythmia globally (Shamloo et al., 2019) and an important modifiable risk factor for stroke (European Society of Cardiology, 2012; Oladiran & Nwosu, 2019; Yoon & Joung, 2018). AF is the outcome of structural and electrical remodelling of the left atrium of the heart, and it is explainable in about 50% of cases by the

underlying risk factors and comorbidities. AF affects up to 4% of the global population and there is life time risk of about 25% (Matei et al., 2021). Symptoms of AF are usually underrecognised, underreported and underdiagnosed (Jacobs et al., 2019).

The National Institute for Health and Care Excellence (NICE) indicates that 20-30% of all strokes are attributable to arrythmia and a patient with AF has a 5-fold increase in the risk of stroke (January et al., 2014; National Institute for Health and Care Excellence (UK), 2014; Wolf et al., 1991). Stroke patients who have AF presents with severe morbidity, longer duration of hospital stay and worse mortality compared to patients without atrial fibrillation (European Society of Cardiology, 2012; Kirchhof et al., 2016; Lau et al., 2017; National Institute for Health and Care Excellence (UK), 2014).

Data on the common stroke risk factors detailed above was collected and analysed during this current study. Having looked at the definitions, pathophysiology, and risk factors for stroke, it is important to now focus on the healthcare services stroke patients receive and how that affects their clinical outcomes.

1.10 Stroke services and quality of care in low resource settings

Stroke outcomes bothers on the quality of care they receive at the hospital. Evidence-based policy decisions have shaped stroke care especially in HIC where 90% of NCD related studies have been conducted as against less than 1% from LICs (Heneghan et al., 2013). In HICs, 91% of stroke units exist compared to only 18% in LICs according to a systematic review on stroke services in 59 countries by Owolabi et al (2021). The lowest proportion of stroke doctors are in sub-Saharan Africa (22%) with the highest in Eastern Mediterranean region and Middle East (59%) and Central Europe, Eastern Europe, and Central Asia (56%) (Owolabi et al., 2021). Acute stroke care treatment which directly impacts stroke outcomes exist in 26% of LICs compared to approximately 60% in HICs and UMICs (Owolabi et al., 2021). In most HICs, “they have a very well-organised acute stroke care network with good structure of hospitals such as in Austria, Canada, France, Germany, Japan, Norway, Slovak, Sweden, United Kingdom, and United States” (Owolabi et al., 2021, p. 898).

It is important to also note that compared to HICs, LICs and LMICs provide the lowest rehabilitation services with just over 25% of the recommended spectrum and quality of care (in-patient rehabilitation, home assessment, community rehabilitation, general and specific

education information and communication about stroke, early hospital discharge programs and policies, among others) available (Owolabi et al., 2021). The lack of investment potentially contributes to the low penetration of stroke units, stroke specialist care and quality care in LIC and LMICs (Engelgau et al., 2018; Malekzadeh et al., 2020; Zenu et al., 2021).

Compounding the challenges of stroke services in low resource settings are informal settlements, unplanned and unmanaged urbanization (United Nations Human Settlements Programme, 2016). These unplanned settlements results in increase inequality, urban poverty, social deprivation and unhealthy lifestyle coupled with increased exposure to pollutants that predispose the population to strokes and other NCDs (Eckert & Kohler, 2014; Hunter-Adams et al., 2017; Peters et al., 2019; Ronto et al., 2018). Of note, unplanned urbanization in Africa has increased more than sixteen-fold between 1950 and 2018, rising from 33 million to 548 million (United Nations Department of Economic and Social Affairs, Population Division (ST/ESA/SER.A/420), 2019). LICs and LMICs are also confronted with vulnerabilities in political instabilities, social, educational, economic, housing and ecological situations which worsens the problem of quality health care provision (Azenha et al., 2015; Simone & Pieterse, 2018).

The next few paragraphs will dovetail into the profile of Ghana, a brief about the study setting and the care pathway for stroke patients who visit the hospital.

1.11 Brief profile of Ghana

The Republic of Ghana known historically as the Black star of Africa is centrally located on the West African coast. It has a total land area of 238,537 square kilometres (92,099 square miles), and it is bordered by three French-speaking countries. Togo on the east; Burkina Faso on the north and northwest and Côte d'Ivoire on the west. The Gulf of Guinea lies to the south and stretches across the 560-kilometre coastline of Ghana (Ghana Statistical Service & Ghana Health Service, 2015). The official language is English, with about 50 spoken local Ghanaian languages (Kropp & International African Institute, 1988; Obeng, 1997). The major local languages are Akan, Ewe, Ga, Dagaare, and Dagbani (Sadat & Kuwornu, 2017). According to the most recent Ghana Demographic Health Survey (GDHS) of people aged between 15 – 59 years, 76.7% of Ghanaian are Christians, 19.4% Muslims, 1.8% are Traditionalist/Spiritualist and other or no religion 2% (Ghana Demographic and Health Survey, 2023).

Ghana has 16 regions, 260 administrative districts, and a 2021 total population of 30,832,019, five times that of 1960 (6,726,815) (Ghana Statistical Service, 2021). The Greater Accra region has the highest population proportion (17.7%) and the least being the Ahafo region (1.8%). The urban population sized increased from 12,545,229 (50.9%) in 2010 to 17,472,530 (56.7%) in 2021 with almost half (47.8%) of the increase in the Greater Accra and Ashanti regions. The most urbanised is the Greater Accra region (91.7%), and the least urbanised the Upper East (25.4%). These are figures from the Ghana Statistical Service (2021). Figure 1.3 shows a map of the Republic of Ghana showing the 16 political and administrative regions.

Figure 1.3 Map of Ghana showing the 16 administrative and political Regions. Credit: (The Permanent Missions of Ghana to the United Nations, 2021)

There are 15.6 million (50.7%) males and 15.2 million (49.3%) males in Ghana (Ghana Statistical Service, 2021). Ghana has a youthful population with about 60% within the age range of 15-64 years. The maternal mortality ratio in Ghana remains high with 308 deaths per 100,000 live births (United Nations Population Fund, 2021). The fertility rate stands at 3.7 per woman with a higher life expectancy of 66 years for women and 63 for men in Ghana (United Nations Population Fund, 2021). In Ghana, healthcare is mainly financed by the government sponsored National Health Insurance Scheme which was established in 2003 and it covers basic care for over 95% of reported diseases in Ghana (National Health Insurance Authority, 2021). This health insurance package covers Ghanaian residents, non-residents, and all visitors to Ghana and it is non-discriminatory to social status, educational background, geographical location, gender or religious affiliations (National Health Insurance Authority, 2021). Head CT scans, MRI studies and advanced laboratory tests are not covered by the scheme, and they must be procured out of pocket at unaffordable prices.

This current study focuses on emergency care of stroke patients and the next few paragraphs briefly brings to perspective emergency service provision in Ghana.

1.12 Emergency health care services and emergency departments in Ghana

Emergency services are "those health care services provided to evaluate and treat medical conditions of recent onset and severity that would lead a prudent layperson, possessing an average knowledge of medicine and health, to believe that urgent and/or unscheduled medical care is required" (American College of Emergency Physicians, 2021 p. 1). These services are critical for patients survival and are mostly provided by health professionals in EDs (Royal College of Emergency Medicine, 2021).

In Ghana, fairly structured EDs exist and they provide medical and surgical services in tertiary, regional and districts hospitals under the supervision of the Health Facilities and Regulator Agency (Ministry of Health, 2021). The Ministry of Health accident and emergency policy mandates accident and EDs to "operate a 24 hour service and provide initial treatment for a broad spectrum of illnesses and injuries, which may be life threatening and require immediate attention." (Ministry of Health, 2011, p. 6) The EDs are to provide rapid initial and appropriate specialist care for patients, arrange subsequent referral and facilitate transportation services to referred patients (Ministry of Health, 2021). Patients in need of emergency services cannot be

turned away for lack of funds as they must be attended to within the first 48 hours of admission, as per the Ghana Ministry of Health policy.

Prior to 2009, EDs were not structured, and postgraduate emergency physician specialists were not trained in Ghana. It took the collaboration of the Komfo Anokye Teaching Hospital and the University of Michigan under the Ghana Emergency Medicine Collaborative (GEMC) to train the first cohort of emergency physicians between 2009-2012 (Oteng & Donkor, 2014). The Komfo Anokye Teaching Hospital is about 4 – 5 hours' drive from the capital city of the Greater Accra Region of Ghana. The only emergency physician at the TGH at the time of this current study was part of the first cohort.

1.13 Care and referral pathway of stroke patients at the TGH

The care pathway for stroke patients at the TGH is contextually described here and the referral pathway detailed in the method section (chapter 3). Stroke patients who arrive at the ED are first triaged by the senior nurse and coded either red (emergency), orange (very urgent), yellow (urgent), green (routine) or blue (deceased). This determines the time needed for intervention (red – immediate, orange within 10 minutes and yellow within 60 minutes). After triaging, the patient is seen by the ED physician in the waiting room where clinical history and examinations are conducted. When a preliminary diagnosis of stroke is made, the patient is put in an available bed and supporting laboratory and imaging studies are requested. The basic tests, such as the full blood count, blood glucose, urine analysis, kidney and liver function test are performed at the hospital laboratory. Other tests such as the cardiac enzymes, clotting profile are conducted outside the hospital for lack of capacity at the in-hospital laboratory. All this testing is usually at a cost to the patient.

TGH do not have a CT scanner or an MRI machine, and stroke patients are referred to imaging facilities outside the hospital for confirmatory images. It usually takes about 2 – 3 hours using the hospital ambulance to get to a facility outside the TGH where there imaging will be done. Anecdotally, most patients are unable to afford the cost of this diagnostic studies. A baseline non-contrast head CT scan costs about £50 - £70. No district hospital in the regional capital has a CT scan or an MRI, they are mostly privately owned. The Greater Accra Regional Hospital, 37 Military Hospital, Police Hospital and the Korle-bu Teaching Hospital and government and quasi hospitals that have CT scans though breakdowns and malfunction have been reported.

Patients who need the services of a stroke unit and advance neuroinvasive and stroke specialist care are referred to the premier and tertiary Korle-bu Teaching Hospital ; about an hour from the TGH using an ambulance. The cost of referral transportation is again borne by the patient and, anecdotally, is in most cases unaffordable. Details of the care and referral pathway is highlighted in the method (chapter 1, section 1.13). The absence of laboratory and imaging facilities have been said to negatively affect quality care of patients. A brief look at the setup of the ED of the TGH is presented below.

1.14 The emergency department of the Tema General Hospital

TGH was established in 1954 and it provides 24 hours general and specialist care every day of the week for people in and out of the Tema metropolis (Justice Brobbey's Commission Report, 2018; The 1992 Constitution of the Republic of Ghana, 1992). The Tema metropolis has a 100% urbanised population of 177,924 people representing 3.26% of the Greater Accra region's total population (5,455,692) (Ghana Statistical Services (2021). The TGH has one medical and surgical ED where this current study took place.

The ED of the TGH was set up in 2013 and had 30 functioning beds at the time of the study. The ED attends to patients 13 years and above with critical health care needs. The staff at the ED run three shifts work system (8:00 am-2:00 pm, 2:00 pm-8:00 pm, 8:00 pm-8:00 am) over 24 hours 7 days a week. The ED attends to an average of 30 critically ill new patients daily (1.3 patients/hour and 10,800/year) according to administrative records at the ED (Tema General Hospital, 2021). At the time of this study, one nurse managed an average of 20 new patients during the 6-hour shift, while during that same 6-hour shift, one doctor managed an average of 30 patients. Details of the setup of the hospital departments and the breakdown of the number of beds, staff distribution, study settings are further discussed in methods and method (chapter 3, section 3.1.1, Tables 3.1 and 3.2).

Since the establishment of structured EDs in Ghana, there have been reported challenges. They include weak referral systems especially in remote communities (Sneha Patel et al., 2016), operational barriers like inadequate logistics, poor patient records and data management (Gyamfi et al., 2017), inadequate managerial support (Afaya et al., 2021) and overcrowding (Aaronson et al., 2017). Other documented ED challenges in Ghana include inadequate specialist education among nurses, undefined roles of nurses, physical and verbal abuse of nurses working at the ED by agitated patients and patients relatives (Atakro et al., 2016). The

ED of TGH is not exempted from these documented challenges. Anecdotally, ED crowding has been reported at EDs in Ghana with paucity of scientific evidence to quantify the extent of crowding. A gap that this current study sought to address.

1.15 Brief overview of emergency department crowding

Crowding to the lay person is patients been turned away from the ED due to the unavailability of admission beds. ED crowding is a recognised global health challenge that impacts on patient safety and quality of care (Pines & Griffey, 2015).

1.15.1 Definition of emergency department crowding

Over the years, there has been no consensus on the definition of ED crowding (Hwang et al., 2011; Jones et al., 2018). The definition, understanding and measurement of ED crowding was explored in the literature review in chapter 1 (sections 1.15.1) and chapter 2 (sections 2.3.1 and 2.7). Summarily, the Royal College of Emergency Medicine (RCEM) and the American college of Emergency Physicians (ACEP) both define ED crowding with focus on the imbalance between patients numbers and resources availability (Royal College of Emergency Medicine, 2015). This is particularly interesting as it does not stress the timeliness of interventions though one could imply. To close that gap, the Canadian Association of Emergency Physicians defined crowding placing emphasis on demand for services and the quality of care within acceptable time periods (Canadian Association of Emergency Physicians, 2001). Another operational definition of crowding was by the Australasian College of Emergency Medicine (ACEM). They identified the impedance to ED function to include patient volumes, unavailability of physical beds and reduced staffing to define ED definition (Australasian College for Emergency Medicine, 2014).

1.15.2 Impact of ED crowding on quality care

The consequences and impact of ED crowding on quality care have been documented in other jurisdictions especially in HICs (Morley et al., 2018; Dewulf et al., 2017). This was further explored in chapter 2 (sections 2.4, 2.4.1, 2.4.2, 2.4.3, 2.5 and 2.6) with particular focus on the impact on stroke patients and the quality of care they receive during the acute phase of the attack. ED crowding negatively impact morbidity and mortality outcomes, increases waiting times, prolong patient length of stay (LOS), creates bed shortages, increase operational and

administrative cost, led to bed shortages and unsatisfactory patient and ED staff experiences (Bucci et al., 2016; Claret et al., 2016; Di Somma et al., 2015; Mentzoni et al., 2019; Pines & Griffey, 2015; Quao et al., 2017; Rasouli et al., 2019; Royal College of Emergency Medicine, 2015). ED LOS, waiting time, ED boarding, bed occupancy and patient turnover are some of the parameters considered when operationally measuring, explaining and modelling ED crowding (Kelen et al., 2021a; Mentzoni et al., 2019; Sartini et al., 2022). ED crowding can be qualitatively and quantitatively measured. ED crowding can be measured quantitatively and qualitatively. Qualitatively, perceptions characterise ED crowding.

Some ED measuring tools developed and used over the past 20 years include but not limited to: the Real-Time Assessment of the Overcrowded ED (Reeder & Garrison, 2001), the Real-time Emergency Analysis of Demand Indicators (READI) (Reeder et al., 2003), the Emergency Department Work Index (EDWIN) (Bernstein et al., 2003); the National Emergency Department Overcrowding Score (NEDOCS) (Weiss et al., 2006), the Community Emergency Department Overcrowding Score (CEDOCS) (Weiss et al., 2014) and the Severely Overcrowded-Overcrowded-Not overcrowded Estimation Tool (SONET) (Wang et al., 2015). These tools are later discussed in the literature review (chapter 2, section 2.7.1, 2.7.2.2 and table 2.9).

1.16 Moral ethics and the theory of care

As a practicing moralist, one of the moral theories known as the "ethics of care" has inherently guided my practice as a health professional for the past 13 years. The ethics of care stipulates the moral significance in the fundamental elements that defines and shapes relationships and dependencies in human life (Sander-Staudt, 2021). Defined as a practice or virtue rather than theory, "care" involves maintaining the world of, and meeting the needs of ourselves and others most often based on the motivation to provide care for the vulnerable and dependent inspired by the memories of being cared for and self-idealization (Sander-Staudt, 2021). When adequate and effective care is provided, life is saved and the ability to carry out regular and daily life activities are assured (Sander-Staudt, 2021).

Representing one of the most popular definitions of care, Joan Tronto and Bernice Fischer, construe care as "a species of activity that includes everything we do to maintain, contain, and repair our 'world' so that we can live in it as well as possible" (Kaufman-Osborn et al., 2018, p. 13). The 'world' according to Tronto referred to "our bodies, ourselves, and our

environment" (Tronto, 1993). The ethics of care dimensions as described by Tronto was regarded as a ground-breaking work in 1993 in her book titled "Moral Boundaries: A Political Argument for an Ethic of Care". The four care dimensions as espoused in this book were "caring about", "taking care of (assuming responsibility for care)", "actual care giving (assuming responsibility for care)", and "care receiving" (Hankivsky, 2014; Tronto, 1993). Tronto (1993, p. 21) intimated that "care is deeply implicated in existing structures of power and inequality". This observation by Tronto (1993) implies that, "care work is determined by relations of power that relegate care giving to those who are least well off in society, leaving those in position of privilege to directly benefit from their care needs attended by others" (Hankivsky, 2014, p. 259).

Implicitly, ethic of care and quality care are interdependent and eschewing the imposed responsibility will contribute to poor patient outcomes especially in low resource settings.

In a press release, the General secretary of the Ghana Medical Association (2021, p. 1) once said that:

> "The key thing is that we have not invested enough in healthcare, so in emergency health care services, we haven't invested at all. We have a huge population, but how many emergency care services exist in the system? What is the level of resources that can handle emergency cases properly? Clearly, our population has outstripped the health system capacity, and we need to quickly invest in there and have a short to the medium-term plan to address the systematic challenges as we prepare for the long term.."

Patients are a vulnerable group more so stroke patients who have experienced permanent disability, and hence are dependent on others for daily sustenance and survival. It is the moral obligation of health systems to ensure they receive adequate, effective, and efficient care at the ED. To theorise and conceptualise care, a key policy worth considering is the quality of care. The conceptual definition and understanding of quality of care since 1980 among professional groups has been centred around health care that is effective, safe and responds to the needs and preferences of using current professional knowledge and legitimate means to achieve the desired results (Busse et al., 2019; Mamalelala, 2022).

Quality emergency care of stroke patients must be antecedents and commensurate with early detection of symptoms, early arrival to the hospital, adequate specialist care by trained emergency physicians, timely patient cantered-decision with the support of family, emergency systems (in and out) of hospital, swift patient flow processes, effective diagnostic mechanisms,

utilization of appropriate equipment and well-designed facilities (Hansen et al., 2020). In LICs and LMICs, it has been estimated that 90% of emergency care is inadequately provided with resultant disparities in patients outcomes when compared with those in HICs (Reynolds et al., 2017). This is of concern to health care professionals and patients in these geographical locations where the population are burdened with infectious diseases, noncommunicable diseases, lack of provider education and training, broken or unavailable equipment, inadequate supplies, inadequate transportation services, lack of infrastructure, poor communication, protocols and guidelines, lack of governmental leadership and community misunderstanding of emergency care systems (Kannan et al., 2020; Kironji et al., 2018).

The ontological appreciation of the challenged ED in low resource settings and the epistemological basis of the negative consequences on patients highlights the relevance of quality care. It is a triangulation of attributes and processes of awareness, responsibilities and actions among the different stakeholders in the circle of care provision (Shaw et al., 2017). Stroke patients who report to the ED are in need of emergency care which must satisfy the concepts of quality emergency care in order to meet patients' needs, promote continuity of care, patient safety, optimal clinal outcomes, reduced mortality and patient outcomes (Mamalelala, 2022).

An updated framework of proposed enablers of quality of care include trained and qualified staff who can deliver efficient patient-centred care; appropriate size and number of rooms for patients mix, waiting area, reception, triage and diagnostics, fail proof and intuitively designed equipment; ED processes that support effective quality care such as specific triage systems and tools for the management of common and high-risk presentations; a coordinated emergency care throughput and patient pathway; information technology based monitoring and analytic systems that provide information on patient care, among others (Hansen et al., 2020).

Rationing of medical care is a controversial proposed enabler. The core idea of rationing which is the allocation of scarce resources potentially withholds beneficial treatments from some patients on grounds of scarcity (Scheunemann & White, 2011). In the context of low resource setting, rationing is unavoidable, and it is complicated by the lack of proper governance structures and guiding principles of healthcare delivery. In a crowded ED, rationing is inevitable where for example a patient who may benefit from critical care monitoring is referred or transfer out to another hospital to pave the way for another critically ill patient. The philosophical underpinnings and principles of rationing are utilitarianism, egalitarianism,

prioritarianism, rule of rescue, conflict between efficiency, equity and rule of rescue (Scheunemann & White, 2011). Moralistic viewpoint details the fair process of rationing as an ethical complex phenomenon which should be prevented in lieu of an existential functioning health system which is not the case in LICs and LMICs. This current study will make observations on quality care of stroke patients.

1.17 Rationale and importance of this research

Evidence adduced from literature, administrative records, personal experience and anecdotally indicates that stroke is an important medical condition worthy of study. Stroke studies in LMICs like the MEGASTROKE, INTERSTROKE, SIREN among others focused on stroke risk factors among Africans and people of African descent (Akinyemi et al., 2021; Akpalu et al., 2019; Akpalu et al., 2018; Edzie et al., 2021; Fatumo et al., 2021; Gallego-Fabrega et al., 2022; Jenkins et al., 2018; Kengne & Mayosi, 2018; Kjeldsen et al., 2017; Namale et al., 2018; Owolabi et al., 2015; Owolabi et al., 2018; Sarfo et al., 2018). The recommendation has been to evaluate the association between some of the common risk factors as stroke mortality especially in Ghana and other LMICs. There exist some knowledge gaps which was further explored in the literature review (chapter 2). One such gap was studying stroke mortality outcomes within the context of ED crowding which bothers on quality care.

There have been studies in HICs and UMICs that have looked at the relationship between ED crowding and how that affects the timeliness and quality of clinical care provided to stroke patients but not stroke mortality outcomes. This was explored further in the literature review in chapter 2 (sections 2.4, 2.4.1, 2.4.2 and 2.4.3). The fundamental question that needs addressing is the impact of ED crowding on quality care and how that impacts mortality outcome in a low resource setting. This is the uniqueness and novelty of this current study and is the first of its kind in Ghana, sub-Saharan Africa and in any LMIC.

Most ED crowding studies in LMICs have focused perceptions, patient waiting times and simple patient and bed count to define ED crowding (Makama et al., 2015; Olofinbiyi et al., 2020; Pascasie & Mtshali, 2014; van de Ruit et al., 2020). The well studied, validated, and preferred multidimensional ED measure metric known as the NEDOCS has not been used in ED crowding studies in Ghana, sub-Saharan African and LMICs to prospectively measure crowding and to determine its association with stroke mortality outcomes. This is a knowledge

gap that this current study seeks to explore. Indeed, this was the first time in Ghana, that the NEDOCS was used to quantify ED crowding especially at the TGH.

Another important rational for this study was to detail for the first time in Ghana and the TGH, the care pathway of stroke patients who visited the ED and tease out qualitatively the extent of quality care provision. This current study documented observations of stroke patients and ED staff experiences at the TGH and draw on lessons learned. In the process, this study also for the first time in Ghana predicted the determinants of in-hospital stroke mortality using relevant patient and ED variables guided by literature.

At the backdrop of this study, an electronic data extraction tool was developed and for the first time in Ghana be used to collect data on stroke care. This approach was used as a mechanism to address the challenges of paper-based data management systems at the ED of the TGH. The forecast is that electronic systems are more efficient, effective, and eventually impacts quality care. This is a worthy intervention to help improve quality care of patients at the ED of the TGH. The findings of this research will be relevant in shaping ED operational policies in TGH, and it aims to be relevant nationally and for other LMICs where EDs exists.

Finally, the novelty and unique contribution of this current study was to add new knowledge to existing literature on stroke mortality outcome and ED crowding in a low resource setting. It will also inform evidence-based policy decisions on quality stroke care. The study will present the contextual appreciation and quantitative extent of ED crowding in a low resource setting. This will inform practical solutions that will improve patient experience and stroke mortality outcomes.

1.18 Aim of the research

The overall aim of this study was to evaluate the levels of overcrowding and predictors of mortality outcomes among stroke patients at the ED of Tema General Hospital in the Greater Accra Region of Ghana, a LMIC in sub-Saharan Africa.

1.19 Research objectives

1. To measure the levels of ED overcrowding using the NEDOCS
2. To establish the case fatality among stroke patients who visit the ED
3. To establish stroke specific mortality outcomes by stroke subtypes

4. To evaluate whether there is an association between CT scan diagnosis and stroke specific mortality.
5. To evaluate whether there is an association between admission BP levels and stroke specific mortality.
6. To evaluate ED overcrowding and other predictors of stroke specific mortality

1.20 Research questions

1. What is the ED crowding situational analysis at the TGH using NEDOCS?
2. What is the case fatality rate among stroke patients who visit the ED?
3. What is the stroke specific mortality outcomes by stroke subtypes?
4. What is the association (if any) between CT scan use and mortality outcomes among stroke patients?
5. What is the association (if any) between admission BP levels and mortality outcomes among stroke patients?
6. What are the predictors of stroke specific mortality?

Chapter 2 LITERATURE REVIEW

2.1 Introduction to the literature review

The literature review assessed different types of evidence including meta-analysis, systematic reviews, and single level peer reviewed papers. The focus was on 1) exploring literature/evidence on ED overcrowding and its relationship/impact on quality of care, mortality as well as the perspectives of patient and ED staff on how overcrowding affects quality of care provided them (search 1), and 2) reviewing and appraising available approaches and tools used to measure aspects of ED care (search 2). In so doing, a two stage search strategy was applied as follows: i) using the PICO (population/patient/problem, intervention/exposure, comparison/control, and outcome) framework to identify and review literature to examine the empirical quantitative literature to highlight the understanding of ED overcrowding and its relationship with mortality and care quality, and ii) a separate search that focused on available tools used to measure aspects of ED care and iii) review of key recommendations regarding acute stroke care.

2.2 Literature review methodology

For a successful literature review, the relevant topics and research questions were defined, and a search plan was developed. Relevant and contextual information identified were examined, evaluated, analysed, and written up. The write up of the literature review was logical, critical, and reflective. I avoided purely argumentative and biases to defend my study. Using the PICO: the primary patients of interest were acute stroke patients; the main exposure of consideration was a crowded ED; expected comparison was among various levels of crowdedness during stroke care at the ED. The main outcome of interest was stroke mortality.

The keywords, phrases, terminologies, concepts, and their alternative words guided the search. They include but not limited to emergency department/ED, overcrowding/crowding, stroke/cerebrovascular accident/cerebrovascular insult, transient ischaemic attack/TIA, stroke diagnosis, clinical management of first-time stroke patients at the emergency department, and clinical outcomes of stroke patients. The key papers so identified was the results of keywords and Boolean operator searches. For search 1, the following search structure was used: (stroke OR cerebrovascular accident OR CVA OR cerebrovascular injury OR cerebrovascular insult)

AND (overcrowding OR crowding OR ED or emergency department OR accident and emergency OR A&E). For search 2, the search was as follows: (overcrowding OR crowding OR ED or emergency department OR accident and emergency OR A&E) AND (measurement OR assessment OR scale OR metric OR quantification OR evaluation).

The databases searched were University of Salford Library online, Medline (Ovid), PubMed, ProQuest Central, ScienceDirect, UK National Statistics, Web of sciences and Wiley Online library, WHO official websites, Cumulative Index to Nursing and Allied Health Literature (CINAHL; EBSCOhost), JSTOR and the Cochrane library (Wiley). Other engines searched were PLOS One, and Sage Journal Online among others. General internet search engines such as Google and Google Scholar were also searched on study themes and topics.

Actual searches were conducted in 2018 and 2019, and they were modified and updated during the following years till the last quarter of 2023. The scope of the study covered the most recent and relevant data and information between 2010 and 2023. In instances where historically documented evidence and records identified spanned before 2010, they were included when found to be relevant to the study. Most of the references were peer reviewed scholarly articles.

For search 1, purposefully selected studies had to meet the following eligibility criteria:

1. peer reviewed journals
2. studies written in English
3. human adult stroke, risk factors, diagnosis and treatment or management or clinical care of stroke
4. Include at least one outcome measure related to a first or recurrent stroke
5. ED overcrowding
6. studies conducted from year 2010 to 2023 or studies conducted before year 2010 that were contextually relevant to the study

Exclusion criteria included:

1. paediatric stroke studies
2. non-English written studies

For search 2, the following criteria was used:

1. measurement of ED crowding or overcrowding, either a framework, understanding, development, validation, appraisal or critique of the measurement tool or scale, or a comparative study on ED overcrowding measurement tools
2. crowding measurement within the context of adult patients at the ED
3. studies written in English

Exclusion criteria for search 2:

1. crowding measurement within the context of paediatric age group at the ED
2. non-English written studies on ED overcrowding measurement

Cited references were examined to allow for full read of the papers cited for better understanding of the subject matter. The methods used for locating cited references were browsing of reference lists, using of citation index, specific author name and title, and setting up email alerts for references citing including studies.

The PRIMSA approach is highlighted in Figure 2.1 on the screening outcome of search 1 and 2. There were only six stroke specific studies with ED overcrowding as exposure and quality care as primary outcomes. Out of these, only one study had stroke specific mortality as a secondary outcome (Ben-Yakov et al., 2015). This secondary outcome was specific for mortalities that occurred among stroke patients on days 7 and 30 after discharge from the ED. None of the studies had stroke specific mortality as a primary outcome. None used the NEDOCS as a metric for ED overcrowding and none was conducted in a LMIC or LIC. A summary of these 6 papers are presented in Table 2.1.

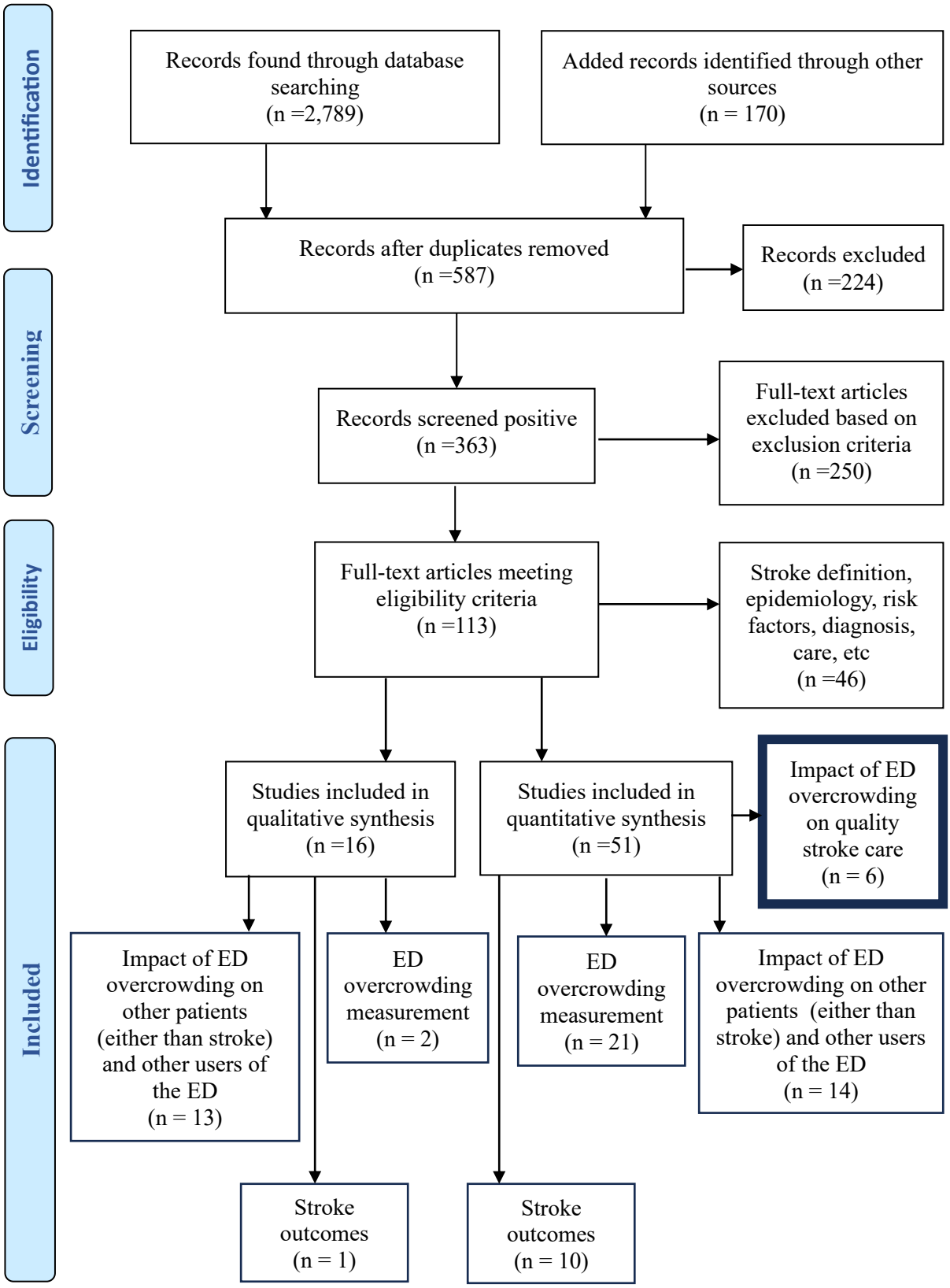


Figure 2.1 PRIMSA flow diagram adapted for the study (Moher et al., 2009)

2.3 Introduction to emergency department overcrowding

The optimal utilisation of the ED translates to timely evaluation, stabilisation, and management of acutely ill patients (American College of Emergency Physicians, 2011). Since the establishment of formal and standard EDs globally, it has been inundated with myriad of practical, structural, technical and operational challenges (Stang et al., 2015). Key among these challenges is the multifaceted phenomenon known as ED overcrowding (Rasouli et al., 2019) described as the canary in the health system (Kelen et al., 2021). The manifestation of overcrowding gives insight to the overarching health system function as experienced by patients, staff and users of the ED (Kelen et al., 2021).

2.3.1 Understanding of ED overcrowding

The definition of ED overcrowding primarily focuses on the inability of the ED to meet patients demands (Pitts et al., 2012), and it secondarily highlights the inherent systematic deficiencies in the entire hospital (Savioli et al., 2022). Substantially, ED overcrowding occurs when the identified need for emergency services exceeds the capacity for which the ED was designed including the lack of available resources in the ED, the hospital or both (American College of Emergency Physicians, 2006; The Royal College of Emergency Medicine, 2015). In agreement with this definition, the ACEM intimates that, when there is access block from the hospital and patients are not been moved from the ED to the in-patient bed, the patients volume at the ED increases (Australasian College for Emergency Medicine, 2014). This increase in patient numbers culminates in overriding the established capacity of the ED, both in space and available resources (Australasian College for Emergency Medicine, 2014).

Despite the relevance of these definitions, they did not encapsulate the concept of quality care provision at the ED, which is principally integral to the safety and survival of patients. The Canadian Association of Emergency Physicians (CAEP) and the National Emergency Nurses Affiliation (NENA) tried to bridge this definition gaps. They indicated that beyond the exceeded capacity and ability of the ED to provide the needed services, demand for quality care within appropriate time frames are also exceeded and this is the defining moments of ED overcrowding (Canadian Association of Emergency Physicians and National Emergency Nurses Affiliation, 2001). To better understand the phenomena of ED overcrowding, a

conceptual framework was developed by Asplin et al in 2003. This is explained in the next few paragraphs.

2.3.2 Conceptual framework for understanding ED overcrowding

Earlier in 2003, Asplin et al developed the first comprehensive conceptual framework for ED overcrowding "to help administrators, researchers, and policymakers understand its causes and develop potential solutions" (Asplin et al., 2003, p. 174). This framework segmented ED crowding causes into systematic and interdependent input, throughput and output factors within an acute care system (Asplin et al., 2003; Badr et al., 2022). The framework presented in Figure 2.2 below has been adopted by many researchers and institutions as the bedrock to unveiling the understanding of ED crowding (Asplin et al., 2006; Hoot & Aronsky, 2008; Stang et al., 2015; Weiss et al., 2004).

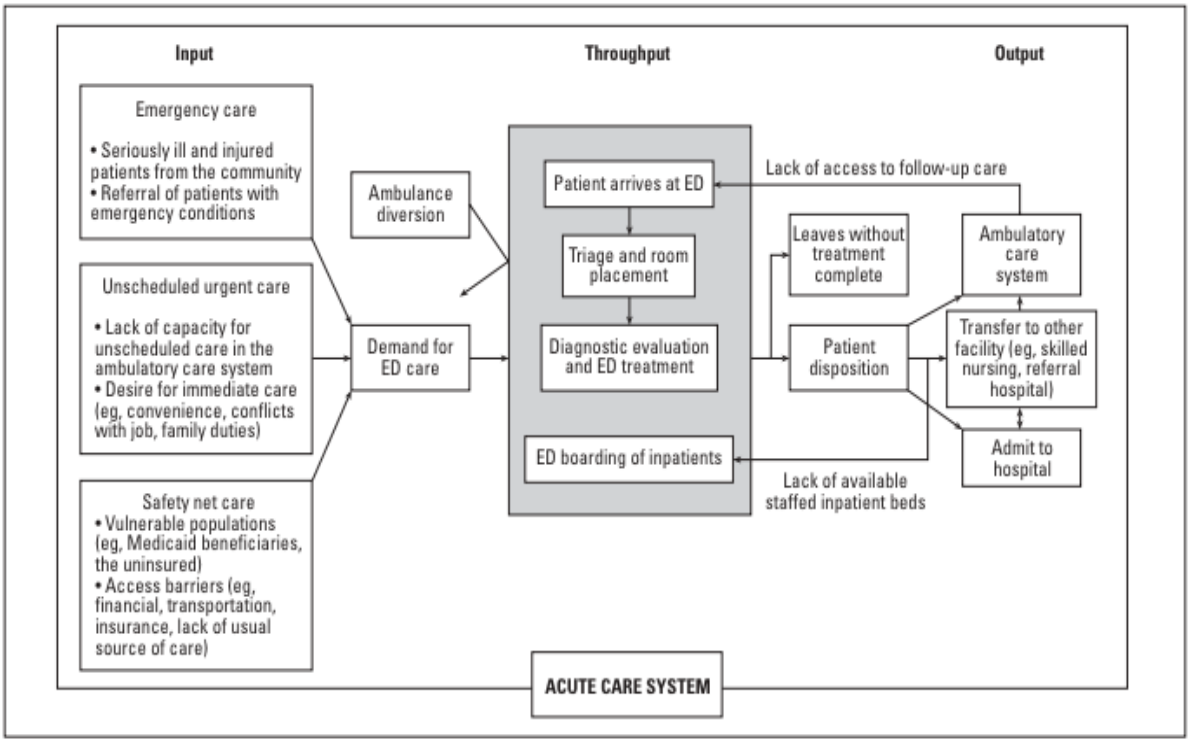


Figure 2.2 Asplin's input-throughput-output conceptual model of ED crowding (Asplin et al., 2003)

2.3.2.1 Input factors of ED overcrowding

Input factors are patient related characteristics that create demand for and access to ED services. They include the severity and complexities of the patients' conditions, the volume of

patients seeking ED services, type of visit (urgent or non-urgent), ambulance arrivals or diversions, ED capacity to hold unscheduled visits and referred patients among others (Arkun et al., 2010; Asplin et al., 2006; Savioli et al., 2022). Ageing population and health seeking behaviour of patients have been found to increase patients presentation at the ED (Carter et al., 2014; Pearce et al., 2023; Rasouli et al., 2019). According to Kelen et al (2021), there are usually surge in patients' volumes the day after weekends and holidays. Also, most patients scheduled for elective admission prefer to be admitted at the ED especially when they anticipate lack of beds at the in-patient hospital space (Kelen et al., 2021). Patients with public based insurance have also been found to visit the ED frequently in a year compared to those without this type of insurance (Salway et al., 2017). These factors contribute to increased ED demand especially during unpredictable times. These patient's complexity of health seeking behaviour has been perceived to cause crowding at the EDs in Pakistan, the Netherlands and many other jurisdictions (Van Der Linden et al., 2017).

2.3.2.2 Throughput factors of ED overcrowding

The throughput factors affects mainly on internal ED processes (McDermid et al., 2020), and they are categorised into two phases (Asplin et al., 2003). Phase one initiates the patient flow processes and they include patient triaging, room placement and initial patient evaluation. Phase two which makes up most of the throughput include diagnostics (laboratory and imaging services), ED evaluation and treatment and boarding of patients. The inability to move patients from the ED to the in-hospital bed referred to as boarding and it has been found to be a core component of the output factors that originates from throughput (Asplin et al., 2003; Derlet et al., 2001). This will further be explored in the next few paragraphs.

2.3.2.3 Output factors of ED overcrowding

ED output factors create hinderance to moving a patient into an in-hospital bed. These factors include hospital occupancy, inpatient bed shortage, internal and external transport delays, inefficient transfer and discharge processes among others (Savioli et al., 2022). When these are not addressed in a timely manner to forestall the operational integrity of the ED, it leads to boarding, an important cause of overcrowding (American College of Emergency Physicians, 2011; Rabin et al., 2012). Boarding and access block have been documented as predominant causes of ED crowding representing the highest intersection of ED overcrowding (Grant et al., 2020; Rasouli et al., 2019; Sartini et al., 2022)..

2.3.2.4 Boarding and access block as principal causes of ED overcrowding

Boarding is the holding of patients in the ED after they have been admitted to the hospital mainly due to lack of in-patient bed (American College of Emergency Physicians, 2011). Patients who board continue to consume nurses and physicians time and inadvertently deny new and other patients the needed attention at the ED (Fatovich & Hirsch, 2003; Royal College of Emergency Medicine, 2021). Boarding can be measured by the number of boarders or boarding time of patients at the ED. Where boarding time is the time difference between the physician decision to hospitalise a patient until the actual transfer occurs and it has been found to be inversely related to patients acuity (Doupe et al., 2018). Boarding at the ED occurs when there an access block in the hospital. Access block primarily affects admitted patients primarily.

According to the ACEM, access block refers to the situation where patients who have been admitted and need hospital beds are delayed from leaving the ED for more than 8 hours because of a lack of in-patient bed capacity (Australasian College for Emergency Medicine, 2022). In that instance admission occurs when a medical decision for the need of in-patient care is made by an appropriately qualified decision maker, a patient is accepted by a hospital in-patient specialty services for ongoing management, and the patient is administratively admitted to the hospital (Australasian Collage for Emergency Medicine, 2020). According to the International Federation for Emergency Medicine (IFEM), access block is a major contributor to ED overcrowding and an important public health issue that adversely causes delays in critical emergency care, leads to preventable patients' deaths and result in poor treatment of ED staff (Javidan et al., 2021; Leong-Nowell et al., 2023).

Summarily, the culmination of ED patients' volume, levels if acuity, patient evaluation and treatment mechanisms, number of available ED and hospital beds, number of patients awaiting in-patient beds, number of boarders, percentage of bed occupied by boarders, referral and transfer systems, number of patients ready for discharge among others at a given time interplay to cause ED overcrowding (Lindner & Woitok, 2021). Documents evidence have provided insight to the impact of an overcrowded ED on the quality care provision at the ED.

2.4 ED overcrowding and its impact on the quality of care

ED overcrowding correlates with ED mortality rates, decision to admit time, left without been seen (LWBS), ambulance hand over times, patient wait times, ED LOS, medical errors, adverse clinical outcomes, poor patients and staff (nurse/physician) satisfaction and negative effect on teaching and research among others (Canadian Association of Emergency Physicians and National Emergency Nurses Affiliation, 2001; Carter et al., 2014; Iacobucci, 2021; Kelen et al., 2021; McCusker et al., 2014; Morley et al., 2018; Phillips et al., 2017; Royal College of Emergency Medicine, 2020, 2022; Savioli et al., 2022; Stang et al., 2015; Verelst et al., 2015; Verma et al., 2021).

These quality care variables listed above are categorised into six domains as described by the Institute of Medicine in the book titled "crossing the quality chasm: a new health system for the 21st century" (Bernstein et al., 2009; Institute of Medicine, 2001). The domains include: 1&2) safety and effectiveness, which bothers on mortality, left without been seen, preventable medical errors and adverse events; 3) timeliness, which is basically the time to interventions including time to antibiotics, time to thrombolysis, time to percutaneous interventions, and time to analgesia; 4) patient centeredness, where patient satisfaction with waiting times, prolonged holding, turnaround time, is considered; 5) efficiency, which focuses primarily on the length of hospital stay and surge capacity among others and 6) equitability, which are more of personal characteristics like gender, ethnicity, geographic location and socioeconomic status which manifest in healthcare disparities like waiting times to see ED providers (Bernstein et al., 2009; Institute of Medicine, 2001).

Evidence from various studies strongly suggest the negative impact of ED crowding on: increased in-patient mortality and admission among critically ill patients (Jo et al., 2015; Khubrani & Al-Qahtani, 2021; Singer et al., 2011; Sun et al., 2013; Björn Ugglas et al., 2020; Bjornaf Ugglas et al., 2021; Wessman et al., 2022); patient LOS (United States. Government Accountability Office Committee & Finance, 2003; Ye et al., 2012); delays in percutaneous coronary interventions in acute myocardial infarction (Kulstad & Kelley, 2009); unexpected in-hospital cardiac arrest among non-traumatic patients (Kim et al., 2020); prolonged hospital laboratory (troponin) processing time (Hwang et al., 2010); lower compliance with the entire resuscitation bundle among severe sepsis and septic shock patients (Shin et al., 2013); and reduced satisfaction among discharged patients (Tekwani et al., 2013) among others.

These evidenced-based studies of the impact of overcrowding on patient care and clinical outcomes have been conducted mostly in HICs and some UMICs like the UK, USA, Sweden, Australia, South Korea, China, Saudi Arabia, Canada, Belgium, Italy, and India, among others.

A report from the Royal College of Emergency Medicine (UK) series on crowding and its consequences in the November 2021 edition reiterated that ED crowding had worsened significantly in recent years. Subsequently it resulted in 4,519 excess deaths in England, basically due to the severe mismatch between demand and capacity of the NHS (Royal College of Emergency Medicine, 2021). The report cited increase in ED attendance, deterioration of the 4-hour target and increase in the 4-hour and 12-hour 'decision to admit' time which have increased over the past 8 years (Royal College of Emergency Medicine, 2021). These time series factors potentially contributed to the crowding situation at EDs with increased associations with mortality and increased LOS in England and Scotland.

In a British Medical Journal report, Boyle, the policy vice president of the Royal College of Emergency Medicine alarmed by the figures intimated that "The situation is unacceptable, unsustainable, and unsafe for patients and staff" and expressed that "To say this figure is shocking is an understatement. Quite simply, crowding kills. For many years we have issued warnings about the harm that dangerous crowding causes, but now we can see the number of excess deaths that have occurred as a result" (Iacobucci, 2021, p. 1). He said that October 2021 saw an "unimaginable" 7,059 stays of 12 hours from the time of decision to admit, the highest number ever recorded and that "The picture is more bleak, as hospital episode statistics show that 12 hour stays from time of arrival are 21 times higher than 12-hour decision to admit stays. We now know that at least one in 67 of these patients are coming to avoidable harm. It is appalling" (Iacobucci, 2021, p. 1).

The ambulance handover times was also reported to have recorded the highest figure (average median time to assessment of 10 minutes) in recent times in the UK. Same as the median amount of time that patients waited from arrival at an ED to treatment which had also increased recording an all-time high in September 2021 (Royal College of Emergency Medicine, 2021). The general impact of ED crowding on health care systems results in impaired efficiencies in hospitals, staff burnout, moral injury and loss of highly skilled emergency care professionals (Royal College of Emergency Medicine, 2021).

A systematic review of 59 LMICs ED studies from 1990 by Obermeyer et al. (2015) revealed that only one study focused on quantifying ED overcrowding (Rehmani, 2004). A study in a teaching hospital in Saudi Arabia looked at the association between ED crowding and overall mortality (Khubrani & Al-Qahtani, 2021). In Ghana, very few studies have been conducted on ED crowding in the past 10 years. In a secondary referral hospital in the Volta Region of Ghana, staff challenges in correlation with ED crowding have been assessed in qualitative studies (Afaya et al., 2021; Atakro et al., 2016). Findings of which iterated the frustration health staff go through in the hands of unsatisfied patients and inadequate resources in an overcrowded ED (Afaya et al., 2021; Atakro et al., 2016). For the purposes of this current stroke study, the impact of overcrowding on three of these quality of care and intervention variables was explored.

Time-based guidelines (American Health Association/American Stroke Association and the National Institute of Neurological Disorder and Stroke rt-PA Stroke Study Group) for emergency evaluation of acute stroke patients recommend the performance of emergency brain imaging within 25 minutes of arriving at the ED before initiation of stroke treatment (Alberts et al., 2000; Jauch et al., 2013; Kelly et al., 2012; Powers et al., 2015, 2019; The National Institute of Neurological Diseorders and Stroke rt-PA Stroke Study Group, 2012). The time between when the patient arrives at the ED and when CT scan is conducted is referred to as the door to imaging time (DIT) or the door to CT (DTCT) completion time. It is recommended that eligible patients (treatment anticipated within 3 – 4.5 hours of symptoms onset) for intravenous rTPA must receive it within 60 minutes upon arrival at the ED among ischaemic stroke patients to improve clinical stroke outcomes (Jauch et al., 2013; Powers et al., 2015, 2019; The National Institute of Neurological Diseorders and Stroke rt-PA Stroke Study Group, 2012). This is measured as the door to needle (DTN) time.

The door to groin puncture (DTP) times for endovascular therapy is another measure of quality of stroke care. Endovascular therapy include among others intra-arterial fibrinolysis, mechanical clot retrieval, mechanical clot aspiration and acute angioplasty and stenting (Powers et al., 2015). For the well-established evidenced-based recommendation for intra-arterial fibrinolysis administration, it is effective and beneficial if administered within 6 hours of symptoms onset of ischaemic strokes (Powers et al., 2015).

2.4.1 Impact of ED overcrowding on the CT scanning and assessment times of stroke patients as quality care indicators

The decision to perform a CT scan through the actual conduct of the scan has various time variables which can be influenced by the crowding status of the ED. Assorted studies have been conducted to assess the impact on ED overcrowding on these CT scanning time intervals. Chatterjee et al (2011) conducted one of the earliest ED overcrowding studies and how that impacted on CT imaging times in the evaluation of stroke patients. Interestingly, the authors found ED overcrowding not to be associated significantly with care delays in CT timing and thrombolysis administration among eligible stroke patients who presented with symptoms onset less than 3 hours (Chatterjee et al., 2011). However, in the same study, stroke patients who presented with symptoms onset greater than 3 hours experienced CT delays at higher levels of ED overcrowding (Chatterjee et al., 2011).

The study by Chatterjee et al (2011) was conducted in two urban hospitals (2005 – 2008). The first was an academic hospital with comprehensive 24-hour facilities for stroke care. The hospital ED had a stroke team that readily responded to stroke codes and there was a CT scan adjacent to the ED on the same floor (Chatterjee et al., 2011). The second was a community hospital with no stroke unit, no stroke team, no stroke neurologist in-house and the CT scanner was located 3 floors above the ED requiring elevator transport (Chatterjee et al., 2011). ED crowding was measured using tracking system queries of waiting room number, ED occupancy, admitted patients' number and total patient-hours.

Among the 253 stroke patients (199 were in the academic tertiary hospital and 54 were in the community teaching hospital) who reported to the ED under 3 hours from onset of acute symptoms, 60 (51 in the academic hospital and 9 at the community hospital) had CT scans read under 45 minutes and 52 (49 in the academic hospital and 3 were in the community hospital) received thrombolysis (Chatterjee et al., 2011). There was no significant delays in CT imaging and thrombolysis in both hospitals for patients with acute symptoms under 3 hours and there were no correlations with ED crowding levels (Chatterjee et al., 2011). The CT scan and thrombolysis timing performance was however better in the academic hospital (Chatterjee et al., 2011). However, the study found delays in CT imaging among patients who reported with symptoms more than 3 hours and these delays were significant at higher levels of ED crowding especially in the community hospital (Chatterjee et al., 2011).

The academic hospital performed better potentially because of the existence of robust protocols and effective response systems. The presence of a stroke code centre, stroke specialists, readily available CT scanner on ED floors potentially improved stroke diagnosis and guided the prompt initiation of treatment. These intervention variables were not affected by levels of crowding as the ED set up could swiftly organise and implement care measures especially among patients who arrived early. Considering that most patients reported during weekdays when crowding was high (Chatterjee et al., 2011), it is assumed that hospital staffing and resources were most likely available to expedite patient care during these crowding peaks (Jaffe et al., 2020). Improved patients flow at the ED as a result of effective patient movement mechanisms improves timeliness and effectiveness of care which subsequently reduces crowding and improves patient outcome (Austin et al., 2020; Jarvis, 2016). On the contrary, in non-stroke community hospitals, intervention delays potentially happen as the infrastructure and care ingredients for stroke patients are not readily available. These care delays are worsened at higher levels of ED crowding especially among patients who do not report with acute symptoms on time (Chatterjee et al., 2011).

In variance to the findings by Chatterjee et al (2011), Tsai et al (2016) found ED crowding to be significantly associated with delays in door to CT completion time (DTCT) and door to assessment time (DTA) time among 1,142 stroke patients who also reported within 3 hours of stroke symptoms onset. In the study by Tsai et al, there were 249 (22%) stroke patients with delays and 893 (78%) without delays in DTCT (Tsai et al., 2016). Stroke patients with DTCT less than 25 minutes were classified as non-delays and greater than 25 minutes were said to have delayed DTCT (Tsai et al., 2016). The 25 minutes threshold was per the recommendations of the American Heart Association and the American Stroke Association (Powers et al., 2019).

The Tsai et al study took place in a tertiary academic hospital with the largest stroke centre and 24-hour stroke team between 2008 – 2013 in Southern Taiwan (Tsai et al., 2016). Interestingly, in the same Tsai et al study, ED overcrowding was found not to cause delays in the door to needle (DTN) for eligible stroke patients who received thrombolysis. The potential reasons for these two distinct and opposite findings from the same study is here in analysed. ED overcrowding was associated with delays in the DTCT and DTA time. It had to do with the roles of the attending physicians, residents and how that affected the initial assessment and DTCTs. Attending physicians from this study spent 70.7% of their time completing CT scans compared to residents who spent more time (Tsai et al., 2016). After adjusting for patient and

ED crowding factors, the number of patients, number of attending physicians and initial evaluation by an attending physician were significantly associated with the DTA and DTCT. In contrast, the number of attending nurses were significantly associated with the DTN for thrombolysis. Whereas an association was found between physician numbers and the DTA and DTCT it was not same for nurses. Also, just as an association was found between number of nurses and DTN time it was not same for physicians.

Physicians conduct initial clinical assessment and nurses implement treatment decision (setting intravenous access, mounting patient monitors, blood sampling, laboratory testing, facilitating transfers for CT scans and administration of medications). It therefore resonates that physician count influences door to assessment time and nurses count influences door to needle time for thrombolysis administration. The assumption in the Tsai et al (2016) study is that majority of the delays in the DCTC could have been contributed mostly by the residents who did the initial evaluation of the stroke patients. When physicians take part in the early evaluation and management of stroke patients they perform better compared to residents. They can activate ED protocols early and collaborate better with residents and nurses inside the hospital. They also liaise better with the stroke team and other ancillary services such as CT scan and laboratories that may be outside the ED. Clinical decisions in the ED are even better with consultants availability and this could save more time (Lee et al., 2020).

2.4.2 Impact of ED overcrowding on the administration of thrombolysis in stroke patients

The use of recombinant tissue plasminogen activator for thrombolysis (rTPA) has been found to be effective in the management of eligible stroke patients with favourable outcomes. The recommended time for rTPA should be within 60 minutes of arrival at the ED and this should only be administered after a CT scan has been performed to determine eligibility (Jauch et al., 2013; Powers et al., 2015, 2019). In the study by Tsai et al (2016), the authors found no association between ED crowding and DTN time among 90 ischaemic stroke patients (with acute stroke symptoms under 3 hours of onset) who received thrombolysis. As has been postulated earlier, no associations were established probably because of the robust set up of the ED and the activities initiated to forestall the negative impact of overcrowding. The findings could therefore not be generalised to settings where these effective facilities are not available.

Jaffe et al (2020) also conducted a similar study to determine the impact of overcrowding on delays in stroke care among 1,379 ischaemic stroke patients between 2016 – 2018 in a single urban academic hospital in Massachusetts, USA. There were 298 stroke eligible patients (reported within 4.5 hours of symptoms onset) (Jaffe et al., 2020). The median DIT was 26 minutes which did not differ significantly by the crowding status of the ED at the time of their presentations (Jaffe et al., 2020). There were 82 rTPA eligible patients whose median DTN was found to be 43 minutes which did not significantly vary by the crowding status of the ED at the time of presentations (Jaffe et al., 2020). There were 52 patients who received endovascular therapy with a mean DTP of 68.5 minutes which did not vary by the crowding status of the ED at the time of presentation (Jaffe et al., 2020). Capacity logs was used by the authors to determine the crowding status of the ED(Jaffe et al., 2020)..

Further analysis showed that the study by Jaffe et al (2020) was in a single, urban, academic hospital with a stroke centre and comprehensive facilities for acute stroke. There were two dedicated CT scanners located within 2 minutes stretcher transfer from the ED (Jaffe et al., 2020). There was an effective code stroke activation systems that mobilised ED neurology team, ED pharmacist, ED radiology team and CT technologist when needed (Jaffe et al., 2020). The presence of these robust stroke care systems again could have influenced the outcome of their study which limits the generalisation of the findings to other jurisdictions with poor ED set up.

Contrary to findings by Jaffe et al (2020) and Chatterjee et al (2011), a different study found an association between ED overcrowding and delays in imaging times among 463 acute stroke patients (Reznek et al., 2017). There was a reduced odds (AOR of 0.83) of meeting DIT target times (equal to or less than 25 minutes) per 10% absolute increase in the overcrowding status of the ED (Reznek et al., 2017). The study by Reznek et al was in an urban, regional referral hospital with stroke code activation systems, 24/7 stroke team and an ED in-patient dedicated CT scanner (Reznek et al., 2017). Though this study took place in a well-established ED with the requisite set up to manage stroke patients, ED crowding negatively impacted imaging times. The inconsistencies in the findings from Chatterjee et al, Jaffe et al and Reznek could be due to explanations.

The determination metric for ED overcrowding in the study by Chatterjee et al and Reznek et was the EDOR (total number of patients in the ED, divided by the number of licenced beds in the ED). Jaffe et al (2020) used crowding logs (normal, high, and severe capacity constraints)

as a measure of overcrowding. The median EDOR in the Chatterjee study was 78%, that for Reznek et al was 122%. A granular analysis of exposure-response relation between ED overcrowding and DIT will help explain the findings better.

Beyond the predictive power of ED overcrowding, there are other ED operational factors that could also predict the imaging times for CT scan among stroke patients. At lowers levels of ED crowding as in the Chatterjee et al study, the barriers of timely DIT could be more easily overcome than at higher burdens of crowding as seen in the Reznek et al study. Also, variation in the categories of stroke patients involved in these studies are worthy of note. Whereas Chatterjee et al and Tsai et al focused-on patients arriving within 3 hours of symptoms onset which is an eligibility criteria for intravenous thrombolysis treatment, Reznek et al focussed-on patients arriving within 12 hours of symptoms onset per stroke code activation protocols. Comparing the findings of all these studies may show some inconsistencies when the finding could be consistent with standardisation in the ED overcrowding determination and the category of stroke patients involved in the studies.

Momeni et al (2018) conducted a study in Iran to assess the impact of ED overcrowding on the quality of care among stroke patients like some of the studies presented above. Using ED occupancy as a measure of overcrowding, they found no significant correlation between ED crowding with the time frame associated with the management of admitted stroke patients (Momeni et al., 2018) in contrast to the study by Reznek et al (2017), Ben-Yakov et al (2015) and Chatterjee et al (2011) but in agreement with the study by Jaffe et al (202), Unlike like these other studies, the Momeni et al study was in the referral Shariati Hospital in Tehran and did not detail the setting of the ED and how robust it responded to stroke acuity patients. It is not clear whether there was an in-ED CT scan or a 24-hour stroke team with stroke specialist within minutes of stroke code activation. However, considering the tertiary status of the hospital it is assumed to have robust ED facilities. Momeni et al admitted to documentation errors as a limitation in their study which made it difficult to document the exact time of some of the activities. They could also not access the DTN time as most of the patients referred to the ED was after 3 hours of stroke presentation yielding only few eligible patients for thrombolysis. Generalization of their findings will therefore be limited (Momeni et al., 2018). These stroke documented studies are relevant towards the understanding of the impact of ED overcrowding on the quality of stroke care and timeliness of interventions.

2.4.3 ED overcrowding and impact on physician decision on stroke patients

In the era of re-hospitalization of discharged stroke patients, studies on how overcrowding potentially influence physician decision becomes relevant. Ben-Yakov et al (2015) studied the impact of ED crowding on the disposition of TIA (4,607) and minor stroke (5,152) patients who visited 12 EDs in Ontario, Canada between 2003 - 2008. This is one of the rare stroke studies that looked at physician decisions and how that was influenced by the crowding status of the ED. Their findings suggested that greater severity of ED crowding was associated with a lower likelihood of physicians discharging patients with TIA or minor stroke irrespective of the ED volume strata (Ben-Yakov et al., 2015). This meant that as crowding worsened fewer stroke patients were discharged and many more stroke patients were admitted. Physician decisions could well lead to medical errors when they feel rushed as a result of crowdedness (Broida et al., 2016; Kulstad et al., 2010; Tekwani et al., 2013). As the physicians and nurses feel rushed, the risk of error increases and these errors could lead to adverse patient outcomes (Canadian Association of Emergency Physicians and National Emergency Nurses Affiliation, 2001; Pines et al., 2008; Pines & Griffey, 2015).

The questions of interest are that, when physicians are under pressure during crowding periods, are their disposition decision influenced by the state of the ED? Do they provide suboptimal care and hastily discharge patients who ought to be admitted? Do these decisions affect re-visits and re-hospitalizations? Are physicians likely to discharge patients when they have confidence that patient clinical situation will not deteriorate especially when their investigations are simple, example in cases of diarrhoea and common cold? To expand the literature, inferences was drawn from non-stroke specific studies due the paucity of data in the subject area in relation to stroke specific studies.

An earlier retrospective 3 months data (14,969 patients of varied acuity) analysis from a community ED showed interesting findings (Albrecht et al., 2011). On "busy" days, 20.1% of the 3400 patients were admitted to the hospital; on "medium" days, 20.6% of the 9057 patients were admitted; on "slow" days, 19.7% of the 2512 patients were admitted (Albrecht et al., 2011). Where "busy" (greater than 180 patients seen), "medium" (147-180 patients seen) or "slow" (less than 147 patients seen) were defined as such (Albrecht et al., 2011). There was no significant association found between ED crowding and the likelihood of admission or discharge from the ED (Albrecht et al., 2011). When each of 14 attending physicians working during distinct levels of crowding at the ED were compared to him- or herself, there was no

significant association found between rate of admission and the number of patients volume at the ED (Albrecht et al., 2011).

A follow up of the discharged patients showed no significant relationship between patients who were discharged during periods of high occupancy at the ED and they returning to the ED within 2 weeks of discharge (Albrecht et al., 2011). Again, there were patients who were discharged during crowding periods at the ED and the assumption was that because they were discharged prematurely, they will revisit the hospital within few days with worsened conditions which will warrant readmission. This was found not to be the case, as no significant association was found between those patients discharged at the index visit during crowdedness at the ED and they been readmitted during their return visits (Albrecht et al., 2011).

As interesting as these findings may be, contrary evidence has been demonstrated in other studies. In a study in the UK involving 1,314,942 eligible ED attendants in 13 English NHS Hospital Trust in 2019, admission thresholds were found to be modestly associated with ED and patient occupancy rates when they reached extreme levels (Wyatt et al., 2022). A patient who arrived at the ED during very high occupancy was 3.3% less likely to be admitted compared to a patient who arrived at a time of low occupancy with a 3.9% more likelihood of been admitted (Wyatt et al., 2022). To the extent that riskier discharge decisions are likely to be taken when the ED is full to capacity (Wyatt et al., 2022). Wyatt et al found that after adjusting for the day of the week and the time of the week, the number of patients admitted shot up when more beds became available in the in-patient hospital and when the bed capacity dropped fewer admissions were made (Wyatt et al., 2022). The average number of patients seen at the ED was 647 (Wyatt et al., 2022) much higher than those seen in the study by Albrecht et al (2011). These average patient volumes should be considered when comparing the two studies with varied findings.

In another recent study where 111,529 ED patients visits were evaluated in an adult, urban and academic ED in USA, there were 12,735 (11.2%) disposition decisions made during high ED occupancy hours (Abir et al., 2019). In that study, disposition decisions taken during high occupancy hours and high boarder counts significantly reduced the odds of admission (OR = 0.90) after controlling for patient acuity, disease severity, daily denials of ED to ED transfers, day of the week and season (Abir et al., 2019). In an earlier large population-based study in all EDs in Ontario, Canada, there were 21,925,275 visits between 2003 – 2008 with 13,934,542 index patients seen and discharged from the ED (Guttmann et al., 2011). Within 7 days of

discharge, 8.1% patients revisited the ED with high acuity, 1.8% were re-hospitalised and the death rate among the revisits was 0.075% (Guttmann et al., 2011). The adjusted odds ratio for death and admission for every additional hour of crowding was 1.79 and 1.95 respectively among high acuity patients and 1.71 and 1.66 respectively among low acuity patients (Guttmann et al., 2011). The risk of death was found to increase incrementally with each additional hour of mean waiting time (Guttmann et al., 2011).

The extrapolated conclusion from the Guttman et al study shows that patients who were seen and discharged from the ED because they were well had a higher likelihood of ED re-visit, admission, and death. This is a significant and consistent finding that bothers on the quality of care of patients who visit the hospital and the ED and how physician decision during periods of crowding impacts negatively on the patient outcome. In scenarios where the clinical evaluation is sophisticated and time consuming, physicians are more likely to opt for admission especially among old and high acuity patients (Ben-Yakov et al., 2015). This would allow for investigations to be completed in the hospital and ensure patients safety especially during crowding periods when physicians are confronted which large patient volumes. In such situations, physicians are bound to consider patient, ED, and hospital factors in deciding on patient disposition.

The evidence reviewed suggest that ED crowding potentially influence physicians' decision to admit or discharge patients and this can result in avoidable discharges or admissions. It is of importance to note that these studies do not offer direct insights into the mechanisms underpinning the relationships between ED crowding and physician decisions to admit or discharge patients. It is hereby hypothesised that some of the mechanisms may be consistence even under different circumstance of patient, ED, and hospital factors. Other potential confounders including patients age, gender, ethnicity, primary diagnosis, prior ED attendances and admission, arrival mode, month of the year, day of the week and time of the day of arrival, the number of patients in the ED, and the number of emergency and elective cases must be considered and analysed for a more comprehensive interpretation and generalisation of findings. Considering that up to about 90% of EDs experience overcrowding with increasing frequencies and severity globally (Affleck et al., 2012; Broida et al., 2016; Kelen et al., 2021) its impact on stroke and other high acuity patients will continue to be relevant for academicians, researchers, policy makers and governments. A summary of ED crowding and stroke specific

studies that met the eligibility criteria explained in the PRIMSA flow chart in Figure 2.1 above are presented in the Table 2.1 below.

Table 2.1 Summary of stroke specific studies on ED overcrowding and its impact on quality of care

Authors	**Study title**	**Location/No. of EDs and eligible stroke patients**	**Type of ED**	**ED crowding measure**	**Quality care measure (primary outcome of interest)**	**Key findings on quality care of stroke patients**	**Conclusions**	**Limitations of the studies**
Jaffe et al. 2020	Impact of ED crowding on delays in acute stroke care	USA 2016 - 2018 1,379 stroke patients	Large, urban, academic centre with comprehensive systems for stroke care 1 ED	ED capacity logs	*DIT *DTN time *DTP time	ED crowded 23% of the time Median DIT: 26 minutes Median DTN: 43 minutes Median DTP time: 58.5 minutes	No significant association between ED overcrowding and stroke care	Retrospective analysis in a single facility Smaller number of patients reported during crowding periods as the hospital was closed to internal and external transfers during crowding
Momeni et al. 2018	ED impact of the quality of care of patients presenting with acute stroke	Iran 2014 104 stroke patients	Tertiary referral hospital 1 ED	*EDOR	Triage to first ED physician visit Triage to neurologist visit Triage to ECG	Average daily ED occupancy rate: 185% Median triage to physician visit: 34 minutes	No significant association between ED overcrowding and time frames for stroke care	Cross sectional analysis in a single facility Documentation errors with regards to various times Most stroke patients were

					Triage to brain CT Triage to aspirin administration	Median DIT: 134 minutes Median first neurologist visit: 138 minutes		referred to ED after 3 hours making it difficult to assess DNT for thrombolysis
Reznek et al. 2017	DIT for acute stroke patients is adversely affected by ED crowding	USA 2014 – 2015 463 stroke patients	Urban, regional referral stroke centre hospital with robust systems for stroke care 1 ED	*EDOR	*DIT *DAT	Median EDOR: 122% Median DIT: 21 minutes Median DAT: 5 minutes	ED overcrowding is significantly associated with reduced odds of meeting DIT goals for acute stroke patients	Retrospective analysis in a single facility Other factors that may have influenced DAT was not accounted for Small thrombolytic patients sample size (46/463)

Tsai et al. 2016	The influence of ED crowding on the efficiency of care for acute stroke patients	Taiwan 2008 - 2013 1,142 stroke patients	Tertiary academic hospital with the largest primary stroke centre in Southern Taiwan 1 ED	No. of ED patients No. of medical staff (physicians, residents, and nurses)	*DTA *DTCT **DTN	Medians no. of ED patients was 22.5 Mean DTA: 8.55 minutes Mean DTCT: 20.5 minutes Mean DTN: 66.62 minutes	No. of ED patients and number of attending physicians was significantly associated with delayed DTA and DTCT. No. of nurses associated with delayed DTCT and DTN time	Retrospective study in a single centre Time for CT scan documentation errors Reasons for the delays not established
Ben-Yakov et al. 2015	The association between ED crowding and the disposition of patients with TIA or minor stroke	Canada 2003 – 2008 9,759 TIA or minor stroke patients	Tertiary hospitals with designated comprehensive stroke care centers 12 EDs	*ED LOS (greater than 4 hours)	Proportion of patients discharged from the ED within each ED LOS group Secondary outcome of interest: mortalities on day 7 and 30 after	Number and Proportion of patients discharged during ED crowding: 7,845 (80.4)	Odds of been discharged decreased with increasing ED crowding levels	Potential documentation error from hospital registry Unable to detect if discharge decision was made by an emergency physician or a consultant

					discharge from the ED			
Chatterjee et al. 2011	ED crowding and the time to care in patients with acute stroke	USA 2005 - 2008 253 stroke patients reported under 3 hours and 253 patients after 3 hours	I ED had comprehensive stroke services with CT scan adjacent to ED on the same floor. 1 ED had no comprehensive stroke services, CT scan located three floor above the ED	*EDOR	*DIT *DTN time	EDOR in academic vs community ED: (78% vs 79%) Median time to CT read in academic vs community ED (67 vs 109 minutes) for patients who reported under 3 hours	No significant association between ED crowing and delays in door to CT read time or DTN time in patients who reported under 3 hours contrary to those who reported after 3 hours	Retrospective study in only 2 EDs Documentation error in time capture Small sample size (52/253) for thrombolysis hence unable to do a multivariate analysis

*DAT: door to activation time – stroke teal activation (≤ 15 minutes)

*DIT: door to imaging time for CT scan for patients eligible for thrombolysis (≤ 25 minutes)

*DTA: door to assessment time (not delayed and delayed was ≤10 and >10 min)

*DTCT: door to CT completion time (non-delayed and delayed DTCT completion times were defined as ≤25 and >25 min, respectively)

**DTN: door to needle time for thrombolysis (non-delayed and delayed DTN were defined as ≤60 and >60 min, respectively)

*DTP: door to groin puncture time for endovascular therapy

*ED LOS: ED length of stay greater than 4 hours was considered as period of ED crowding

*EDOR: ED occupancy rate is the total number of ED patients divided by the number of licensed ED

2.5 Impact of ED overcrowding on patient mortality

The ED exist to ensure that patients experience avoidable deaths. There are a few studies in general and very few stroke specific studies that have looked at ED overcrowding and it impact on patient mortality outcomes. Two broad categories of such studies exist in this regard. One primarily on mortality outcome among admitted patients at the ED, and the other on mortalities that occur in non-critically ill patients discharged from the ED. Majority of studies have revealed distinct associations between higher levels of ED crowding and increased patients mortality and more significantly during increased hours of exposure to higher levels of crowding at the ED (Jo et al., 2014, 2015; McCusker et al., 2014; Richardson, 2006). In contrast, a few studies have found no significant differences or any association in patients mortalities or mortality rates and ED crowding level (Derose et al., 2014; Gaieski et al., 2017; Van der Linden et al., 2016; Verelst et al., 2015; Wu et al., 2015).

In a systematic review, 20 (71.4%) of the final 28 articles analysed reported direct association between ED crowding and ED patient mortality (Mahmoodi et al., 2023). These articles concluded that mortality rates increases as crowding became worse (Mahmoodi et al., 2023). However, the remaining 8 (28.6%) articles reported no associations between ED crowding and mortality outcomes among admitted patients (Mahmoodi et al., 2023). Most of the articles (23/28) were retrospective in character and the countries of studies were in North America (13/28), Asia (8/28), Europe (4/28) and Australia (3). Non from the African region (Mahmoodi et al., 2023). This highlights again geographical research gaps especially in LMICs and LICs.

In a large scale study involving every Type 1 (major) ED in England between 2016 – 2018, where 5,249,891 patients were admitted for the first time, a total of 433,962 (8.71%) deaths were recorded within 30 days of admission (Jones et al., 2022). It was found that, from 5 hours after time of arrival at the ED up to 12 hours, a statistically significant linear relationship in mortality existed (Jones et al., 2022). There was an 8% increase in the 30-day mortality for patients who waited in the ED for more than 6 to 8 hours after arrival (Jones et al., 2022). In another study conducted among 103,196 ED visits in Tampere University Hospital ED, Finland between 2018 and 2020, the overall 10-day mortality rate was found to be 1% (1,022 deaths) with an increase of odds of mortality (OR = 1.3) among patients treated during higher levels of ED crowding (Eidstø et al., 2023).

In an earlier large population-based study in Ontario, Canada where about 14 million patients were seen and discharged from the ED between 2003 to 2007, the adjusted odd of death among high (AOR = 1.79) and low acuity (1.71) admitted patients was higher for LOS greater than 6 hours compared to under 1 hour respectively (Guttmann et al., 2011). A much earlier Australian study involving 3 difference metropolitan hospital EDs found significant associations found between ED crowding and deaths (3,084) among 62,495 first ED attendants between 2000 to 2003 (Sprivulis et al., 2006). In that study, a relative increase in mortality by 18% was recorded on day 7 when hospital occupancy was between 90% - 99% and the mortality rate increased to 46% when the occupancy was at 100% or more (Sprivulis et al., 2006).

In a much earlier Australian study where 34,377 (144 deaths) and 32,2231 (101 deaths) patients presented during ED overcrowded times respectively between 2002 to 2004, there was increased in-hospital mortality during high ED occupancy (Richardson, 2006). The relative risk of deaths at 10 days was found to be 1.34 (Richardson, 2006). In a Korean study, a data review of 54,410 patients who visited the ED of an urban tertiary academic hospital for two years revealed that ED crowding measured as EDOR was significantly associated with increased day 1 (AOR = 1.42), day 2 (AOR = 1.31) and day 3 (AOR = 1.27) mortality after controlling for potential confounders (Jo et al., 2014). In the USA, a study of 995,379 index patients ED visits to 187 hospitals in California in 2007 revealed that patients who were admitted on days with ED crowding experience 5% greater odds of in-patient death (Sun et al., 2013).

In New Zealand, an analysis of 5,793,767 visits by 2,214,865 patients to 25 EDs between 2006 and 2012 revealed a 10% relative increase in the 7-day mortality among patients who arrived when the hospital access block was greater than 10% and experienced non-compliance with the 4 hour emergency access target (Jones & Van der Werf, 2021). In a Swedish study involving two large hospitals, the odds of 10-day mortality among 705,076 patients (623 deaths within 10 days) seen and discharged between 2009 to 2016 was found to increase by 50% when the ED was most crowded compared to when it was least crowded during first patient visits (Berg et al., 2019). The adjusted odds ratio of death was 5.86 using mean ED LOS greater than 8 hours verses ED LOS less than 2 hours (Berg et al., 2019). Beyond a mean ED LOS of 6 hours, higher risk of mortality has been reported among ED patients compared to those with a mean LOS of less than 6 hours (Guttmann et al., 2011).

Among 2,440,392 visits from 1,142,631 patients in 14 EDs in Sweden between 2015 to 2019, no significant association was found between ED crowding and mortalities within 30 days

(Bjornaf Ugglas et al., 2021). Interestingly an earlier study by the same authors found a significant association between ED crowding and increased 30 days mortality among 884,228 patients who visited the ED 2,252,656 times in 7 EDs in Stockholm Region, Sweden between 2012 to 2016 (Björn Ugglas et al., 2020). Both studies used non-traditional and uncommon measures of ED crowding. This was the mean hourly ED census during the shift that exposed the patient at arrival, divided by the expected ED census for that shift (Björn Ugglas et al., 2020; Bjornaf Ugglas et al., 2021). These studies need further validation using commonly known and used ED overcrowding measures like the EDOR which has been used in most of the studies presented above. Among 136,740 first visits to 13 EDs in California, USA between 2008 to 2010, crowding measures like ED LOS, boarding and EDOR) were not predictive of mortality after case-mix adjustment (Derose et al., 2014). Among 108,229 index patients who presented to the ED of an academic teaching hospital in Leuven, Belgium between 2010 to 2012, there was no association found between ED crowding (using occupancy as a crowding measure) and mortality (Verelst et al., 2015). The specific contribution and mechanisms by which overcrowding contributes to the mortality statistics evidenced are not granularly explored in most of the studies. The extrapolation that explains the findings are hinged on poor physician decision making and medical errors of different forms, delays in interventions, unavailability of the needed space and resources for care, among others.

2.6 Perspective of patients on the impact of overcrowding on quality care delivery at the ED

Beyond the quantitative expressions of the impact of overcrowding on quality care outcomes, the ultimate beneficiaries, and users (patients and staff) have expressed views and opinions on their experiences at the ED in a number of studies. When patients board at the ED, they continue to occupy bed, space and access to healthcare professionals and consume staff time (Kelen et al., 2021; Leong-Nowell et al., 2023; Van de Ruit et al., 2020). Beyond the impact on the old patients, new patients requiring clinical evaluation and management do not have access to ED beds and are most likely turned away or they leave without been seen or they are managed in hallways and midshaft structures (Savioli et al., 2022). This according to a study in Canada creates an unsafe ED environment where there is accelerated depletion of available equipment, space and human resource which eventually leads to increased avoidable patient harm and mortality (Bentz et al., 2023).

Bentz et al (2023) reviewed nine systematically eligible publication (conducted in Sweden, Thailand, USA, South Africa, and Samoa) with a sample of 215 users of the ED (including patients, their families and caregivers, and learners and staff working in the ED). This qualitative study explored the phenomenon of ED crowding and the perspectives on, experiences of, and understanding of ED overcrowding on quality of patients care, patients safety, and the wellbeing of health staff at the ED (Bentz et al., 2023). They employed the optimised critical appraisal skills programme (CASP) tool to facilitate synthesize of the evidence (Bentz et al., 2023; Long et al., 2020).

Whiles patients perceived the ED as inappropriate during crowding, they also indicated that the unsafe environment at the ED led to patients experiencing delays, missed, and inappropriate care that resulted in potential or actual physical harm, threats to their human rights and dignity, exposures to secondary suffering, reduced satisfaction, and worsening emotional and psychological states (Bentz et al., 2023; Rantala et al., 2021). Perceptively, the concept of quality care per the patient is basically the timely provision of critical care needs that leads to the attainment of optimal or desired outcomes including physical, psychosocial and spiritual health as understood or experienced by patients, their families and ED health staff (Allen-Duck et al., 2017; Han et al., 2017). Apart from the poor quality and unsafe patients care that ED staff are involved in during periods of crowding, the impact on their well-being have equally been reported as negative (Bentz et al., 2023).

ED staff have reported been overwhelmed and pessimistic during extended periods of crowding at the ED (Chen et al., 2018; Lin et al., 2019). According to the staff they may lose track of some patients as they may not be aware of their presence at the ED due to the chaos and challenges associated with ED crowding (Chen et al., 2018; Lin et al., 2019). ED staff may also be forced to spend longer than expected time in the ED when it is crowded. According to a study in Sweden, ED nurses reported of negative psychological impact on them when they stay longer at the ED as a result of crowding (Eriksson et al., 2018). This according to them significantly reduce their level of nursing and caring they provided to patient at the ED (Eriksson et al., 2018).

A study on the perception of health workers in the ED of the Komfo Anokye Teaching Hospital in Ghana was conducted in 2015 (Quao et al., 2017). This study reported the negative impact of ED crowding on health workers to include staff stress, poor work satisfaction which contributed to poor quality care and patients outcome (Quao et al., 2017). This study did not

clearly define the phenomenology of crowding, and the cross-sectional methodology involving a few (110) health workers was considered inadequate to generalise the findings. However, considering the paucity of data on ED crowding in LMICs and LICs, it worthies of mention as it potentially can influence policy decisions in these low resource settings. The chronic levels of psychological stress and moral distress at the ED, and the awareness of crowding among ED staff creates anxiety, burnout, interpersonal tension, violence and physical harm among ED staff (Bentz et al., 2023; Eriksson et al., 2018; Lin et al., 2019; Rantala et al., 2021). These perceived powerlessness experienced over the extreme working conditions lead to higher dimensions of professional dissatisfaction, emotional exhaustion and cynicism (Bentz et al., 2023; Eriksson et al., 2018; Lin et al., 2019; Rantala et al., 2021).

Suffice to say that most of these perception studies are typically retrospective and patients satisfaction results were obtained through remote survey data gathering and analysis conducted weeks after the index visits (Wang et al., 2017). The findings may therefore suffer recall bias and subjectivity. According to Bentz et al (2023) the focus of most of these studies are on ED staff perception with a few detailing patients' perception of ED crowding on the quality of care. These studies do not assess and analyse the care pathway and processes to determine the critical sub areas in the ED where the impact of crowding can be studied and scoped appropriately. These key factors may limit the transferability of the findings to other jurisdictions.

Summarily, various studies have demonstrated the effects of ED crowding on patients, healthcare delivery system processes, quality care and efficiency in service delivery and the ultimate impact on direct patient mortality outcomes (Rasouliet al., 2019). Due to the retrospective nature of most of these studies, coupled with the limitations in the exhaustive analysis on potential confounding variables on the patients outcomes, generalisation of the findings must be cautiously done (Burgess et al., 2022). Interestingly most of these studies have taken place in HICs and conducted in urban, tertiary, referral hospitals and ED with well establish time to critical therapies and protocolised care systems. In these EDs, optimised systems that provide time-sensitive treatments to critically ill patients exist, and diagnostic imaging services are readily available compared to what exists in LMIC and LICs. The set up of the ED in these high resource settings enable high quality centred care delivery especially during crowding periods. To the extent that similar studies have not been conducted in LMICs where poorly established EDs exist, the findings are applicable and can guide evidence-based policy decision. This indicates an existing gap in the literature and ED clinical practice

especially for stroke patients and quality care delivery in LMICs which needs attentions. This current study intended to bridge that gap in the best way possible no matter how small scaled this current study might have been.

2.7 Measuring ED overcrowding

Over the past 30 years, the measurement of ED overcrowding has progressively evolved though consensus on the definition remains uncertain (Di Somma et al., 2015; Hwang et al., 2011; Hwang & Concato, 2004; Morley et al., 2018; Salway et al., 2017). To highlight the push by researchers to constellate a standard definition and measure of ED overcrowding, over 200 different papers on ED overcrowding have been published in the past few years (Darraj et al., 2023; Pearce et al., 2023; Rasouli et al., 2019). Most of these publications between 2000 – 2018 have been quantitative (95%) and retrospective (87%) in character (Morley et al., 2018). A summary highlighting the historical journey of how some of the ED overcrowding metrics came about is presented in the next few paragraphs. Then a comparative analysis of how they perform against each other in measuring overcrowding in various validation studies was presented.

2.7.1 Historical overview of the development of ED crowding measuring tools

Historically, various recognised metrics have been developed and some successfully validated to help measure ED overcrowding. These tools are either clinician opinions of overcrowding, unidimensional or multidimensional metrics in character and they are explored in the next few paragraphs. Clinician opinion and perception studies characterised the initial attempts to develop a metric for ED overcrowding.

2.7.1.1 Clinician opinion as a measure of ED overcrowding

Derlet et al (2001) in describing the definition, extent and factors associated with ED crowding as perceived by clinicians surveyed 836 ED directors in all 50 states of the USA. In places where the ED served larger populations, 91% of the directors perceived the existence of overcrowding in those EDs (Derlet et al., 2001). The defining circumstances that characterised ED crowding as opined by the directors were: patients wait time of greater than 60 minutes; all ED beds filled for more than 6 hours per day; patients who had to lie in the hallways for more than 6 hours per day; emergency physicians who felt rushed for more than 6 hours per day and

having the waiting room filled for more than 6 hours per day (Derlet et al., 2001). Clinician perception as a crowding measure have been evaluated against outcomes like physician satisfaction and patients leaving without been seen (Ospina et al., 2007; Vieth & Rhodes, 2006). These perception studies according to Hwang et al (2011) were the least studied measures of overcrowding due to their subjectivity, non-reliability, non-generalisability, and biases. The projection was that more empirical evidence will strengthen an objective metric for overcrowding at the ED (Derlet et al., 2001).

2.7.1.2 Heterogenous and quantitative measures of ED overcrowding

Reeder and Garrison (2001) improved on the study by Derlet et al (2001). Using real time data from the ED, they defined four metrics of crowding at the ED: bed ratio, acuity ratio, provider ratio and demand as explained in the Table 2.2 below. The bed ratio measured the imbalance between patients' numbers and available beds. The acuity ratio measured the total number acutely ill patients at the ED indicting the relative burden at the ED. The provider ratio measure gave insight into the number of patients that could be treated by physicians. This became known as the Real-Time Assessment of the Overcrowded ED in a safety net (Reeder & Garrison, 2001). With a demand value greater than 7, corrective actions were to be instituted at the ED (Reeder & Garrison, 2001).

Table 2.2 Parameters that define the READI score (Reeder et al., 2003; Reeder & Garrison, 2001)

Variable	Definition	Formulae	Interpretations
Bed Ratio (BR)	Quantifies the relationship between the number of ED patients and the number of treatment spaces available at a given time	BR = (number of patients in ED +predicted arrivals – predicted departures)/ED spaces	BR < 1 means there will be adequate ED treatment areas. BR > 1 means an overcrowded ED
Acuity Ratio	Total number of the total patient acuity of the ED, which is an indication of the relative burden of illness at the ED	AR = Σ (triage category) (number at each category)/ number of patients	An AR near 1 indicates low average acuity, while an AR near 4 indicates very high acuity
Provider Ratio	Indicates the relationship between patient arrivals and ED physician staff	PR = arrivals per hour/Σ patients per hour for each physician	A ratio of less than 1.5 indicates adequate staffing, while a ratio of

			more than 1.5 indicates understaffing
Demand Value	Indicates the overall measure of ED demand	DV = (BR + PR) x AR	DV > 7 gives an indication for examining the cause and institute actions

As objective as the study by Reeder & Garrison, the crowding measures defined were crudely done and the authors recommended a more objective study to determine the true value and usefulness of the tool so developed. This was made possible by the same authors as demonstrated in a paper they published in 2003.

Reeder et al (2003) as a follow up on the initial work used ED data to calculate demand ratio called the Real-Time Emergency Analysis of Demand Indicators (READI) score. They then compared the READI scores with ED staff perceptions of demand and capacity (Reeder et al., 2003). This was to assess the validity of the tool and establish the correlation between staff perception and READI scores. They concluded that a bed ratio greater than one meant an overcrowded ED and a demand values greater than 7 gave indication for examining the cause and instituting corrective measures (Reeder et al., 2003). This was the beginning of assigning scores to determine ED overcrowding. However the subjective assessment of excess ED demand did not correlate between physician groups and charge nurses and the READI scores did not correlate with staff perception of ED (Reeder et al., 2003). The authors therefore recommended the development of an improved READI score or a more objective and reliable measure of the ED overcrowding using real-time demand of the ED (Reeder et al., 2003).

Bernstein et al. (2003) developed and validated a potentially new objective ED crowding and busyness measuring tool in an urban Level 2 trauma teaching hospital during the spring of 2002 (Bernstein et al., 2003). The authors used a similar approach from earlier studies by comparing perception of nurses and physicians on ED crowding to the new Emergency Department Work Index (EDWIN) developed. The clinicians were made to grade ED crowding by responding to certain perception questions and used the Emergency Severity Index (ESI) (Nicki Gilboy et al., 2005) as a comparator to the new ED measuring tool developed. The variables of the EDWIN are summarised in Table 2.3 below.

Table 2.3 Parameters that define the EDWIN score (Bernstein et al., 2003)

Variables measured that defined ED crowding	**Variables measured that defined ED crowding**	**Formulae**	**Interpretations**
n_i is the number of patients present in the ED in triage category. t_i is the triage category (ordinal scale 1–5, 5 being most acute) Na the number of attending physicians on duty at a given time. B_T the total number of beds, or treatment bays available in the ED B_A the number of admitted patients (holds) in the ED	• Patients wait > 60 minutes to see physician. • All ED beds filled > 6 hours/day. • Patients placed in hallways > 6 hours/day. • Emergency physicians feel rushed > 6 hours/day. • Waiting room filled > 6 hours/day. (Bases on clinical perception)	EDWIN= $\Sigma n_i t_i / Na (B_T - B_A)$	• EDWIN < 1.5 means an active but manageable ED. • EDWIN = 1.5 – 2 means a busy ED • EDWIN > 2 means a crowded ED

An EDWIN score less than 1.5 meant a manageable ED and a score greater than 2 meant an overcrowded ED. The EDWIN was based on the Emergency Severity Index (ESI) which is a validated and reliable 5-Level patient triaging tool developed by ED physicians Richard Wuerz and David Eitel in the US. Bernstein et al. (2003) recommended the conduct of a multicentre study to see the variations of EDWIN in other EDs based on patient volumes, staffing regimes and the provision of other ancillary services (Bernstein et al., 2003).

The NEDOCS developed by Weiss et al (2004) was found to be a more objective tool that measured overcrowding at the ED. The authors used a previously developed data sampling form and collected data over a 3 weeks' period from 8 different academic EDs in the USA (Weiss et al., 2004). The eventual outcome of the study by Weiss et el. (2004) led to the development of NEDOCS (a web-based calculator) shown in Figure 2.3. The variables and interpretations of the NEDOCS is presented in Table 2.4 below.

Table 2.4 The variables and interpretation of the NEDOCS (Weiss et al., 2004)

NEDOCS Variable measures that define ED crowding	**Scores**	**Interpretations**
1. Number of ED beds	00-20	Not busy
2. Number of hospital visits	21-60	Busy
3. Total number of patients in the ED	61-100	Extremely busy but not overcrowded
4. Number of respirators in use, longest admit time in hours	101-140	Overcrowded
5. Total admits in the ED and the waiting room	141-180	Severely overcrowded
6. Wait time for the last patient called in hours	181-200	Dangerously overcrowded

The NEDOCS has six variables that are fed into the NEDOCS calculator, and an automatic score is generated which categorise the ED status as not busy (NEDOCS of 0 – 60) to dangerously overcrowded (NEDOCS of 181 – 200) (Weiss et al., 2004). The NEDOCS reflects the statistical analysis of input, throughput, and output variables related to the ED.

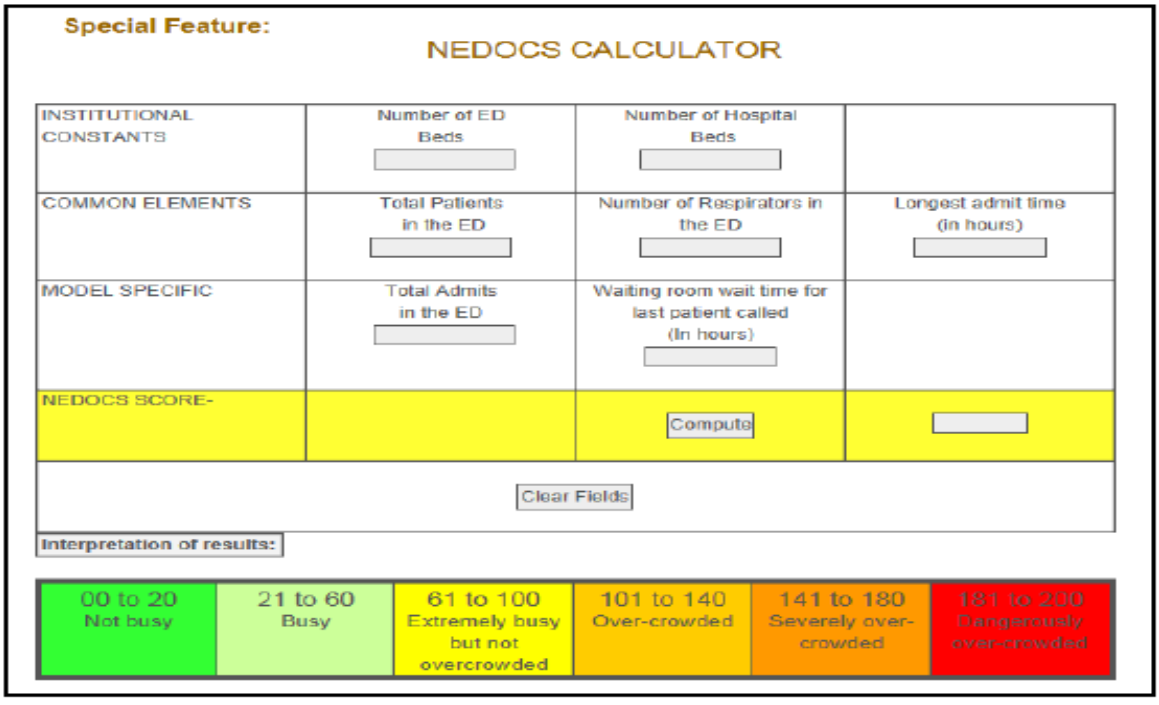


Figure 2.3 A web-based calculator using the NEDOCS algorithm to determine the degree of overcrowding (from https://www.nedocs.org/Company/PressKit accessed on 20th February 2019) (Weiss et al., 2004)

The earlier overcrowding metrics presented did not address ED crowding measurements at the level of community hospitals. To address this gap, a new study was conducted in 2011 in 13 community hospitals in California, USA to objectively evaluate ED crowding in a community hospital (Weiss et al., 2014). The outcome of this study led to the development of the Community Emergency Department Study Score (CEDOCS) with six predictor variables just like that of the NEDOCS which highly correlated with ED crowding. The variables and interpretations of the CEDOCS are shown in Table 2.5.

Table 2.5 The Community Emergency Department Overcrowding score (CEDOCS) variables and interpretation (Weiss et al., 2014)

CEDOCS Variable measures that define ED crowding	**CEDOCS Scores**	**Interpretations**
1. ED visits per year	00-20	Not busy
2. Number of ED beds	21-60	Busy
3. Total number of patients in the ED	61-100	Extremely busy but not overcrowded
4. Number of critical care patients in the ED	101-140	Overcrowded
5. Number of patients in the waiting room	141-180	Severely overcrowded
6. Waiting time of the longest admitted patient (since admission in hours)	181-200	Dangerously overcrowded

Weiss et al. went on to develop a website with an easy access to the CEDOCS calculator online shown in Figure 2.4. A CEDOCS score of 0 – 20 indicated a not busy ED and a score of 181 – 200 meant a dangerously overcrowded ED (Weiss et al., 2014) as detailed in the Table 2.5.

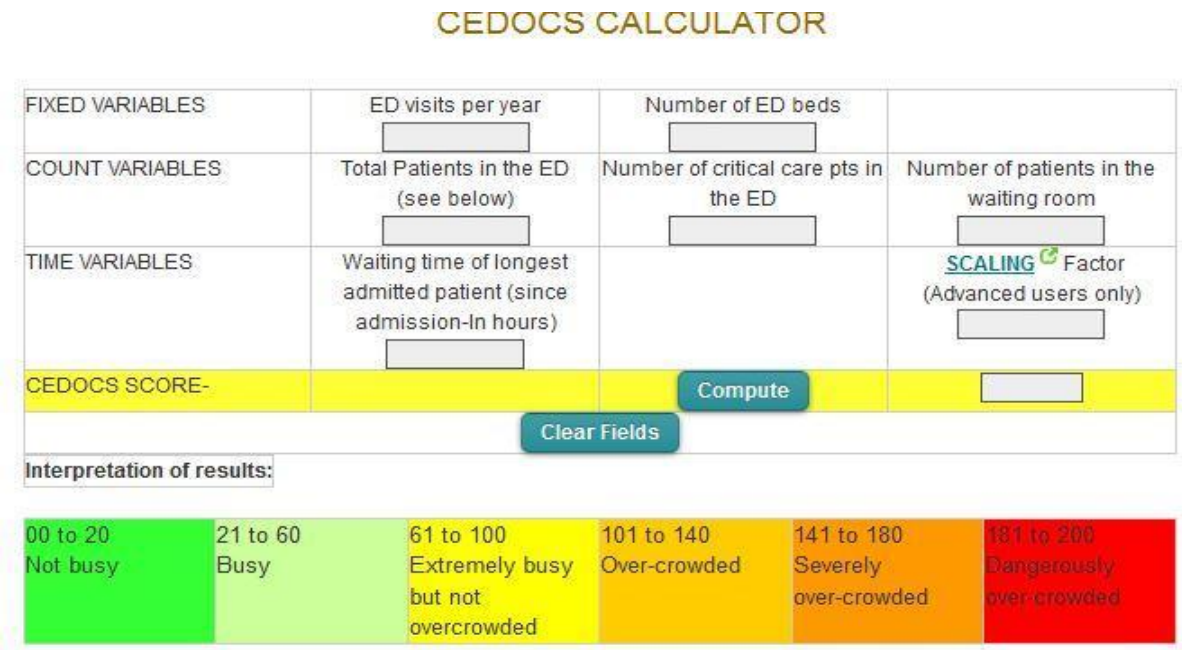


Figure 2.4 Online interface of the CEDOCS calculator (accessed from http://emed.unm.edu/clinical/resources/cedocs.html on 20/01/19)

The search for a standard ED crowding measuring tools continue unabated. The Severely Overcrowded-Overcrowded-Not overcrowded Estimation Tool (SONET) recently developed was used to evaluate overcrowding in an extremely high volume ED setting (Wang et al., 2015). It uses only three categories just like the "traffic light system" model (Delia, 2007) to represent the crowding status of the ED: green (ED at normal functional status), yellow (ED at alert status) and red (ED approaching and/or existing in a dysfunctional status) as detailed in the Table 2.6 below.

Table 2.6 Summary of the interpretation of the SONET (Wang et al., 2015)

SONET score	**Scores Interpretation**	**Colour coding**	**ED Functional Status**
< 100	Not overcrowded	Green	Normal functional status
100-140	Overcrowded	Yellow	Alert status
=/> 140	Severely overcrowded	Red	Approaching and/or existing dysfunctional status

The study by Wang et al. (2015) determined ED overcrowding and patient care outcome which included the number of patients left without being seen, the average ED LOS, ED 72-hour returns, and mortality compared under different crowding statuses. The SONET formulae is summarised in Table 2.7 below.

Table 2.7 Interpretation of the SONET formulae and the variables involved.

SONET variable measures that define ED crowding	SONET Formulae	SONET Formulae
• W indicated the number of acuity Level-3 patients in the waiting room. • A indicated the number of acuity Level-2 patients occupying an ED bed. • V indicated the number of patients on ventilators in the ED. • E indicated the total number of ED patients divided by the total number of ED beds	SONET score = 0.8 × number of acuity Level-3 patients in the waiting room + 0.5 × number of acuity Level-2 patients occupying an ED bed + 10 × number of ventilation patients in the ED+ 53 × total patient index + 18	SONET score = $0.8W + 0.5A + 10V + 53E + 18$

The next few paragraphs will summarise validation studies of the common ED crowding measuring tools and how they perform against each other in determining the status of crowding at the ED.

2.7.2 Comparative review of common ED overcrowding measurement tools

The summary analysis of ED crowding measures indicate two broad themes of categorisation: patient flow measures and non-flow measures (Badr et al., 2022; Hwang et al., 2011). Another approach to critically appraise ED crowding measures follows the three "buckets" framework (input, throughput, and output factors) developed by Asplin et al (2003). A third way of looking at these metrics are the frequency of studies conducted using the tools and actual validation of the tools in other studies. The next few paragraphs synthesis the critical appraisals of ED crowding measuring tools.

2.7.2.1 Measuring ED overcrowding using input, throughput, and output variables

Studies on input measures of overcrowding define factors that potentially increase the total number of patients at the ED (Ansah et al., 2021; Asplin et al., 2003; Pearce et al., 2023). These studies focus mainly on the number of patient arrivals (Asaro et al., 2007; Hoot et al., 2009), number of patients with different acuity levels (Bullard et al., 2009), number of patients waiting to be triaged Derlet et al., 2001; Richards et al., 2000) and waiting times of patients (Derlet et al., 2001; Hoot et al., 2009; Hoot & Aronsky, 2008; Micró et al., 2003; Richards et al., 2000).

Numerical counts or percentages of patients in the ED are the most studied input crowding measures (Hwang et al., 2011). These measures have been validated mostly against ED LOS as an outcome measure (Hwang et al., 2011).

Throughput measures studied define factors that affect the flow of patients through the ED (Asplin et al., 2003). These studies mostly include ED capacity measures, patient care times, and ED LOS. According to Hwang et al (2011), the most commonly used throughput crowding measures are the total number of patients in the ED (Bullard et al., 2009; Hoot et al., 2009; Lucas et al., 2009; McCarthy et al., 2009; Micró et al., 2003; Weiss et al., 2002), ED occupancy (Hoot et al., 2009; Hoot & Aronsky, 2008; McCarthy et al., 2008; Ospina et al., 2007; Schweigler et al., 2009) and patient care times (Bullard et al., 2009; Hoot et al., 2009; Hoot & Aronsky, 2008; Ospina et al., 2007; Weiss et al., 2002). All three commonly used throughput measures of ED crowding positively correlated with clinical perception of ED crowding (Hwang et al., 2011).

Output measures of crowding studies include hospital measures of numerical counts, mean values and percentage of admissions, patients boarding in the ED, number of hospital beds and census, and times of care to leave the ED (Badr et al., 2022; Hwang et al., 2011; Jones et al., 2022; Stang et al., 2015). The most commonly used heterogenous outcome measure is the number, mean number and percentage of boarders and boarding times at the ED (Gilligan et al., 2008; Hoot et al., 2009; Hoot & Aronsky, 2008; Ospina et al., 2007; Weiss et al., 2002). These commonly used output measures have been mostly validated and found to significantly correlate with ED processing times, clinician perception, ambulance diversion and LWBS (Hwang et al., 2011).

A systematic review of 90 included papers by Badr et al (2022) showed that between 1990 - 2020, the most commonly accepted and widely used homogenous crowding measures were ED occupancy followed by ED LOS, ED volume, ED boarding time, number of boarders and waiting room number (Badr et al., 2022). These variables are easily measured, calculated, communicated and self-explanatory (Badr et al., 2022). Overall, ED LOS measures of overcrowding showed association with higher mortality (45% of studies), worse quality of care (75% of studies) and worse perception of care (100% of studies) (Badr et al., 2022).

The definitions of these variables and tools are summarised in Table 2.8 below.

Table 2.8 Various ED crowding indicators and their operational definitions (Badr et al., 2022; Ahalt et al., 2018)

No.	ED crowding measure	Summary Definition
1	ED occupancy	The proportion of occupied ED beds, which is the number of occupied beds divided by the total number of ED beds, usually expressed in percentage
2	ED LOS	The time patients spend in the ED
3	ED Volume	The total number of patients in the ED during a defined time.
4	ED boarding time	The time admitted patients spend in the ED waiting for transport to their assigned hospital bed.
5	Number of boarders	The number of patients waiting in the ED for a hospital bed
6	Waiting room number	The number of patients in the waiting room of an ED
7	Arrival time	Patient arrives to the ED, either by ambulance or walk-in
8	Bedtime	Patient is assigned to an ED bed or treatment space
9	Disposition decision time	Physician or resident makes the decision to admit the patient to an inpatient hospital bed, or to complete medical care and send the patient home
10	Discharge time	Patient leaves ED, either for admission to an inpatient hospital bed or to depart for home

2.7.2.2 Performance of multidimensional ED overcrowding metrics

The input, throughput and output measured can be combined to generate object quantitative scores commonly referred to as to multidimensional tools (Badr et al., 2022; Hwang et al., 2011; Morley et al., 2018; Stang et al., 2015). A multidimensional tool that combines time intervals (flow measures) and patients counts (non-flow measures) is a preferred choice for measuring overcrowding.

Two of the most frequently studied and validated multidimensional tools from literature are the NEDOCS (Badr et al., 2022; Boyle et al., 2016; Cooney et al., 2013; Garcia-romero et al., 2017; Mosallam & Kandil, 2020; Phillips et al., 2017; Raj et al., 2006; Reeder et al., 2003; Strada et al., 2019; Wang et al., 2017; Weiss et al., 2002, 2004, 2006, 2007) and the EDWIN

(Ahalt et al., 2018; Badr et al., 2022; Bernstein et al., 2003; Hoot et al., 2007; Hoot & Aronsky, 2008; Kulstad et al., 2010; McCarthy et al., 2008; Tekwani et al., 2013; Weiss et al., 2006). The NEDOCS and EDWIN have demonstrated high ability to reflect the current levels of ED overcrowding (Colella et al., 2022).

A comparative study on three ED crowding scores NEDOCS, EDWIN and READI assessed the strengths and weaknesses of each score importantly their predictive powers (Ahalt et al., 2018). The study concluded that both NEDOCS and EDWIN accurately predicted ED crowding and they demonstrated the ability to anticipate impending crowding situation at the ED (Ahalt et al., 2018). In another comparative study, the SONET was found to show greater accuracy in predicting overcrowding than the NEDOCS (Wang et al., 2015). However, the authors suggested that beyond high volume ED, the SONET may not yield accurate and reliable results (Wang et al., 2015).

A comparative study to optimally measure the interval for ED crowding using 1-, 2-, 3- or 4-hours intervals was conducted using the NEDOCS, SONET, EDWIN and EDOR (Wang et al., 2017). The outcome of interest was ED LOS and LWBS (Wang et al., 2017). The study concluded that measuring ED crowding every 4 hours may be a reasonable interval for assessing ED crowding (Wang et al., 2017). The 4-hour time interval was going to reduce the burden on ED staff from frequently assessing ED crowding (Wang et al., 2017). This recommendation therefore favours the use of NEDOCS. In addressing superiority in sensitivity and specificity in measuring ED overcrowding, Weiss et al (2006) found NEDOCS to have a higher accuracy for predicting ED overcrowding. However, the NEDOCS and EDWIN have been found to be complex, difficult to calculate and explain (Badr et al., 2022). They have also not been studies against mortality outcomes (Badr et al., 2022).

The most studied ED crowding measures in association with quality ED care was the ED occupancy rate (38%), process times (31%), workload (19%) or combination (9%) as synthesised from 25,607,375 patients, 2,368 staff, 9,089 hospitals and 101,177 sampling times from 183 systematically reviewed papers (Jones et al., 2021). For complex crowding metrics, the NEDOCS was associated strongly with efficiency of care with moderate evidence whiles the EDWIN score was found to be weakly associated with efficiency (low certainty of evidence) and READI was very weakly associated with efficiency of care (low certainty of evidence) (Jones et al., 2021). The NEDOCS and the EDWIN have generally shown positive

association with clinician perception of overcrowding, ambulance diversion and LWBS (Hwang et al., 2011).

2.8 Limitations of ED overcrowding measuring studies

In the systematic review of 183 final papers by Jones et al (2021) on overcrowding measures and quality care, two thirds of the studies have been conducted in urban tertiary hospitals in North America (65%), Australia (13%), Europe (12%) and Asia (8%). None of these studies were from LICs or LMICs. In the ED of a teaching hospital in Ghana, the NEDOCS have been used to measure ED crowding (Quao et al., 2017) with no outcome on quality of care. The synthesis of these overcrowding papers and reviews reveals several limitations as identified by the authors. Firstly, the papers were mostly English studies. This creates a gap in generalising the findings in other jurisdictions. Secondly, majority of the studies were retrospective in character with inherent weaknesses. Thirdly, the prevalence of data errors, missing data, and the inability of the researchers to ascertain the validity of the various stroke interventions times captured especially during patient processing times remains a difficult challenge. Fourthly, the diversity of methodologies in overcrowding measures studies cannot be overlooked as they directly impact the findings. The authors adopted various definitions of overcrowding, studied different outcome measures using varied sample sizes, mostly single urban sites with different data capturing systems. These complex variations inherently challenge the reproducibility and transmissibility of these studies.

However, there is evidence that suggest that substantial body of literature exist when it comes to the general understanding of ED overcrowding, its causes, consequences, primary outcomes, potential harm, interventions, and solutions. The emphasis has however been quantitatively and thematically measuring ED overcrowding without paying close attention to the quality of care and mortality outcome of patients. No study had looked at ED overcrowding and how that impacted stroke specific mortality. No study had applied the NEDOCS as a metric for ED overcrowding and how that correlated with stroke mortality outcome. Moreso no study on the levels of ED overcrowding and its impact on stroke specific mortality has ever been conducted in a LIC or LMIC. These gaps identified are what this current study sought to address: the relationship between ED overcrowding on stroke specific mortality in the ED of a LMIC. This current study looked to bridge as possible some of the geographical research gap highlighted above. It drew on lessons from the qualitative observations on the quality of care provided to

stroke patients in low resource setting with limited imaging of stroke patients where thrombolysis is also not routinely administered. A summary of the ED overcrowding tools developed is presented in the Table 2.9 below.

Table 2.9 A summary of some of the measuring tools and their comparative analysis as described above.

ED crowding measuring tool	Study design and ED setting (centre/volume/duration and frequency of data collection)	Strengths	Study Limitations
Clinical Perception of ED Directors (Derlet et al., 2001)	1. Prospective survey study of ED directors in all 50 states in US from academic, county, community and private hospitals data collected over 6 months 2. Responses based on perception	1. Data is easy to collect through interviews and questionnaire use.	1. Responses were voluntary and subjective 2. No standard method had been established for defining overcrowding 3. Study was conducted in winter–spring and may reflect seasonal usage of EDs
EDWIN (Bernstein et al., 2003)	1. Prospective, observational study in an urban teaching hospital, Level 2 trauma centre, with an annual volume of 78,000 visits. Data collected over 36 days	1. It assigns scores which is objective in nature and can be replicated. Can be applied to urban teaching hospitals with high patient annual volumes. It is multicentric	2. Convenience sample of time blocks over a brief interval 3. Monocentric study 4. EDWIN does not include a term for nursing staffing.
NEDOCS (Weiss et al., 2004) NEDOCS calculator online	1. Survey study with convenience sampling conducted at eight academic medical centres, each with an ED census of over 2. 40,000 (medium to high volume ED) adult patient visits per year. 3. Data collected over 21 days and sampling times were every 4 hours (9:00 am, 1:00	1. Toolkits developed. Online calculator accessible. Used in many countries and at various patient annual volume (low, medium, and high). It is an objective metric with well guided steps to follow when using it. Useful for community hospitals like TGH. 2. It has been superior to other ED crowding measuring tools	1. Lack of a criterion standard definition ancillary services, hospital staffing, and rate of ambulance arrival were not assessed because of difficulty obtaining these data 2. Inability to evaluate interrater reliability of the scale 3. Generalisable only to academic EDs 4. Cannot necessarily be generalised to the remainder of the year since research was done in February

	pm, 5:00 pm, 9:00 pm, and 1:00 am)	during comparative analytical research in the past. 3. multicentric with both time and numeric variables. Data can be collected conveniently straightforward.	
CEDOCS (Weiss et al., 2014) CEDOCS calculator online	1. Prospective observational study in 13 California community hospitals ranging in size from 18 to 65 thousand annual ED visits, 64 to 643 licensed hospitals beds, 7 to 49 ED beds, and between 4 and 19 thousand admissions. 2. It was 26 days' study and data were collected every 4 hours	1. It is multicentric and good for community hospitals. 2. Data is easy to collect, and the tool is online for easy access. Was built on NEDOCS as an improved tool	1. Limited external validity based on the hospitals included 2. The need to include more variables that may determine ED crowding 3. Different definitions and understanding of the variables used
SONET (Wang et al., 2015)	1. Prospective study in a high-volume single urban academic ED (annual volume of the study ED was over 113,000) 2. Data was collected over 21 days with score calculated every two hours	It is good for high volume ED.	1. Results may be skewed since study was conducted single urban academic ED 2. Limited in external validation and a multicentric study recommended 3. Perception was used at some point in the study and that was subjective 4. Sample size was small due to incomplete data 5. This tool might not be suitable for a low volume ED setting.

2.9 Aspects of ED care of acute stroke patients

The last section of this literature review focuses on key aspects of ED care of stroke patients that bothers on quality care. Emphasis was placed on triaging, neurological assessment, imaging diagnosis, thrombolysis and blood pressure management of stroke patients who visit the ED. Evidence suggest that robust and early intervention in stroke care reduces death and disability and improves prognosis and long-term recovery (Lees et al., 2010; Minhas et al., 2022; Trialist Collaboration Stroke Unit, 2013). Care recommendations for stroke patients are basically on pre-hospital, emergency evaluation and acute treatment and in-hospital management (Powers et al., 2019).

Other recommendations focus on care of the stroke patients within 72 hours (Middleton et al., 2015) and after 72 hours of presentation at the ED (Summers et al., 2009). There are also published guidelines for optimal stoke care continuum at national and subnational levels (Jauch et al., 2013; Lindsay et al., 2008; Powers et al., 2019). Key examples of some of the recommended protocols are: intraarterial treatment within 6 hours of acute stroke (Berkhemer et al., 2015; Powers et al., 2019); extension of stroke thrombolysis to 4.5 hours and change from positive to negative recommendation for the use of thigh-length antithrombotic stockings for deep vein thrombosis prevention (Wright et al., 2012); and rehabilitation and occupational therapy among stroke survivors (Crow & Smith, 2023). Interestingly these guidelines have been developed and published from the HICs including Australia (Wright et al., 2012), Canada (Lindsay et al., 2008), Netherlands (Berkhemer et al., 2015), UK and Ireland (Crow & Smith, 2023) and USA (Jauch et al., 2013) among others.

2.9.1 Triaging of stroke patients at the emergency department

Triaging offers a rapid assessment of the clinical status and severity of the patient's condition at ED arrival and it informs the next step of priority treatment actions and treatment locations (Ausserhofer et al., 2020; Hinson et al., 2019). Four internationally recognised five-level triaging tools include Emergency Severity Index (ESI) (Wuerz et al., 2000), Australasian Triage Scale (ATS) (Australasian College for Emergency Medicine, 2016), Canadian Triage and Acuity Scale (CTAS) (Beveridge et al., 1998), Manchester Triage System (MTS) (Manchester Triage Group, 2006). Over time these tools have been modified and updated to reflect current scientific knowledge and recommendations.

The ESI was developed in Massachusetts, USA by Wuerz et al (2000) and it uses a single algorithm scoring from Level 1 (most critically ill patient) to Level 5 (least resource-intensive patient). It is currently the most commonly studies triage method in the USA and other parts of the world (Bergs et al., 2014; Bernstein et al., 2003; Cairós-Ventura et al., 2019; Chmielewski & Moretz, 2022; Nicki Gilboy et al., 2005; Nicky Gilboy et al., 2011; Mistry et al., 2018). The ESI incorporates both patient severity and resource consumption needs to decide on treatment option.

The ATS developed in Australia differentiates patients into 5 categories: Category 1 (immediately life-threatening condition) to category 5 (less urgent) and its reliability and validity have been widely studied (Australasian College for Emergency Medicine, 2016; Elsayeda et al., 2020; Forero & Nugus, 2011; Middleton et al., 2019). Level 1 and 2 for both ATS and ESI must be (Australasian College for Emergency Medicine, 2016; Elsayeda et al., 2020).

The CTAS introduced in the 1990s (Beveridge et al., 1998) accurately defines patient acuity level with Level 1 patient needing resuscitation to level 5 patients classified as non-urgent (Elkum et al., 2011; Gravel et al., 2012). Just like other triage tools, the CTAS can be applied within seconds from the critical first look for critically ill patients to a few minutes for the less acute patients (Arafat et al., 2016; Bullard et al., 2017).

The Manchester Triage System was founded in 1994 and Level 1 patients need immediate physician visit and Level 5 (non-urgent) patients can wait up to 4 hours for physician visit (Manchester Triage Group, 2006, 2014). The MTS recognises patients' symptoms with a reduced discriminator identification. The MTS have been studies widely and findings on reliability and predictive powers on hospitalization and in-patient clinical presentations and mortality outcomes has been mixed and varied (Brouns et al., 2019; Gräff et al., 2014; Parenti et al., 2014; Santos et al., 2014; Zachariasse et al., 2017).

The ESI, ATS, CTAS and MTS have shown varied degrees of intrarater and interrater variabilities (Bullard et al., 2017; Dallaire et al., 2010; Fernandes et al., 2013a; Murray, 2003; Wulp, 2010; Lähdet et al., 2009) and in some instances have demonstrated different sensitivities towards under triaging or over triaging (Elkum et al., 2011; Mirhaghi et al., 2015; Parenti et al., 2014; Storm-Versloot et al., 2011; Zakeri et al., 2022).

In Ghana, the South African Triage Scale (SATS) developed in South Africa is the main triaging tool used at the EDs (Dixon et al., 2021; South African Triage Group, 2012; Twomey et al., 2012). The SATS was used at the TGH where this current study was conducted. The SATS was first introduced at the Komfo Anokye Teaching Hospital, in the Ashanti region of Ghana in 2010 (Rominski et al., 2014). The SATS have been studied and used in other low LICs and LMICs like Afghanistan, Haiti and Sierra Leon (Dalwai et al., 2017). In these jurisdictions, the SATS have been proven to be friendly and useful in triaging and making urgent decisions to save patient lives. SATS code of red indicate an emergency that needs immediate physician attention and resuscitation, and a code of green means the patient can be attended to within 4 hours. The Table 2.10 below itemises some of these triaging scales, their scores and recommended intervention times.

Table 2.10 Different triaging scales and their interpretation (Australasian College for Emergency Medicine, 2016; Bullard et al., 2017; Nicky Gilboy et al., 2011; Manchester Triage Group, 2014; South African Triage Group, 2012)

Triaging System	Countries	Levels/Category	Response Time
Australasian Triage Scale (ATS) formerly known as National Triage Scale of Australis	Australis New Zealand	1 = Resuscitation 2 = Emergency 3 = Urgent 4 = Semi-urgent 5 = Nonurgent	Level 1-0 minutes Level 2-10 minutes Level 3-30 minutes Level 4-60 minutes Level 5-120 minutes
Manchester Triage System (MTS)	England Scotland Ireland	1 = Immediate (red) 2 = Very urgent (orange) 3 = Urgent (yellow) 4 = Standard (green) 5 = Nonurgent (blue)	Level 1-0 minutes Level 2-10 minutes Level 3-60 minutes Level 4-120 minutes Level 5-240 minutes
Canadian Triage and Acuity Scale (CTAS)	Canada	1 = Resuscitation 2 = Emergency 3 = Urgent 4 = Less urgent 5 = Nonurgent	Level 1-0 minutes Level 2-10 minutes Level 3-30 minutes Level 4-60 minutes Level 5-120 minutes
Emergency Severity Index (ESI)	USA	1 = Immediate 2 = High risk 3 = Two or more resources needed 4 = One resource needed 5 = No resource needed	Level 1-immediate Level 2-15 minutes Level 3-15 minutes Level 4-30 minutes Level 5-30 minutes
South African Triage Scale	South Africa Used in Ghana	Red = Emergency Orange = Very urgent Yellow = Urgent Green = Non urgent Blue = Death	Red – Immediate Orange – 10 minutes Yellow – < 60 minutes Green – < 240 minutes Blue – < 120 minutes

2.9.2 Neurological assessment of stroke patients at the emergency department

Neurological state assessment at arrival and subsequently helps to track improvement in stroke patient condition and monitor the effectiveness of treatment (Powers et al., 2019). Two of the commonly used, widely studied and validated in-patient neurological clinical assessment tools are the National Institute of Health Stroke Scale (NIHSS) and the Glasgow Coma Score (GCS) (Bill et al., 2019; Zerna et al., 2018).

2.9.2.1 The National Institute of Health Stroke Scale and stroke severity assessment

The NIHSS is the most referenced protocol and the gold standard neurological tool for assessing stroke severity and used mostly in HICs (Khan et al., 2022; Lyden, 2017; Lyden et al., 2009). It is recommended to be used within 12 hours of admission of stroke patients to the ED by a certified examiner (Joint Commission Quality Measures for Disease-Specific Care Certification, 2021; Leifer et al., 2011). As a 42-point scale that focuses on 6 major areas, the NIHSS determines rapidly and accurately reflects the vascular territory and anatomical location of the brain` injury (Mahdy et al., 2019). The score assesses the level of consciousness, best gaze, visual fields, facial palsy, left arm motor drift, right arm motor drift, left leg motor drift, right leg motor drift, limb ataxia, sensation, best language, dysarthria, extinction and inattention (Bill et al., 2019; Rost et al., 2016; Zerna et al., 2018).

Prior to the development of the NIHSS, other clinical methods and metrics used to measure the severity in stroke patients included the Canadian neurological scale, Edinburgh-2 coma scale and Oxbury initial severity scale among others (Brott et al., 1989). The NIHSS was introduced as improved versions of these older metrics (Lyden & Lau, 1991; Muir et al., 1996; Tilley et al., 1996). The NIHSS has been found to: predict mortality outcomes after an acute stroke; assist clinically in the initiation of thrombotic therapy, rehabilitation or both; and it gives an indication of who should be sent for CT scan or MRI (Farooque et al., 2020; Herath et al., 2021; Mahdy et al., 2019; Rost et al., 2016).

The NIHSS can also help to distinguish between haemorrhagic and ischaemic strokes. Using the NIHSS, symptomatic intracerebral haemorrhage reflects as worsening score by greater than 4 points within the first 36 hours of stroke onset (Farooq et al., 2022). The overall correlation between the NIHSS and intracerebral haemorrhage volume was found to be 0.77, where for every 10cc increase in intracerebral haemorrhage, the NIHSS increased by 4.5 points (Farooq

et al., 2022). On the contrary, another study found haematoma volume in haemorrhagic stroke patients not to significantly correlate to NIHSS (Christensen et al., 2012). Lesion increases in ischaemic stroke generates greater NIHSS sensitivity to the left hemisphere function than the right hemisphere (Abbas et al., 2022; Farooq et al., 2022; Hosomi et al., 2008; Mahdy et al., 2019; Mustanoja et al., 2015). The NIHSS has also been found to predict significantly and independently out of hospital 90-day functional outcome after endovascular therapy in stroke patients (Lu et al., 2020).

Despite its effectiveness and reproducibility properties, the NIHSS has been found to be deficient in the daily monitoring of functional changes and post treatment improvement in stroke patients (Marsh et al., 2016). The use of the NIHSS is not common in low resource settings (Marks, 2018) as physicians are not trained on its application. Secondly, certified NIHSS examiners are not readily available in LICs and LMICs.

2.9.2.2 The Glasgow coma score and level of brain injury assessment

In LMICs like Ghana, Nepal and South Africa among others, the GCS is a preferred tool for assessing the neurological severity of stroke patients at the bedside (National Department of Health (South Africa), 2020; Sedain & Bhusal, 2019; Standard Treatment Guidelines (Ghana), 2017). The GCS was designed in 1974 by Graham Teasdale and Bryan J. Jennett to assess the level of consciousness of patients with acute traumatic brain injury (TBI) (Mattei & Teasdale, 2020). It is the most commonly used clinical scale in neurological practice (Mattei & Teasdale, 2020; Ponce & Lozano, 2010). The GCS has since been studied, trialled, and validated in the UK, the Netherlands and in many other places. It is considered as one of the most researched tool across countries (over 16,000 citations in ScienceDirect/PubMed) in the history of neurosurgery (Mattei & Teasdale, 2020; Ponce & Lozano, 2010).

The GCS was first published in the Lancet in 1974 by Teasdale and Bryan under the heading "Assessment of coma and impaired consciousness – a practical scale" (Mattei & Teasdale, 2020). The GCS assesses a patient eye opening, verbal response and motor response against a set of criteria on a scale resulting in ratings between 3 and 15 (Mattei & Teasdale, 2020; Ratcliff et al., 2014). Patients are classified as severe traumatic brain injury or comatose when the GCS score is 3-8, a score of 9-12 (moderate) and between 13-15 (mild) traumatic brain injury (Weir et al., 2003). Some of the documented challenges with the use of the GCS include; the non-reporting of the confounders in a standardised manner (Wolfgang et al., 2009); interrater

reliability variations (Kebapçı et al., 2020); the non-standardised time interval for the application of the tool on patients (Wolfgang et al., 2009); and knowledge gaps in its application, warranting further training of clinician on its effective use in places like Ghana (Alhassan et al., 2019) and Nigeria (Ehwarieme & Anarado, 2016).

Comparatively, 'slim' scales like the GCS has been shown to produce normal score of 15 when NIHSS reflects in the same patient significant disability hence not recommended for ongoing monitoring in ischaemic stroke patients as it substantially decreases the value of a structured neurological assessment especially in patients with low NIHSS score (Nye et al., 2012). The NIHSS has been found to be more accurate than the GCS in significantly predicting the outcomes of stroke patients in 72 hours (Mansour et al., 2015). The admission NIHSS also predicts 3-months survival in intracerebral haemorrhage stroke patients better than the GCS (Bae et al., 2001).

Other stroke assessment tools less commonly used and found to have varied levels of sensitivity, specificity, convenience, validity, reproducibility and expertise needed for use include: Face Arm Speech Time (FAST) (Berglund et al., 2014; Saberian et al., 2019), Balance, Eyes, Face, Arm, Speech Time (BE-FAST) (Aroor et al., 2017; Pickham et al., 2019), Cincinnati Prehospital Stroke Scale (CPSS) (You et al., 2013), Medic Prehospital Assessment for Code Stroke (Med PACS) (Studnek et al., 2013), PreHospital Ambulance Stroke Test (PreHAST) (Andsberg et al., 2017) Melbourne Ambulance Stroke Scale (Bray et al., 2010) among others (Budinčević et al., 2022; English et al., 2018). These stroke rating scales despites their jurisdictional, non-generalizability, research and operational limitations are used for either stroke recognition or quantification measure of stroke severity, disability, outcome or other aspect of sub-stroke types (Budinčević et al., 2022). The physicians at the TGH where this current study was conducted used the GCS as the tool of choice used in assessing the neurological status of stroke patients. This was therefore adopted for the study.

2.9.3 Modified Rankin scale in assessing the functional disability of stroke patients

To assess the functional outcome of stroke patients, the modified Rankin Scale (mRS) and Barthel Index (BI) are widely used. They determine mild, moderate and severe levels of disability outcomes in stroke patients (Kwon et al., 2004; Liu et al., 2022; Sulter et al., 1999; Weimar et al., 2002). The preferred 7-Level mRS was introduced by John Rankin in 1957

(Quinn et al., 2008) and modified to its current form by Charles Warlow and others as part of the UK-TIA trial in the 1980 (Broderick et al., 2017). The mRS covers the entire range of functional outcome from no symptoms (score of 0), no significant disability (score of 1), significant disability (2), moderate disability (3), moderately severe disability (4), severe disability (5) to death (6) and it can be used by both clinicians and patients (Harrison et al., 2013).

Systematic reviews and meta-analysis has established strong evidence of correlation between the mRS and measures of stroke pathology in agreement with other scales (Harrison et al., 2013). Evidence from clinical trials, primary research and secondary analysis suggest that the mRS is a valid and reliable tools for assessing the impact of new stroke treatment, identifying meaningful differences among ischaemic stroke patients and TIA patients, predict functional and disability outcome from the time of discharge to over 5 years of stroke onset (Askew et al., 2020; Banks & Marotta, 2007; De Havenon et al., 2021; Lebovitz et al., 2012; Pérez & Tilley, 2016; Yochelson et al., 2020).

A study compared the mRS and the Korean modified Barthel Index (K–MBI) scores in assessing the residual functional status among 5,759 stroke survivors after 3 months of stroke onset (Kim et al., 2018). The mRS was found to be more sensitive in differentiating mild residual disability against K-MBI providing specific information on moderate to severe residual disability among stroke survivors (Kim et al., 2018). Another study found the 3-months mRS to have better long term prediction outcomes with the ordinal mRS (0, 1, 2, 3, 4, 5, or 6) among 1,607 ischaemic stroke patients than the dichotomous (0/1,2-6 or 0-2/23-6) form of the mRS (Ganesh et al., 2018). In this study the population was 95% white and hence a limitation on racial bias limits generalisation of the findings. This calls for its application and studies among non-white dominant population. The mRS has since its development gone through evolution including standardized nomenclature and it has been predicted to be used widely in the future where dichotomised good outcome prediction is a score of 0-2 and poor functional outcome with a score of 3-6 (Broderick et al., 2017; Saver et al., 2021).

In Ghana, the mRS is not routinely used at the bedside, but it has been adopted in a few stroke related studies (Akpalu et al., 2018; Sarfo et al., 2022). Some of these studies as part of secondary analysis looked at the association between hypercalcaemia (Sarfo et al., 2015), diabetes mellitus (Sarfo et al., 2018) and adverse clinical outcomes in stroke patients using mRS as an adverse long term outcome measure. However, mRS studies in LMICs and LICs

has been challenged with smaller stroke sample sizes usually not diagnosed with imaging studies (Sarfo et al., 2022). Also, a number of patients are also lost to follow up and non-documentation of the cause of death remain as documented generalisation hinderances (Sarfo et al., 2022).

2.9.4 Clinical and imaging diagnosis of stroke patients

About 85% of strokes (ischaemic) occurs as blood flow to distant brain cells are interrupted (National Institute of Health, 2023). This is predominantly caused by small vessel arteriolosclerosis, cardioembolism and large artery athero-thromboembolism (Murphy & Werring, 2020). Haemorrhagic strokes (15%) occurs when an aneurysm in the cerebral artery break open and bleeds into the brain resulting in brain cell death (National Institute of Health, 2023). Some diseases can manifest as stroke based on the neurological deficits at presentation. Symptoms experienced by victims of road traffic accidents for example, can mimic stroke in instances where traumatic brain injury has occurred, and the risk of haemorrhagic stroke has been estimated to be high (Qu et al., 2022; Turner et al., 2021).

2.9.4.1 Stroke mimics and stroke chameleons

Stroke mimic is a diagnosis of exclusion and occurs after the suspicion of clinical stroke has been discarded and a more convincing evidence has been established to explain another clinical disease including non-vascular conditions (Anathhanam & Hassan, 2017). Stroke mimics therefore occurs when the diagnosis of stroke is not confirmed after a workup for a suspected stroke patient during the period of admission (Edwards et al., 2015; Moulin & Leys, 2019). Examples of stroke mimics include seizures, epilepsy, migraine, headaches associated with acute neurological deficits and lymphocytosis, non-vascular conditions, TIA, cerebral venous thrombosis, reversible vasoconstriction syndrome, posterior reversible syndrome, psychogenic disorders, post ictal paralysis, toxic-metabolic disturbances, hypertensive encephalopathy, drug toxicity hypoglycaemia, functional disorder, and brain tumours, functional neurological disorder presenting with limb weakness, numbness, or speech disturbances (previously known as psychogenic or conversion disorder) among others (Ifergan et al., 2020; Jauch et al., 2013; Moulin & Leys, 2019; Okano et al., 2018; Popkirov et al., 2020; Rodriguez-Hernandez et al., 2023; Vilela, 2017). Stroke mimics have less vascular risk factors including younger age, female predominance, lower to near normal BP, milder deficit at presentation, good functional

status before a stroke and they have milder deficits and shorter length of hospital stays (Al Khathaami et al., 2020; Pohl et al., 2021).

Interestingly, severe disease on admission and high mortality rates (54.5%) have been reported among 363 patients with suspected stroke in Tanzania (Matuja et al., 2020). In that study 6.6% of the patients were finally diagnosed as stroke mimics (Matuja et al., 2020). A study of suspected strokes in the National Institute of Health Stroke Program conducted between 2001 and 2010 in two hospitals in Washington DC revealed that as high as 30% of the 8,197 patients who were initially suspected to be stroke patients ended up been diagnosed as stroke mimics (Merino et al., 2013). These findings are particularly of interest in the outcome of the patients.

Stroke chameleon on the other end of the diagnostic spectrum occurs when clinical symptoms that are not usual during stroke actually reveals a stroke (Moulin & Leys, 2019). At the instance of admission, the diagnosis of stroke is usually not considered during the initial workout only for the final diagnosis to turn out as stroke. Examples of stroke chameleon include among others hypertensive emergency, systemic infection, suspected acute coronary syndrome, dizziness and vertigo, monoplegia, altered mental status and movement disorders (Dupre et al., 2014; Jauch et al., 2013; Moulin & Leys, 2019; Vilela, 2017). Subtle presentations of stroke including confusion and peduncular hallucinosis which are consequences of stroke may be attributed to an acute psychiatric event (Dupre et al., 2014). In some instances, ischaemic stroke patients with predominant chest or epigastric pain may lead to a wrong stroke chameleon diagnosis of acute coronary syndrome (Rebordão et al., 2020).

Patients with stroke chameleon may benefit from stroke treatment like thrombolysis though the same may be harmful for stroke mimics (Fernandes et al., 2013b) and hence all efforts are to be employed to minimise the proportions or mimics and chameleon. Once stroke mimics and chameleons are properly diagnosed in a timely manner, there are likely to be appropriate thrombolysis rates with potentially better outcomes (Zinkstok et al., 2013). Ideally, stroke mimics and chameleon should be entertained in the differential diagnosis and treatment for stroke as they account for 20 – 50% of suspected cases of stroke to avoid the use of inappropriate and harmful medications in the long run (Buck et al., 2021; McClelland et al., 2019; Moulin & Leys, 2019).

Stroke mimics are therefore “false positives, overdiagnosis” and stroke chameleons are “false negatives, underdiagnosis” and there is a need to identify common diagnostic pitfalls, come up

with strategies to limit diagnostic error and inform future research (Benson et al., 2015; Liberman & Prabhakaran, 2017). These umbrella diagnoses are crucial in low resource settings where high level imaging and tissue diagnosis are not commonly available (Silva & Viana, 2011).

2.9.5 Imaging diagnosis of acute strokes presenting to the ED

To accurately diagnose acute stoke and limit mimics and chameleons and their attendant implications, imaging studies are preferably required.

2.9.5.1 CT scanning and stroke diagnosis

The use of the CT scan for the initial evaluation of suspected stroke patients remain the primary imaging modality (American College of Radiology, 2019) in stroke diagnosis and initiation of thrombotic therapy. CT scan presentations for stroke are described in three stages. Acute stage (less than 24 hours) is characterised by "early ischaemic changes" with cytotoxic intracellular oedema, loss of normal gray matter/white mater interface (differentiation) and effacement of the cortical sulci with subtle but significant changes; subacute stage (24 hours to 5 days) which is more of a vasogenic oedema with greater mass effect with an increased risk of herniation, hypoattenuation with well-defined margins; and the chronic stage (weeks) which presents as loss of brain tissue with hypoattenuation (Birenbaum et al., 2011). The middle cerebral artery is commonly affected in stroke patients and may have an intravascular thrombus or embolus which typically shows on CT scan as a hyperdense area in the vessel (Akbarzadeh et al., 2021)

The advantage of CT scanning over conventional radiography is its ability to distinguish between tissue density differences (like cerebrospinal fluid, brain tissue and bones) as expressed in Hounsfield Units (Bhattacharyya, 2016). CT scanning also provides cross sectional (tomographic) slices through the brain, subdural and bone windows (Schwarts, 2008). An important type of CT scanning is the non-contrast-enhanced CT scanning. Non-contrast-enhance computed tomography (NECT) is sufficient in assessing exclusion criteria for intravenous rTPA and identifying contraindications for fibrinolysis (Jauch et al., 2013). It excludes parenchymal haemorrhage as well and allows patients with ischaemic stroke to receive timely intravenous fibrinolytic therapy (Jauch et al., 2013). NECT should be obtained within 25 minutes of arriving at the ED (Jauch et al., 2013). Though NECT can accurately identify most cases on intracranial haemorrhages and distinguish it from other nonvascular

causes like brain tumour, it is relatively insensitive (occurs in less than 67% of cases images) in detecting acute and small cortical or subcortical infarctions (mostly in the posterior fossa) within 3 hours of the injury (Jauch et al., 2013). Other imaging techniques available for the diagnosis of stroke include CT angiography (CTA) of the head and neck, CT perfusion (CTP) and non-contrast CT scans (Akbarzadeh et al., 2021).

2.9.5.2 Magnetic resonance imaging and stroke diagnosis

Conventional MRI compared to the standard NECT has been reported to be more sensitive in detecting new and preexisting ischaemic lesions in patients with 24-hour time defined TIA when compared to standard NECT (Jauch et al., 2013). Diffusion weighted imaging (DWI) MRI is the most sensitive (88 -100%) and specific (95 – 100%) imaging technique for acute infarct at very early time points compared to NECT or other conventional MRI sequence (Jauch et al., 2013; Powers et al., 2015, 2019). DWI can detect lesion size, site, age and relatively small deep or subcortical lesions (including those in the brain stem or cerebellum) which are usually not visualised using standard MRI sequence and NECT scan techniques (Jauch et al., 2013; Powers et al., 2015, 2019). MRI has some advantage over CT scan though it has been found to take a few minutes longer to conduct using the stroke-onset-to-imaging time (MRI: median 114 minutes; CT scan: 107 minutes) (Provost et al., 2019). However CT scans are non-inferior to the MRI in the diagnosis and confirmation of stroke (Cabral Frade et al., 2022).

Due to the difficulties clinicians face in accurately and correctly diagnosing and distinguishing stroke subtypes, stroke mimics and chameleon, brain imaging with CT scan and/or MRI is recommended. It has been found that, less than one CT scan facility exist per million population in LMIC compared to about 40 CT scanners per million population in HICs (Bergeron et al., 2017; Frija et al., 2021; Hricak et al., 2021). However, the unavailability of CT scan is not confined to LMICs: in rural Canada for example, less than 15% of the rural population have access to CT scan (Bergeron et al., 2017). This highlights the scarcity of imaging technology across various countries irrespective of the economic status.

2.9.6 Imaging studies in low resource settings

A systematic review on epidemiological studies of stroke in Africa between 1970 and 2017 showed significant flaws in the research methodologies (Owolabi et al., 2018). Typically, these studies did not employ the use CT scan or MRI to diagnose stroke patients recruited simply

because they were not available in the health facilities where the studies were conducted. Some of these studies have been conducted in Tanzania (Walker et al., 2011), urban Nigeria (Danesi et al., 2007), semi urban Nigeria (Sanya et al., 2015) among others. In areas where timely review and interpretation of brain CT scan and MRI scan imagine by experts are not available, teleradiology systems approved by the Food and Drugs Administration are recommended (Jauch et al., 2013) and where all these are not available clinical diagnosis can be used.

Out of 1,688 stroke patients studied in a central hospital in Cameroon, 640 (37.9%) did not have a head CT scan diagnosis (Lekoubou et al., 2016). Higher mortality rates (27.5%) were found among the non-CT scan group compared to 16.4% of CT scan group (Lekoubou et al., 2016). This indicates the relevance of imaging diagnosis of stroke patients. Though studies in LMICs and LICs are mostly single site studies they give indications what may be happening in a low resource setting where stroke patients may not have the benefit of CT scan imaging and timely interpretation of results for decision making (Akinyemi et al., 2021; Owolabi et al.,, 2018).

There are less than an average of 1 CT scanner (0.69) available to one million population in LICs, 4.3 CT scanners to one million population in LMICs compared to about 38.8 CT scanners per a million population in HICs and this gap is even wider for MRI scanner (Frija et al., 2021; Hricak et al., 2021). There exists an average of 27.3, 1.1 and 0.2 MRI scanners per one million population for HICs, LMICs and LICs respectively according to Hricak et al (2021). A paucity of imaging expert exist, whereas there is an average of about 22.3 radiologists per one million population in LMICs, 1.9 in LICs, there are close to 97.9 radiologist per one million population in HICs (Frija et al., 2021; Hricak et al., 2021). In places where the diagnostic imaging machines exist, only the top 10 - 20% of the population in LICs and less than 40% of the population in LMICs are able to afford the imaging cost (Mclane et al., 2015). Limitations in the use of CT scan and MRI include high cost, relative unavailability of the scanners and interpretation radiologist specialist especially in LICs and LMICs and patient contraindication like cardiac pacemakers, claustrophobia and metal implants (Jauch et al., 2013; Powers et al., 2015, 2019).

It has been anticipated that the use of CT scan for stroke diagnosis will see an upward trend in demand and supply (Campbell & Parsons, 2018). Secondly, it is hoped that there will be frequent use of automated CTP (Vagal et al., 2019) for the benefit of stroke patients. Thirdly, through non-contrast CT images and the use of deep learning residual network, there will be

early detection of infarct core that will inform next steps in the management of stroke patients (Pan et al., 2021). Fourthly, the use of Artificial Intelligence (AI) in the current technological advancement globally has been heavily predicted in the diagnosis of stroke (Murray et al., 2020). This therefore calls for intensified training of clinicians who use these imaging facilities for confirmatory diagnosis, most especially in places where they are not readily available for use (Clèrigues et al., 2019) and be in readiness to embrace the future of stroke diagnosis.

2.10 Supportive care in stroke management

Considering the diagnostic constraints especially in low resource settings, the best approach will be to improve aspects of supportive care offered to stroke patients reporting to the ED. In such situations, supportive care that are needed by both ischaemic and haemorrhagic stroke patients include: temperature control, blood glucose control, provision of adequate hydration and nutrition, treatment of seizures, early mobilization treatment of seizures, prevention of aspiration, prevention of deep vein thrombosis and prevention of recurrence of the stroke as similar for both ischaemic and haemorrhagic stroke (Berkowitz, 2016; Jauch et al., 2013; Morgenstern et al., 2010; Powers et al., 2019). Two aspects of care that differ between haemorrhagic and ischaemic stroke are blood pressure management and the use of antithrombotic therapy (Berkowitz, 2016). Focus for the purposes of this current study was on BP management and not on rTPA as it is not routinely administered in Ghana and in TGH where this current study was conducted.

2.10.1 Blood pressure management in acute stroke patients

Elevated systolic BP (equal to or greater than 140 mmHg) and elevated diastolic BP (equal to or greater than 90 mmHg) are prevalent among acute and recurrent stroke patients (Bhammar et al., 2017; Gorgui et al., 2014; Zeigler et al., 2016). In 60% of stroke patients, high BP was observed within the first 24 hours of ischaemic and haemorrhagic stroke (Fischer et al., 2014). However, the first post stroke BP measured are relatively higher after an intracerebral haemorrhage compared to an ischaemic stroke (Fischer et al., 2014). Recurrent strokes have been reduced when BPs are well controlled and within targeted ranges (Linxin et al., 2021). Blood pressure values and their interpretations are presented in the Figure 2.5 below.

BLOOD PRESSURE CATEGORY	SYSTOLIC mm Hg (upper number)	and/or	DIASTOLIC mm Hg (lower number)
NORMAL	LESS THAN 120	and	LESS THAN 80
ELEVATED	120 – 129	and	LESS THAN 80
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 1	130 – 139	or	80 – 89
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 2	140 OR HIGHER	or	90 OR HIGHER
HYPERTENSIVE CRISIS (consult your doctor immediately)	HIGHER THAN 180	and/or	HIGHER THAN 120

Figure 2.5 Blood pressure measurements and interpretation, retrieved on 15 September 2022 from https://www.heart.org/en/health-topics/high-blood-pressure/understanding-blood-pressure-readings.

Following an ischaemic stroke, autoregulation control of BP is usually recommended unless there is an indication for intravenous rTPA (Patarroyo & Anderson, 2012). During such situations of thrombolytic therapy with rTPA, blood pressure must be maintained below 180/105 mmHg (Jauch et al., 2013). In which case lowering blood pressures aggressively may generally impact ischaemic stroke outcome negatively (Dirks et al., 2015). However, lowering blood pressure is mostly recommended for patients with acute haemorrhagic stroke who present with elevated blood pressure (Morgenstern et al., 2010; Powers et al., 2019). This has been found to be probably safe, however when the BP is rapidly lowered during the acute phase, adverse renal events are likely to occur with resultant negative clinical outcome (Kim et al., 2020).

Albeit the benefit of intensive reduction of systolic BP below 140 mmHg is uncertain though it may be safe. In a study among 2,839 acute intracerebral haemorrhage patients, Anderson et al found mortality rates to be 11.9% and 12% among the group that received rapid blood pressure lowering treatment and those who received the recommended blood pressure treatment (Anderson et al., 2013). There was no statistical difference between the two groups. Some data available indicate that haematoma expansion takes place in the presence of high BP after an intracerebral haemorrhage and this has been found to potentially worsen stroke outcomes (Bath et al., 2018).

Summarily, pathophysiological arguments for or against control of BP measurements is centred around but not limited to the following: the reduction of the risk of acute stroke recurrence, cerebral oedema, reperfusion haemorrhage for acute ischaemic stroke post reperfusion therapies (Appiah et al., 2018); the reduction of cerebral oedema and haematoma expansion in intracerebral haemorrhages and the significant role of cerebral autoregulation alteration (Sandset et al., 2021; Szu-Ju et al., 2021). Extremely low and extremely high blood pressure have a direct effect on the outcomes of stroke in respect of mortality, inability to ambulate independently post discharge, non-discharge from the hospital and haemorrhagic complication of thrombotic therapy (Bangalore et al., 2017; Jatinder et al., 2019).

The European Stroke Organization (ESO) in using standard operating procedure as well as Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) methodology has made the following BP control recommendations during stroke. Firstly, early, and modest blood pressure control (avoiding blood pressure levels > 180/105 mmHg) in acute ischaemic stroke patients undergoing reperfusion therapies (Sandset et al., 2021). Secondly, intensive rapid BP lowering in acute intracerebral haemorrhage after hospitalization where haematoma expansion will be reduced to improve recovery (Sandset et al., 2021).

The controversy of treating or not treating high blood pressure after an acute stroke lingers on though there appears to be some consensus on the optimisation of BP management during and post-acute ischaemic and haemorrhagic stroke (Carcel & Anderson, 2015). It is assumed that in the absence of CT scan to distinguish between haemorrhagic stroke and ischaemic stroke patients, lowering systolic BP below 180 mmHg is recommended for stroke patients with unknown aetiology (Berkowitz, 2016; Dirks et al., 2015). This will eventually benefit patients with haemorrhagic stroke and be safe in patients with ischaemic stroke patients (Berkowitz, 2016; Dirks et al., 2015). Recommendation for further studies to understand the dynamics of BP control during acute stroke has been made (Doogue et al., 2020) as BP management vary with the chronology of events during and after a stroke (Gorelick et al., 2019).

2.11 Summary of the gaps from the literatures and justification for the study

From the literature review, the gaps identified that justifies this current study is herein presented. Very few ED overcrowding studies have looked at its impact on stroke related mortality. There are few key papers referenced in the literature review that focused on

timeliness on stroke intervention with none focussing on mortality outcome as a primary outcome measure. Secondly, in LMICs and LICs, no study has used a complex heterogenous metric like the NEDOCS to assess the impact of overcrowding levels on stroke mortality. Thirdly, no study has qualitatively detailed stroke care within the context of a low resource setting with emphasis on mortality outcomes on the backdrop of crowdedness at the ED as an exposure worthy of study. Fourthly, no study especially in a LMIC or LIC has looked at the predictors of stroke mortality with the inclusion of the crowding levels at the ED as an important variable. Fifthly, majority of the ED overcrowding studies, and stroke related studies have been conducted in HICs where resources are available with paucity of data from LMICs and LICs. Sixthly, no study has been conducted on stroke care and mortality outcome at the ED in the era of CT scan in the TGH one of the sub-regional hospitals in Ghana.

2.12 Summary of the literature review as written

The literature review started with an introduction and a methodology on the steps and strategies used in doing the search. The subsequent review and write up focused on the definition and conceptual understanding of ED overcrowding. The overcrowding framework looked at input, output and throughput factors described by Asplin et al (2003). The most important causes of ED overcrowding being boarding, and access block was explored. The next phase of the review highlighted the impact of ED overcrowding on the quality of care especially among stroke patients. In detail was the impact on ED overcrowding on the use of CT scan and MRI in the diagnosis of stroke. The impact of overcrowding on thrombolysis was also reviewed. Important, a review of overcrowding impact on patient mortality specifically stroke patients was also highlighted. Qualitatively, the impact of overcrowding on physician decisions regarding stroke patients. The impact of overcrowding from the viewpoint of the staff and patients was also synthesised.

The next aspects of the literature review presented the historical development of ED overcrowding measuring tools, and a comparative analysis of the tools was undertaken. Specific attention on ED overcrowding in low resource setting was also undertaken. The last phase of the review was centred on the relevant aspects of ED care of stroke patients with emphasis on triaging and triaging tools, neurological assessment (GCS, mRS and NIHSS) and blood measurement in stroke patients. The gaps in the literature review justifying the essence of this current research were included at the end of the review.

Chapter 3 METHODS AND METHODOLOGY

3.1 Introduction to methods and methodology

The methods and methodology chapter is organised as such: 1) research setting, 2) research design, 3) participants and data sources (including participants, assessments, treatment, and dataset), 4) Sample size estimation, 5) data collection, 6) description of variables in the data set, 7) data or variables limitations, 8) data analysis, 9) impact of COVID-19 on data collection and 10) ethics and ethical considerations.

There were four research assistants who were trained to assist in information/data gathering, clinical records review and extraction from physicians and nurses' notes as documented in the patients' clinical records. The research assistants were health professionals: one with a master's in public health, a physician, a nurse, and a physician assistant. The assistants were not paid for their services as their role in the study was considered as part of their mandatory national service work. The administrative clerk at the ED was also trained to assist in collecting relevant information/data needed for the study.

3.1.1 Research setting

This study was conducted in TGH, the largest hospital located within the Tema metropolis in the Greater Accra region of Ghana. TGH is an urban, subregional, academic, specialist and referral hospital that operates 24-hours every day of the week. The immediate catchment area of hospital included the Tema metropolis which has 100% urban population of 177,924 for both sexes (Ghana Statistical Service, 2021). The census of the adjourning districts served by the hospital are as follows: Tema West (100% urban population of 196,224), Tema Central (100% urban population of 66,191) and Tema East (100% urban population of 111,733) (Ghana Statistical Service, 2021). The hospital receives referrals from other municipalities and districts in the Greater Accra region mainly Ningo Prampram, Shai Osudoku, Ada West, Ada East, Ashaiman, Kpone Katamanso, Ledzekuku and Krowor. TGH also receives referrals from other regions in the country the Volta region and Eastern region.

Between January and December of 2020 at the outset of the study, a total of 715 deaths were recorded in the medical certificate cause of death (MCCOD) at TGH. The medical certificate cause of death is the main data capturing tool that records the cause of death of patients at Tema

General Hospital and it is recognised as the legal medical cause of death. Among the 715 deaths, stroke related deaths (163) contributed 22.8% of all-cause death representing the highest cause of death, followed by hypertensive heart disease (16.4%), other hypertension related deaths (16.1%), and heart failure (9.5%) among others. The high numbers of stroke deaths were of topical concern to health professionals in the hospital.

TGH had no stroke centre, no stroke team, no code stroke activation system, no in-house neurologist, or stroke specialist at the time of the study. TGH did not have an in-hospital CT scanning or MRI machines and all such services were procured outside the hospital at a cost to the patient. Patients who needed advanced stroke care were referred mostly to the Korle-Bu Teaching Hospital and at other times to the Greater Accra Regional Hospital (previously known as Ridge hospital) or 37 Military Hospital which was about 45 – 60 minutes from the TGH using a high speeding ambulance (Tema General Hospital, 2021). These referral hospitals had comprehensive facilities for stroke care.

Table 3.1 Departments, units, centres, and the bed distribution (Tema General Hospital, 2021)

No.	Treatment Ward/Unit/Centre	No. of Beds	Percent (%)
1	Post-delivery ward	47	11.5
2	Adult emergency	35	8.6
3	Gynecology ward	34	8.3
4	Antenatal ward	33	8.1
5	Male surgical ward	32	7.8
6	Female surgical ward	18	4.4
7	Male medical ward	32	7.8
8	Female medical ward	32	7.8
9	Neonatal Intensive Care Unit	27	6.6
10	Pediatric medical ward	26	6.4
11	Post Cesarean ward	25	6.1
12	Infectious Disease Center	20	4.9
13	Pediatric emergency	15	3.7
14	Pediatric surgical ward	13	3.2
15	Accident and Trauma Center	10	2.4
16	Intensive Care Unit	6	1.5
17	Obstetrics and Gynecology emergency ward	4	1.0
Total	**17**	**409**	**100.0**

As at 2021, the number of beds in TGH was 409 (Tema General Hospital, 2021) and Table 3.1 below highlights the distribution of these bed. The post-delivery ward had the highest number

of beds (47) representing 11.5% of all beds in the hospital followed by 35 beds at the ED (8.6%) and the gynaecology ward with 34 beds (8.3%). The obstetrics and gynaecology emergency unit had the least number of beds (4) representing 1.5% of all beds in the hospital followed by that of the intensive care unit with 6 beds representing 1.0% of all beds in the hospital as of 2021. The situation may have since changed. Tema General Hospital had a total staff strength of 1,083 with 60% being technical and 40% non-technical as of August 2021. The cadre of technical staff distribution is shown in Table 3.2 below. Professional nurses (154) were the highest cadre representing 14.2%, followed by enrolled nurses (7.4%). There was only one emergency physician specialist in the hospital at the time the study. He managed the ED.

Table 3.2 The distribution of the cadre of staff at the Tema General Hospital (2021)

Cadre of Staff	No.	(%)	Cadre of Staff	No.	(%)
Professional nurses	154	14.2	Pediatric nurses	3	0.3
Enrolled nurses	80	7.4	Technical officer (mental health)	3	0.3
Midwives	72	6.6	Physiotherapist	3	0.3
Senior house officers	60	5.5	Optometrists	3	0.3
Community health nurses	54	5.0	Obstetrics and gynecology Specialist	2	0.2
Medical officers	39	3.6	Ophthalmologist	2	0.2
Physician assistant (anesthesia)	16	1.5	Medical officer (dental surgeon)	2	0.2
Critical care nurse	15	1.4	Dental technician/technologist	2	0.2
Public health nurses	14	1.3	Dieticians	2	0.2
Ward assistant	10	0.9	Field technicians	2	0.2
Biostatics assistants	9	0.8	Emergency care assistants	2	0.2
Ophthalmic nurse	8	0.7	Human resource manager	2	0.2
Pharmacist	7	0.6	Medical director	1	0.1
Biomedical scientist	7	0.6	Radiologist	1	0.1
Physician assistant (medical)	6	0.6	Pathologist	1	0.1
Mental health nurses	6	0.6	Doctor anesthetist	1	0.1
Physiotherapist assistant	6	0.6	Emergency physician specialist	1	0.1
Technical officer (laboratory)	5	0.5	Physician specialist	1	0.1
Laboratory assistant	5	0.5	Urologist	1	0.1
Peri operative nurse	5	0.5	Orthopedic surgeon	1	0.1
Pediatrician	4	0.4	Nutrition officer	1	0.1
Dispensary assistants	4	0.4	Medical records assistant	1	0.1
Ent nurse	4	0.4	Technician (clinical engineering)	1	0.1
Technical assistant (optical)	4	0.4	Technical officers (radiography)	1	0.1
Surgeon specialist	3	0.3	Private secretary	1	0.1
Pharmacy technician	3	0.3	Stenographer secretary	1	0.1
			Telephonist	1	0.1

At the time of the study the ED of the TGH had 30 fully functional and licensed beds and 5 partially functional beds. The ED did not have an in-house radiology team, ED pharmacist or CT technologist. The ED had one mobile ventilator, one defibrillator, two functioning suction machines and a mobile X-ray viewing machine. The department facilitated the transfer and transport of patients for laboratory and imaging services in and out of the hospital where applicable. The ED recorded a total of 5,126 patient admissions in 2018, 6,791 in 2019 and 7,677 in 2020 (Tema General Hospital, 2021). On average the ED attended to 544 patients per month and approximately 18 patients per day between 2018 – 2020.

The ED run a 3-shift system: morning shift (8:00 am – 2:00 pm), afternoon shift (2:00 pm – 8:00 pm) and evening shift (8:00 pm – 8:00 am). For each shift, there was one medical officer (a medical doctor who have worked for 2 - 5 years after graduating from medical school) and one house officer (a doctor who has completed medical school and working as a first-year intern) or a senior house officer (a doctor who has completed medical school and working as a second-year intern) on duty at the ED. The head of the ED was an emergency physician specialist who was on a 24-hour on-call cover at the ED. During each shift there were usually 3 nurses of varied ranks (included clinical nurse, critical care nurse and an emergency care nurse) who provided nursing services to patients (Tema General Hospital, 2021). Non-technical staff (mostly administrative) provided support during each shift.

3.1.2 Research design

This was a retrospective facility-based study of prospectively collected data on consecutive acute stroke patients who presented to the ED of the TGH between 01 October 2019 to 24 March 2020. The study was designed to access and collect secondary data from stroke patients' medical records from the ED of the TGH. This was conducted alongside using participants observation methods to observe stroke care practices. Upon the diagnosis of stroke, the clinicians and the administrative clerk at the ED notified the research assistant. The research assistants were granted access to the clinical records, and they engaged the ED staff to better understand the information that had been captured in the clinical records of the patients.

The research assistants observed the flow and non-flow movement of the patient at the ED. They extracted all the relevant information/data documented in the patient's clinical record by the ED clinicians. This included the patient's sociodemographic information, comorbidities, signs and symptoms of acute stroke, initial and final diagnosis, laboratory and imaging test

order and results, time of order, initiation, type and frequency of pharmacological and non-pharmacological therapies, decision of admission to the inpatient bed, referral or trans out order and execution time to another hospital and any other relevant information that was needed for this current study. The patients were followed, and the information was updated periodically as and when an activity regarding the care of the patient took place. In the night when patients arrived and there were no research assistants at post, the information needed for the purpose of the study were extracted the following morning. Data capture for the NEDOCS calculation is discussed in chapter 1 (section 3.1.3.2.4).

The journey started with the arrival of the patient at the ED. Triaging was immediately conducted by the triage nurse at the entrance to the ED. A determination was made regarding the acceptable time within which physician care must be started. The patient was attended to, and specific care and care pathway decisions were made. The process continued till disposition where the patient was either admitted, discharged, referred, or declared clinically demised. The journey of the patients at the ED is displayed in Figure 3.4.

3.1.2.1 Participant observation methodology

Participants (stroke patients) observations were applied, where the research team were immersed in observations of the day-to-day processes and care of the stroke patients at the ED. This was primarily done to bring a qualitative and an explanatory aspect to the study. The naturalistic observation approach was adopted where there was no interpersonal interaction between the research team and the stroke patients. These observations were made between 8:00 am to 8:00 pm every day at the ED for the entire duration of data collection by the research assistants. The principal investigator made periodic visits to the ED to undertake direct observation using the same laid down participant observation methods outlined. Where observations made could help inform physician decisions and improve patient care, formal discussion were had with the ED clinicians without interfering with their routine work.

To do this, the head of the ED was notified physically if present or by a phone call if not available. When the head of the ED could not be reached, the senior medical officer who was the shift supervisor was informed of the relevant observations made. These processes were detailed during the initial engagements had with the administration of the TGH and the managers of the ED. In instances where peculiar clerical errors were seen whiles extracting patients' clinical records, the same processes were followed to draw the attention of the

managers of the ED without interfering with the day-to-day operations. Participant observation as part of the scientific method was applied systematically, purposefully and on scientific grounds to better understand the phenomenology of ED overcrowding as well as patient care processes. This provided insider knowledge of patients care at the ED of the TGH.

3.1.3 Participants and data sources

The description here covered participant, clinical assessment, treatment of stroke patients and the dataset.

3.1.3.1 Participants

The participants for this study included male and female patients aged 18 years and above who presented at the ED of the TGH with any focal neurologic deficit suggestive of acute stroke (ischaemic, haemorrhagic, and TIA) during the period of data collection between October 2019 to March 2020. Patients who had concomitant head trauma were excluded as well as chronic stroke patients and their data were not included in the analysis.

3.1.3.2 Clinical, laboratory and imaging assessment of stroke patients

To diagnose first time stroke patients, clinicians at the ED conducted clinical history taking and physical examination. Stroke patients usually presented with acute onset of rapidly developing clinical signs of neurological deficits with no apparent cause other than that of a vascular origin. To distinguish between haemorrhagic and ischaemic stroke, acute onset of headache, vomiting, agitation, weakness on one side of the body, severe increases in blood pressure, medical history of hypertension and uncontrolled high blood pressure, lower GCS, dilated pupils, eye gaze impairment, rapidly worsening neurological deficits or consciousness, were prevalent in haemorrhagic stroke (Ojaghihaghighi et al., 2017). The clinical assessment processes started with patient triaging.

3.1.3.2.1 Clinical presentation at the ED at Tema General Hospital

Patients who visited the ED at TGH were triaged by nurses using the South African Triage Scale and this assisted in prioritising patient intervention target times (South African Triage Group, 2012). The triage score was determined after assessing the patient's mobility, respiratory rate, heart rate, systolic BP, temperature, APVU (Alert Voice Pain

Unresponsiveness), and the presence or absence of trauma. For a stroke patient who could not speak, patient relatives provided the necessary symptom information needed. The nurse looked for emergency, very urgent or urgent signs and subsequently calculated the triage early warning score (TEWS) as shown in Figure 3.1.

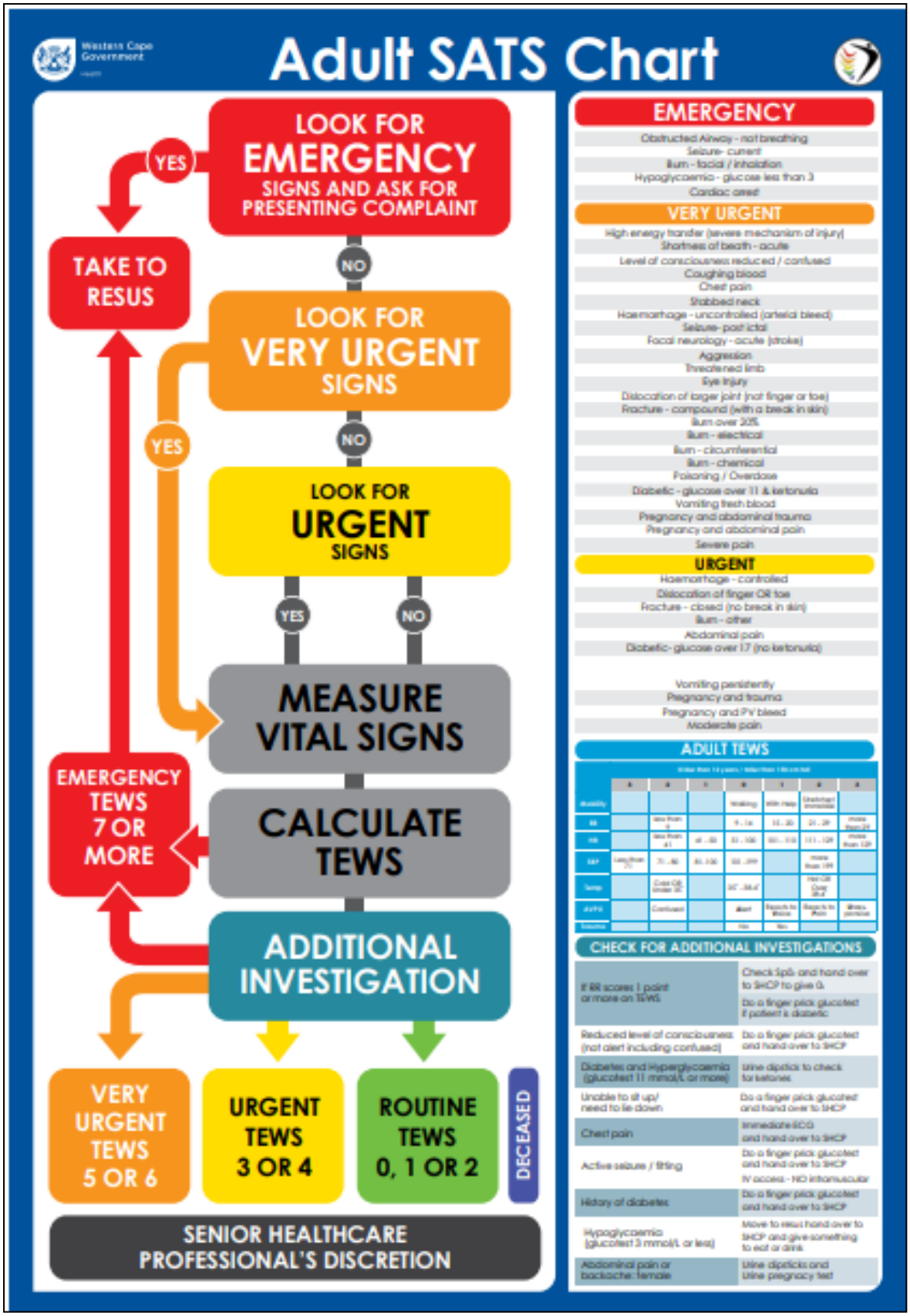


Figure 3.1 The interface of the South African Triage Scale, the interpretations and actions expected to be undertaken (South African Triage Scale, 2012, p. 8)

The overall triage early warning score assigned was colour coded, and only patients coded red (TEWS of 7 or more), orange (TEWS of 5 or 6) and yellow (TEWS of 3 or 4) were admitted to the ED. Patients coded green (TEWS of 0, 1 or 2) were referred to the out-patient for care. A systolic BP of more than 199 mmHg was given a score of 3 and that of 100-199 mmHg was assigned a TEWS of 0. The TEWS chart is presented in Figure 3.2 below.

OLDER THAN 12 YEARS / TALLER THAN 150 cm tall)	ADULT TEWS						
	3	2	1	0	1	2	3
Mobility				Walking	With Help	Stretcher/ Immobile	
RR		less than 9		9 - 14	15 - 20	21 - 29	more than 29
HR		less than 41	41 - 50	51 - 100	101 - 110	111 - 129	more than 129
SBP	Less than 71	71 - 80	81-100	101 -199		more than 199	
Temp		Cold OR Under 35˚		35˚ - 38.4˚		Hot OR Over 38.4˚	
AVPU		Confused		**A**lert	Reacts to **V**oice	Reacts to **P**ain	**U**nres-ponsive
Trauma				No	Yes		

Figure 3.2 SATS priority levels and target times to be seen with captured from the South African Triage Group (2012, p. 26)

The priority colour coding provided the target time for intervention and the nature of intervention. Red represented the topmost priority which demanded immediate resuscitation by the ED team. Orange indicated that the patients was to be attended to in under 10 minutes for very urgent management. Yellow colour coded patients had up to an hour to be attended to for management. Colour code blue indicated death and the ED physician was called to confirm and certify the death. This interpretation is presented in Figure 3.3 below.

Priority COLOUR	Target time	Management
RED	IMMEDIATE	Take to the resuscitation room for **emergency** management
ORANGE	< 10 mins	Refer to majors for **very urgent** management
YELLOW	< 1 hour	Refer to majors for **urgent** management
GREEN	< 4 hours	Refer to designated area for non-urgent cases
BLUE	< 2 hours	Refer to doctor for certification

Figure 3.3 SATS priority levels and target times to be seen with captured from the South African Triage Group (2012, p. 7)

After triaging, first physician attendance took place. During the physician clinical assessment of the patient the following vital signs were measured by the clinicians and documented in the patients' records: systolic BP (mmHg), diastolic BP (mmHg), heart/pulse rate (beats/mins), respiratory rate (cycles/min), temperature (Degree Celsius) and oxygen saturation (SPO2) (%). A normal systolic BP was less than 120 mmHg and above 120 mmHg was considered as abnormal (elevated, hypertension stage 1, hypertension stage 2 or hypertensive crises). For diastolic BP, the normal value was less than 80 mmHg and above 80 mmHg was considered abnormal (hypertension stage 1, hypertension stage 2 or hypertensive crises). A normal heart rate was between 60 – 100 beats per minutes, less than 60 was considered as bradycardia and above 100 tachycardia. A normal respiratory rate ranged from 12 – 20 cycles per minutes and rates of less than 12 was bradypnea and greater than 20 cycles per minute was considered as tachypnoea. A normal body temperature ranged from 36.5 – 37.5 degree Celsius. The interpretation of the findings on clinical examination as displayed in in the Table 3.3 below.

Table 3.3 Clinical findings and the interpretation of the values

Variable	Systolic BP (mmHg)	Diastolic BP (mmHg)	Heart rate (beats/mins)	Respiratory rate (cycles/min)	Temperature (Degree Celsius)	SPO2 (%)
Normal values/ranges	< 120	< 80	60 - 100	12 - 20	36.5 – 37.5	95 0-100

Neurological examination by the ED clinicians assisted in the diagnosis and monitoring of stroke patients. The use of a standard neurological examination ensures that the major components of a neurological examination are performed in a timely and uniform manner (Jauch et al., 2013; Powers et al., 2019). As highlighted in the literature review (chapter 2,

sections 2.9.1 and 2.9.2.1), the NIHSS was not used for this current study. This was because it was not part of the routine tools used at the ED of the hospital. Secondly, there were no trained and certified physicians at the ED who could apply the NIHSS. Thirdly, attempts made to train ED physicians to use the NIHSS for the purposes of this current study was declined by the management of the hospital.

However, in all established EDs in Ghana, the GCS remain the main neurological assessment tool for stroke patients (Standard Treatment Guideline, 2017). The GCS was therefore used routinely at the ED to document the neurological status of the stroke patients at the time of first physician examination. The GCS when applied measured the level of consciousness by assessing motor, verbal, and eye response of the patient to audio-visual and tactile stimuli. The motor response was assigned a score of 1-6 with 1 been no motor response and 6 indicating best motor response. For verbal response, a score of 1 meant no verbal response and 5 meant patient was fully oriented to time, place, and person. For eye response, a score of 1 meant no eye response and 4 indicated normal and spontaneous response of the patient's eye. A cumulative score of 3 - 8 signified severe levels of unconsciousness, between 9 - 12 implied moderate levels of unconsciousness and 13 - 15 indicated mild to full consciousness levels (Standard Treatment Guidelines, 2017). A sample of the GCS is displayed in Table 3.4 below.

Table 3.4 Glasgow coma score variables and interpretation. Accessed from https://www.ncbi.nlm.nih.gov/books/NBK513298/ (Jain & Iverson, 2021)

Best motor response	**Best verbal response**	**Best eye response**
1 No motor response	1 No verbal response	1 No eye opening
2 Abnormal extensions to pain	2 Incomprehensible sounds	2 Eye opening to pain
3 Abnormal flexion to pain	3 Inappropriate words	3 Eye opening to sound
4 Normal flexion from pain	4 Confused	4 Eye opening spontaneously
5 Localizing pain	5 Oriented	
6 Obeys command		

Motor function in all the four limbs were also assessed by the physicians. A score of 0 indicated no power in the limb with no form of motor function. A score of 5 indicated maximum power and displayed movement of the limb against maximum physical force as applied by the physician to the limb. The grading of motor power and function is presented in the Table 3.5 below.

Table 3.5 Interpretation of the motor function scores.

Motor function score	Interpretation
0	No visible muscle contraction
1	Visible muscle contraction with no trace of movement
2	Limb movement but not against gravity
3	Movement against gravity but not resistance
4	Movement against minimum resistance
5	Full strength and movement against maximum gravity

The mRS was applied by the ED physician to all stroke patients whiles on admission. It assessed the degree and severity of disability in stroke patients (Farrell et al., 1991; Quinn et al., 2008). An mRS of 0 indicated no symptoms, 5 meant sever disability and 6 indicated death (Lai & Duncan, 1999). Attending physicians at the ED usually documented the severity of disability of stroke patients in a free text format, non-graded and non-structured scale as part of routine patient's clinical information. During routine work, the mRS variables were collected but not interpreted in a grading format as was done for this current study. The information routinely collected only served as clinical information on the patient. Due to the simplistic nature and easy to use mRS, the hospital administration and the staff of the ED agreed to use the tool for the purposes of this current study and expressed desire of using it in the future (Tema General Hospital, 2019). The use of the mRS in the format that assigned a score to the level of disability and handicap of the stroke patient brought some form of standardization and interpretation to the patients' clinical state at disposition as displayed in the Table 3.6 below.

Table 3.6 Modified Rankin score and the interpretation of the values

Modified Rankin score	Interpretation
0	Asymptomatic
1	No significant disability despite symptoms
2	Slight disability, unable to carry out all previous activities
3	Moderate disability, requiring some help, able to walk
4	Moderate to severe disability, unable to walk or attend to bodily needs without assistance
5	Severe disability, bedridden incontinent and requiring constant care
6	Deceased

3.1.3.2.2 Investigation works up of stroke patients

After the clinical diagnosis of the stroke patients, laboratory investigations and imaging studies were requested to assist in the diagnosis and management of the patient.

3.1.3.2.3 Laboratory investigations and CT imaging of stroke patients

After the clinical diagnosis of all stroke patients, supporting laboratory tests were ordered by the ED physician. They included but not limited to full blood count, random blood glucose, serum lipid profile, liver function test, serum electrolytes/renal function test, cardiac enzymes and prothrombin time/international normalised ratio and activated partial thromboplastin time.

For machine assisted and confirmatory diagnosis of acute stroke, the ED physicians ordered for non-contrast CT imaging studies. Because TGH did not have a CT scanning machine, the patients had to be transported to CT scanning diagnostic facilities outside of hospital to have the scan conducted at a cost to the patient. When a cardiac abnormality was suspected an electrocardiogram (ECG) was ordered to aid diagnosis. In patients where seizures were suspected, electroencephalogram (EEG) was ordered. In instances where lung pathology/aspiration was suspected, chest radiography was ordered. In cases of suspected hypoxia, arterial blood gases were ordered. Treatment of the stroke patients were however initiated with or without the CT scan confirmatory diagnosis. This is further explored in a few paragraphs away.

3.1.3.2.4 Assessment and measurement of ED overcrowding using NEDOCS

The NEDOCS as discussed in the literature review (chapter 2, sections 2.7.1.2, 2.7.2, table 2.4 and figure 2.3) was used to assess the overcrowding status of the ED. The NEDOCS estimated the ED crowding status objectively following its demonstrable validity, simplistic usability, reliability, and reproducibility as cited in the literature review. The NEDOCS calculator was incorporated into the online electronic data collection platform that was developed for purposes of this current study. Site sampling data were obtained for numbers and times variables. The research assistants obtained numerical data on statutory licensed beds for the ED and the TGH. They also made counts of specific NEDOCS variables after which these numbers were entered into the NEDOCS calculator imbedded in the electronic data extraction tool for this current study.

To calculate the NEDOCS the following variables was collected and used:

1. Institutional Constants variable
    a. Number of ED beds
    b. Number of hospital beds
2. Common elements variables
    a. Number of patients in the ED
    b. Number of critically ill patients (on intranasal oxygen)
    c. ED admission time (Longest time for an admitted patient waiting in the ED since admission in hours)
3. Model specific variables
    a. Total admits at the ED,
    b. ED door to bed wait time (Waiting room time of the last patient put in bed in hours)

These 7 variables were manually documented and subsequently entered into the NEDOCS calculator online that had been incorporated into the electronic database management system. Once entered, an automatic NEDOCS was generated and assigned uniquely to a patient. The values and interpretation of the NEDOCS is presented in the Table 3.7 below.

Table 3.7 Interpretation of the NEDOCS score (adopted from Asplin et al., 2003)

NEDOCS	**Crowding status**
0-20	Not busy
21-60	Busy
61-100	Extremely busy but not overcrowded
101-140	Overcrowded
141-180	Severely overcrowded
181-200	Dangerously overcrowded

The counts were made 4 times during the day at a 4-hour interval (8:00 am, 12:00 pm, 4:00 pm and 8:00 pm) by the research assistants. Automatic NEDOCS scores were then generated for these times. The time after 8:00 pm to before 8:00 am were excluded because these periods were slow with historically low patient volume and reduced hospital activity in general, according to administrative records (Tema General Hospital, 2019). There is no ideal time frequency for measuring ED crowding using a multidimensional metric. A study by Wang et al (2017) concluded that measuring ED crowding status every 4 hours was reasonable as

insignificant variations were found to exist between measures conducted at 1-, 2-, 3- or 4-hours interval. In the original study that lead to the development of the NEDOCS, the 4-hour interval frequency was used (Asplin et al., 2003).

At every point during data collection, the calculated NEDOCS gave an indication of the crowding status of the ED. All stroke patients that arrived at the ED were assigned the nearest preceding calculated NEDOCS. For example, if a patient arrived at 8:00 am - 11:59 am, that patient was assigned the crowding score calculated at 8:00 am and if the patient arrived at/after 12:00 pm (i.e., 12:00 pm to 3:59 pm) he/she was assigned the score calculated at 12:00 pm. This was replicated throughout all the data collection points. This approach of overcrowding status allocation to patients at the arrival (as documented by the clinicians in the clinical records of the patient) at the ED was adapted from the study by Phillips et al. (2017) where the authors used three measuring tools: NEDOCS, CEDOCS and SONET to measure ED overcrowding and its association with patients' outcome in a medium to low volume ED.

3.1.3.3 Treatment of stroke patients

After the diagnosis of stroke, patients were admitted into a bed at the ED. The nurses at the ED implemented the necessary therapeutic and nursing interventions. The objective of stroke treatment was to slow down the impact of the vascular injury and limit post stroke disability. The physicians and nurses provided general supportive care and treatment of acute complications of the stroke patients. The treatment options were either pharmacological or non-pharmacological. These interventions included but not limited to airway, ventilation and supplemental oxygen support, patient positioning and suctioning, temperature control, cardiac monitoring, blood pressure control, nutrition and hydration support with intravenous fluids, blood glucose monitoring and control, management of patients with aspiration, treatment of infections and blood transfusions where applicable. In instances where the patients need could not be met by the professional, logistic, and interventional capacity of the ED, the patient was referred to a higher-level hospital for advanced and subsequent care.

3.1.3.4 Dataset

The patients' information/data that were recorded in their clinical record booklet by the clinicians when a stroke patients presented to the ED became secondary data that was assessed, reviewed, and extracted for this current study. The types of information/data are herein summarised.

At arrival, the patients' sociodemographic characteristics were documented at registration by the ED administrative clerk in the patients' medical record booklet. At triaging the nurses documented the triage score and the values of the triage variables in the patient medical record booklet. The physicians documented the medical history, clinical signs and symptoms including neurological finding, laboratory test order, imaging studies order, initial and final diagnosis, treatment order and disposition decisions in the patients' medical record booklet. All nursing care and administration of pharmacological and non-pharmacological interventions were documented by the nurses in the patients' medical record booklet.

The times when patients were attended to by the clinicians were documented in the patients' clinical record booklet. The order times for various laboratory test request, imaging studies, treatment orders among others were also documented in the patients' clinical record booklet. The times when laboratory test results and imaging results became available to the physicians for decision making were also documented by the physicians in the patients' medical record booklet. The times when nursing care and treatments were administered were also documented by the nurses in the patients' medical record booklet.

3.1.3.5 Sample size estimation

At the outset of the study, the number of stroke patients that constituted an adequate sample size was estimated. To have an idea of the prevalence of stroke at the ED of the TGH, summary data on stroke related mortalities at the ED between November 2018 and January 2019 were obtained from the ED clerk and hospital administration. The records, as detailed in Table 3.8 indicated that, for the three months period, stroke related deaths were 102 (n = 221) and it represented 46% of all deaths experienced at the ED. It is also important to note that the prevalence of the potential predictor variables was not known for the ED.

Table 3.8 Stroke related mortality from review of the medical certificate cause of death from the ED of Tema General Hospital

Month	Total Number of Deaths among admitted patients at the ED of TGH	Total number of stroke related deaths at the ED of TGH for the year
November 2018	84	33 (39.3%)
December 2018	60	32 (53.3%)
January 2019	77	37 (48.1%)
Total	221	102 (46.2%)

Receiving University of Salford biostatistician support, a rule of thumb was used for several predictor variables to estimate the sample size for low-prevalence predictors in the model. The most relevant reference found was a study by Ogindimu et al. (2016) which concluded that higher events per variable (EPV) was needed when low-prevalence predictors were present in a model to eliminate bias in regression coefficients and improve predictive accuracy (Ogundimu et al., 2016). The suggestion was that 20 EPV was required when there were low-prevalence predictors in the model. The estimated sample size for this current study was about 200 stroke deaths. Since the prevalence of the predictors was unknown, this approach for estimating the sample size was a safer (more conservative) option.

With 200 events (i.e., deaths) there were going to be many more non-events and so a large sample size overall would be obtained. Between six to nine months' duration was to allow for sufficient time to collect data of a sample size of about 200 deaths calculated for this current study and it should be enough for a regression analysis with several predictor variables. The predictors of focus included gender, age, having a functional national health insurance scheme, period between onset of symptoms and arrival at the ED, triage score, first BP measure upon arrival at the ED, clinical risk factors, GCS, laboratory findings, CT scan findings, door to imaging time, door to CT interpretation/results time, type of stroke, ED boarding, ED LOS, mRS, NEDOCS at arrival, and average NEDOCS during the entire stay of the patient, among others.

3.1.4 Data collection and innovations

To assess the patients' records, the necessary ethical approvals and administrative permissions were in place. The clinicians and administrative staff of the ED were also engaged prior to the initiation of data collection. No patient was directly engaged or interviewed as the information/data collected was secondary. In that regard no permission or informed consent was applicable. The already collected information/data by the clinicians in the patients' clinical records was extracted by the research team. Arrival time was obtained from the earliest registration time at the ED, the triage time which was handwritten. All other relevant data as described above in chapter 3 (section 3.1.3.4, 3.1.4.2 and 3.1.5) were extracted from the clinical record of the patient. None of the documented times by the clinicians were time stamped.

For effective and efficient data collection and management two innovations were initiated at the ED. The ED staff embraced this after they were oriented on the importance of the

innovation. These innovations were to enhance the quality of routine clinical information/data collected for the purpose of the study and for the benefit of the patient. They included an:

1. enhanced standardised paper-based data collection tool
2. electronic database management system with the inclusion of the NEDOCS calculator

These innovations did not entail collection of new types of data for research purposes: it was simply a standardization of the format of data that should already be collected as routine.

3.1.4.1 Enhanced standardised paper-based data collection tool

An enhanced standardised data paper-based data collection tool was used to extract clinical and treatment records of the stroke patients from the patients' clinical records. This was a structured and standardised paper form attached to the clinical record booklet of the patient. Immediately the diagnosis of acute stroke was made, the physicians affixed this form to the clinical record booklet of the patient. There were seven sheets included in the enhanced data extraction form. They included the triage score sheet, the medical risk factor sheet, GCS sheet, the motor function assessment sheet, mRS sheet, nurses blood pressure monitoring chart, treatment, and intervention sheet. These sheets had the various components that allowed the clinicians to enter their routine patient information/data as captured in the clinical record folder of the patients.

This was to standardise the information/data collected by the ED clinicians. During the pre-data collection stage, a pilot review of previously diagnosed stroke patients' records at the ED was conducted. It was obvious that, poor data quality was a challenge at the ED. This informed the decision to help structure and collect standardised patient information/data at the ED. Previous attempts to help improve the data quality at the ED according to the clinicians had not yielded the desired results and this innovation was welcomed by them. The staff volunteered to use the innovation form as part of their routine work. They confirmed that this activity did not in any way add an extra work burden to their routine work.

This structured data collection tool was designed to be a more efficient way for staff to record the information, without adding to the workload. Patient records were usually reviewed during periods of non-active use of the clinical records by the staff at the ED. This was to ensure that data extraction did not interfere with the routine clinical work of the staff at the ED. As this was a study that made use of routine data, no patient or patient relative was contacted by the

study team and no interviews or enrolments of patients were made during the period of data collection.

3.1.4.2 Electronic database management system

The second innovation for this current study was the development of an electronic database management system. This consisted of a clinical data collection component and the NEDOCS automatic calculation component. All the relevant patient's data that were duly extracted by the research team from the clinical records and the enhanced paper-based data collection tool were entered into the electronic database management tool. The various sections of the tool included:

A. Patients' identity (ID)
B. Patients' arrival information
C. Demographic characteristics of the patient
D. Patient triage information and NEDOCS
E. Initial clinical subjective findings after patient have been taken
F. Initial clinical objective findings after patient have been examined
G. Stroke diagnosis
H. CT scan breakout
I. Laboratory and X-ray request details
J. Laboratory and X-ray results
K. Therapy intervention
L. Blood pressure control chart within 24 hours of admission at the ED
M. Final CT scan diagnosis at discharge based on ICD – 10
N. Disability levels using the modified Rankin scale
O. ED and hospital LOS
P. Decision at disposition of patient
Q. NEDOCS variables

The ED at the outset of the study did not have any form of electronic patient information/data collection system. Imbedded in this innovative electronic tool were the variables needed to automatically calculate the NEDOCS. Once these variables collected by the research team were entered into the NEDOCS component of the electronic database management system, an automatic NEDOCS was generated. Each stroke patient had his or her own unique information page in the electronic database. This meant that the NEDOCS score automatically calculated

with machine learning assistance was automatically assigned uniquely to each stroke patient at arrival and during the stay of the patient at the ED. When the NEDOCS calculated indicate overcrowding (greater than 100), the managers and the ED staff were alerted to take the necessary action to decongest the ED and make space available to new patients. This also prompted the managers and clinicians in the hospital to as a matter of urgency address access block challenges to free up space and resources for the management of patients. This innovation was helpful to an extent in finding some form of solution to boarding and access block in the hospital.

This electronic tool developed had online and desktop versions and it was web and mobile friendly. The computer program scripts were written using PHP coding system. 'SQLite' was used as the data formats and all the tables and queries were kept in a single file that made it easily downloadable and transferable. A username and password were required to log in to the tool. It was secured using passwords, encryptions, and had different administrative clearance levels before assessing by the research team. The passwords had alphanumeric characters and symbols totalling eight in all. Each research assistant had their own uniquely assigned password which was constantly changed and updated by the principal investigator.

The data collected were stored online and the backend was only assessable to the principal investigator and Dr Martin Beattie who was instrumental in the design and hosting of the electronic databased tool. He had no role in the data handling. His role was to ensure that the tool was available and readily assessable online. He also conducted trouble shooting exercises and run queries anytime an internet or information technology technical challenge was encountered. He did this successfully and voluntarily without any charge or fee. According to him this was his personal and professional contribution to help improve data management and quality of care of stroke patients in a LMIC. The processes and experience in developing the electronic database management system is presented in the appendices.

3.1.5 Description of the variables

Using the electronic database management tool, the individual variables and drop-down responses are herein presented.

A. Patients' identity (ID)
   A. Data collection date (DD MM YYYY)
   B. Data collection time (HH: MM: SS)
   C. Clinical record number
   D. Serial number (automatically generated by the computer)
   E. Code generated for the patient automatically for anonymisation
   F. First name
   G. Family name
B. Patients' arrival information
   1. Door date (DD MM YYYY)
   2. Door time (HH: MM: SS)
   3. Triage date (DD MM YYYY)
   4. Triage time (HH: MM: SS)
   5. First clinician date (DD MM YYYY)
   6. First clinical time (HH: MM: SS)
   7. Arrival status
      a. Referral
      b. Walk in
      c. In patient transfer
      d. Other
   8. Any comment on arrival status
   9. Mode of arrival
      a. Ambulance
      b. Private car
      c. Taxi
      d. Uber
      e. Motorcycle
      f. Walk in
      g. Other
   10. Comment on mode of arrival if any
C. Demographic characteristics of the patient
   1. Date of birth (DOB)
   2. Age (automatically calculated by the computer ones the DOB is entered)
   3. Sex
      a. Male
      b. Female
   4. Marital status
      a. Single
      b. Married
      c. Divorced
      d. Widowed
      e. Separated
      f. Other
   5. Religion

a. Catholic
b. Anglican/Methodist/Presbyterian (orthodox churches in Ghana)
c. Pentecostal/Charismatic
d. Muslim
e. Traditional/Spiritualist
f. No religion
g. Other

6. Occupation
    a. Formal
    b. Informal
    c. Retired (> 60 years as cut off for retirement in Ghana)
    d. Student
    e. Self employed
    f. Unemployed
    g. Other
7. Residence
    a. Within Tema metropolis (where Tema General Hospital is situated)
    b. Outside Tema metropolis
8. Neighbourhood
    a. Urban
    b. Rural
    c. Peri-urban
9. National Health Insurance Status (NHIS needed to financially access health care
    a. Active (meaning health care could be accessed)
    b. Not active (meaning renewal of activeness has not been completed and hence cannot access health care financially, payment must be made out of pocket
    c. Not enrolled (meaning not a member of the National Health Insurance Scheme)
10. Education
    a. No education
    b. Primary
    c. Middle/ Junior high school
    d. Secondary/Senior high school
    e. Tertiary
    f. Technical/Vocational
    g. Other

D. Patient triage information and NEDOCS
1. Triage Date (MM DD YYYY)
2. Triage time (HH: MM: SS)
3. Triage score (0, 1, 2, 3, 4, 5, 6, 7 or more, dead)
4. Systolic blood pressure (mmHg)
5. Diastolic blood pressure (mmHg)
6. Heart rate/pulse rate (beats/mins)
7. Respiratory rate (cycles/min)
8. Temperature (Degree Celsius)
9. SPO2 (the oxygen saturation of the patient (expressed as % (from 0-100))
10. NEDOCS
11. NEDOCS reference as entered earlier (this featured linked the NEDOCS to the patient during the period the patient stayed at the ED and hence allowed for ease of calculating the specific average NEDOCS for the entire duration of the patient at the ED.

E. Initial clinical subjective findings after patient have been taken

a. Onset
    a. Date of onset of symptoms (DD MM YYYY)
    b. Time of onset of symptoms (HH: MM: SS)
    c. Date of first visit to the ED (DD MM YYYY)
    d. Time of first visit to the ED (HH: MM: SS)
b. Risk factors (all that applied is ticked in the tick box displayed (yes/no):
    a. Hypertension
    b. Diabetes Mellitus
    c. Overweight and Obesity
    d. Lack of physical activity
    e. Stress and depression
    f. Unhealthy diet
    g. Alcohol
    h. Illegal drug use, including cocaine, amphetamines, and other drugs
    i. Use of nonsteroidal anti-inflammatory drugs (NSAIDs) but not aspirin
    j. Cigarette Smoking
    k. Plasma Lipid Abnormalities
    l. Heart and Peripheral Vascular Disease
    m. Previous history of Stroke
    n. Previous Transient Ischaemic Attack
    o. Family history of stroke
    p. Sickle Cell Disease
    q. Atherosclerosis
    r. Atrial Fibrillation
    s. Other(s)

F. Initial clinical objective findings after patient have been examined
a. Initial findings by ED doctor
    a. Systolic blood pressure (mmHg)
    b. Diastolic blood pressure (mmHg)
    c. Power in limbs
        i. Right upper limb (0-5)
        ii. Right lower limb (0-5)
        iii. Left upper limb (0-5)
        iv. Left lower limb (0-5)
    d. Other clinical presentations
        i. Facial palsy (yes/no)
        ii. Alteration of speech (yes/no)
        iii. Difficulty in swallowing (yes/no)
        iv. Seizures (yes/no)
        v. Signs of increased intracranial pressure (yes/no)
        vi. Aspiration (yes/no)
        vii. Urine incontinence (yes/no)
        viii. Stool incontinence (yes/no)
b. Glasgow coma score at first clinical assessment (score of 3-15)
    a. Eye response (score of 1-4)
        i. No spontaneous eye movement (score = 1)
        ii. Eye opening to pain stimulus (score = 2)
        iii. Eye opening to speech (score = 3)
        iv. Spontaneous eye opening (score = 4)
    b. Verbal response (score of 1-5)

i. No verbal response (score = 1)
ii. Incomprehensible sounds (score = 2)
iii. Inappropriate words (score = 3)
iv. Confused (score = 4)
v. Oriented (score = 5)

c. Motor response (score of 1-6)
i. No motor response (score = 1)
ii. Abnormal extension to pain (score = 2)
iii. Abnormal flexion to pain (score = 3)
iv. Normal flexion from pain (score = 4)
v. Localise to pain (score = 5)
vi. Obeys command (score = 6)

d. Glasgow Coma Score (3-15)

G. Stroke diagnosis
a. Haemorrhagic stroke (clinical)
b. Haemorrhagic stroke (CT scan)
c. Ischaemic stroke (clinical)
d. Ischaemic stroke (CT scan)
e. Query stroke (non-specific stroke)

H. CT scan breakout
1. CT scan request made (yes/no)
2. CT scan request date (DD MM YYYY)
3. CT scan request time (HH: MM: SS)
4. Arrival date (DD MM YYYY)
5. Arrival time (HH: MM: SS)
6. Door to CT scan request (automatically calculated)
7. CT scan departure from ED date (DD MM YYYY)
8. CT scan departure time (HH: MM: SS)
9. CT return date (DD MM YYYY)
10. CT return time (HH: MM: SS)
11. CT scan results available date (DD MM YYYY)
12. CT scan results available time (HH: MM: SS)
13. Door to CT scan results (automatically calculated)
14. CT scan conducted at hospital disposition/discharge (yes/no)
15. Mode of transport for CT scan
a. Ambulance
b. Taxi
c. Private car
d. Uber
e. Other

I. Laboratory and X-ray request details
1. Order or results date (DD MM YYYY)
2. Order or results time (HH: MM: SS)
3. Test
a. Full blood count
b. Lipid profile
c. Clotting profile
d. Renal function test
e. Liver function test
f. Blood glucose

g. Electrocardiogram
h. Chest x-ray

J. Laboratory and X-ray results
    1. Full blood count
        a. Haemoglobin (Hb in g/dl)
        b. White blood cell count (WBC in 10 ^ 9 L)
        c. Platelet (Plt in 10 ^ 9 L)
    2. Lipid profile
        a. High density lipoprotein (HDL in mmol/L)
        b. Low density lipoprotein (LDL in mmol/L)
        c. Very low-density lipoprotein (VLDL in mmol/L)
        d. Total cholesterol (TChol in mmol/L)
    3. Clotting profile
        a. International Normalised Ration (INR) which makes use of prothrombin time (PT) that is the time it takes for blood to clot
    4. Renal function
        a. Sodium (Na as mmol/L)
        b. Potassium (K as mmol/L)
        c. Blood urea (in mmol/L)
        d. Blood creatinine (in mmol/L)
        e. Estimated glomerular filtration rate (eGFR in mL/min/1.73 m^2)
    5. Liver function
        a. Alanine Aminotransferase (ALT in U/L)
        b. Alkaline Phosphatase (ALP in U/L)
        c. Gamma-glutamyl Transferase (GGT in U/L)
        d. Albumin (in U/L)
    6. Random or fasting blood glucose (RBS/FBS in mmol/L)
    7. Electrocardiograph (ECG) findings
    8. Chest X ray (CXR) findings.
    9. Comments

K. Therapy intervention
    1. Intervention administration date (DD MM YYYY)
    2. Intervention administration time (HH: MM: SS)
    3. Reference Arrival time and date (automatically populated) as it has been captured in the e-DET earlier
    4. Interventions
        a. Intranasal oxygen (requested (yes/no): administered (yes/no))
        b. Intravenous fluids (requested (yes/no): administered (yes/no))
        c. Antiplatelet (mostly aspirin per protocol) (requested (yes/no): administered (yes/no))
        d. Thrombolysis rTPA are not administered at the ED) (requested (yes/no): administered (yes/no))
        e. Antilipids (atorvastatin per protocol) (requested (yes/no): administered (yes/no))
        f. Antipyretic (paracetamol per protocol) (requested (yes/no): administered (yes/no))
        g. Piracetam (requested (yes/no): administered (yes/no))
        h. Mannitol (osmotic diuretic) (requested (yes/no): administered (yes/no))
        i. Blood glucose control plan (requested (yes/no): administered (yes/no))
        j. Other medications specify (requested (yes/no): administered (yes/no))

k. Blood pressure monitoring chart (requested (yes/no): administered (yes/no))
l. Regular suctioning to prevent aspiration (requested (yes/no): administered (yes/no))
m. Nasogastric tube insertion (to decongest the stomach and prevent aspiration) (requested (yes/no): administered (yes/no))
n. Urethral catheter passage (requested (yes/no): administered (yes/no))
o. Cardiac monitor set up (requested (yes/no): administered (yes/no))
p. Diaper wearing (requested (yes/no): administered (yes/no))
q. Turn patients every two hours to prevent bed sores acquisition (requested (yes/no): administered (yes/no))

L. Blood pressure control chart within 24 hours of admission at the ED
1. Arrival date (DD MM YYYY)
2. Arrival time (HH: MM: SS)
3. Hour from arrival (0 – 24 hours)
4. Date/ time of systolic blood pressure measured (DD MM YYYY and HH: MM: SS)
5. Date/time of diastolic blood pressure measured (DD MM YYYY and HH: MM: SS)
6. Date/ time of antihypertensive administered (DD MM YYYY and HH: MM: SS)
7. Date/ time of intravenous fluids administered (DD MM YYYY and HH: MM: SS)
8. Date/ time of antiplatelet administered (DD MM YYYY and HH: MM: SS)
9. Date/ time of Antilipids administered) (DD MM YYYY and HH: MM: SS)
10. Other comments

M. Final CT scan diagnosis at discharge based on ICD – 10

161.0-	Non traumatic intracerebral haemorrhage in hemisphere, subcortical
161.1 -	Non traumatic intracerebral haemorrhage in hemisphere, cortical
161.2 -	Non traumatic intracerebral haemorrhage in hemisphere, unspecified
161.3 -	Non traumatic intracerebral haemorrhage in hemisphere, brainstem
161.4 -	Non traumatic intracerebral haemorrhage in hemisphere, cerebellum
161.5 -	Non traumatic intracerebral haemorrhage in hemisphere, intraventricular
161.6 -	Non traumatic intracerebral haemorrhage in hemisphere, multiple localised
161.8 -	Other non-traumatic intracerebral haemorrhage
161.9 -	Non traumatic intracerebral haemorrhage unspecified
163.50 -	Cerebral infarction due to unspecified occlusion or stenosis of unspecified cerebral artery
163.519 -	Cerebral infarction due to unspecified occlusion or stenosis of unspecified middle cerebral artery
163.529 -	Cerebral infarction due to unspecified occlusion or stenosis of unspecified anterior cerebral artery
163.549 -	Cerebral infarction due to unspecified occlusion or stenosis of unspecified cerebellar artery
163.549 -	Cerebral infarction due to unspecified occlusion or stenosis of unspecified another cerebral artery
163.9 -	Cerebral infarction, unspecified
G45.9 -	Transient cerebral ischaemic attack, unspecified

N. Disability levels using the modified Rankin scale (0 -6)
O. ED and hospital LOS
1. Arrival data (DD MM YYYY)

2. Arrival time (HH: MM: SS)
3. Admit order date (DD MM YYYY)
4. Admit order time (HH: MM: SS)
5. ED departure date (DD MM YYYY)
6. ED departure time (HH: MM: SS)
7. Admit order to ED departure time (automatically calculated)
8. ED LOS (automatically calculated)
9. Hospital departure data (DD MM YYYY)
10. Hospital departure time (HH: MM: SS)
11. Hospital LOS (automatically calculated)

P. Decision at disposition of patient
    a. Disposition decision
        a. Discharged
        b. Transfer to an inpatient bed
        c. Referral to another facility
        d. Alive
        e. Dead
    b. Disposition comments
    c. Summary comments

Q. NEDOCS variables (0 – 200)

3.1.6 Data or variables limitation

This current study set out to answer a set of research questions that bothers on the crowding status of the ED, stroke specific case fatality, stroke specific mortality by stroke subtype, association between CT scan use and stroke mortality, association between admission BP levels and mortality and predictors of stroke specific mortality. The two innovations described in chapter 3 (sections 3.1.4.1 and 3.1.4.2) helped to structure, standardise, and improve the quality of data. However, there were some data limitations that was further explored in the results and discussion section of this current study.

One key issue was the inadequate and missing data on patients' blood pressure monitoring values. The frequency of administration of blood pressure controlling medications and other therapeutics was a data challenge. Records of patient medical history was also not readily available, and reliance was solely on verbal information provided by the patient or the patient relation. This posed a challenge as a more scientific verification of the information would have improved the quality of the data.

The time variables were not verifiable, not time stamped and were not always documented by the clinicians. This made clinical assessment times, laboratory order and treatment order mostly unavailable for extraction. Also, the CT scanning time breakouts including the time of order,

time of initiation, time of completion and time of interpretation or availability of CT scanning results to the physician were not readily documented in charts. Attempts to get this information captured by the relevant clinician handlers of the patients was unsuccessful. In some instance the patients clinical record booklet got missing and this posed a great deal of challenge where extra efforts were made to look for and retrieve these records. It was obvious that data quality was a difficult challenge at the ED of the TGH.

3.1.7 Data analysis

The electronic patient database was downloaded into Microsoft Excel (2010) from the website hosting the data online and all the necessary cleaning was conducted. The patient identity (ID) on the paper version of the enhanced information/data extraction tool was the same ID that was entered into the electronic database system. The electronic tool had algorithms that ensured for example that numerical variables remained same and tries to enter alphanumeric or alphabets were rejected automatically and had to be corrected before once could continue data entry. This was an internal mechanism which ensured the entry of the required type of data. When data was missing, the clinical record of the patient was retrieved, and information searched, reviewed, and relooked. In instances where the information was not available the ED clinicians were engaged to help supply the data if they were privy to. However, if the clinicians and the administrative clerks were not privy the information was treated as missing during the analysis. Also, in instances where some of the figures appeared as outliers, further checks from the patient clinical record and engagement with the ED staff ensured clarification and validation. If it was instated that the information supplied was accurate and a true reflection, they were included in the data set for analysis and further statistical methods were used to manage them as outliers.

After data cleaning in excel, the data was exported from excel into SPSS package software analysis program where data coding, transformation and data analysis was conducted. For example, males were coded as 1 and females as 0. This allowed for the variable to be transformed into numerical variable for the purposes of analysis. Their true meaning was not lost during the analysis. All the variables were labelled as either nominal, ordinal, interval, and ratio type variables. Shapiro-Wilk test was performed for the normality analysis of the data set.

The results were presented and displayed in words, figures, tables, graphs, and charts where applicable. The analysis was conducted in stages. Firstly, a descriptive analysis was conducted

and secondly analytical analysis which were evaluated at the 95% confidence interval (CI) and a p-value of <0.05 was considered significant. In presentation, categorical data was expressed as numbers (n) and percentage (%). Continuous variables were displayed as mean ± standard deviation (SD) for normally distributed data, whiles median and interquartile range were used for abnormally distributed and non-parametric data The student T-test was applied to compare the means of normally distributed data whereas the Mann-Whitney U test was used for the comparison of means of abnormally distributed data between groups.

To establish the association between categorical variables, the Chi square or Fisher's exact test was performed where the Phi Chi square gave sign of the strength of the association. Correlation analysis for continuous variables was performed using Pearson's correlation analysis while Point Biserial correlation analysis was used where the dependent variable was categorical, and the independent variable was continuous. Spearman's correlation analysis was performed where the independent variable was ordinal and ranked. Binary logistic regression analysis was conducted with the dependent variable as mortality outcome. Tables and graphs were used to display the analysis where applicable either descriptive or analytical. Survival analysis was not conducted because the study was conducted out within a shorter period of 6 months and mortality outcomes occurred at a shorter time after admission at the ED. This followed advice provided by biostatistics support from the University of Salford. It is preferred to conduct a survival analysis if patients are followed for about 2 - 5 years.

Binary logistic regression analysis was performed to predict the probability of death from stroke. There were 8 independent predictor variables (5 were categorical and 3 were continuous) included in the model. The categorical groups were mutually exclusive and exhaustive as dependent variables. It was assumed that the independent variables needed not be interval, nor normally distributed, nor have a linearly relationship, nor the error terms (residuals) normally distributed nor of equal variance within the groups. To avoid creating an overfit model, adequate number of observations for each independent variable in the dataset was assured. It has been recommended that a minimum of 30 observations per independent variable can be applied for such a study for low prevalence predictor models.

The predictor variables were average NEDOCS assigned each stroke patient whiles on admission at the ED, type of stroke suffered, systolic BP at presentation, having a CT scan done to confirm diagnosis. These four variables were selected from the priori aims of the study. The other four variables based on the literature review were past medical history of hypertension,

diabetes mellitus, age, and gender. The outcome variable of interest was stroke mortality at the ED. The categorical groups were mutually exclusive and exhaustive as dependent variables. The influence of outlier data points which had the potential to distort the outcome and the accuracy of the logistic model was checked using the Mahalanobis distance where a distance < 0.00 excluded a data point from the final analysis. The cases selected and included in the analysis were 172 with no missing cases and three cases excluded because they were influential outliers. The dependent and outcome variable of interest was classified dead as 1 and alive as 0 during encoding.

An omnibus test of the full model versus the null model with intercept only was statistically significant, χ^2 (8, N = 172) = 121.767; p = 0.047 (p > 0.05). The Hosmer and Lemeshow test indicated a good fit and that the model adequately fitted the data and there was no difference between the observed and the predicted model as they were almost equal χ^2 (8, N = 172) = 8.871; p = 0.353 (p > 0.05) The Nagelkerke's R^2 which is a pseudo-R-squared, and an adjusted Cox and Snell R-square approximates variation in the criterion variable. It indicated that 13.8% change in the criterion variable could be accounted to the predictor variables in the model. The model was able correctly to classify 99.3% of stroke patients who died showing good sensitivity and an overall percentage accuracy in classification (PAC) which was good at 80.2%.

3.2 Corona Virus Disease 2019 (COVID-19) and its impact on the study

In late December 2019, the world was hit with a global pandemic, Corona Virus Disease 2019 (COVID-19). The implications of this highly infectious disease affected data collection at the ED of TGH. Ghana recorded its first two cases on of COVID-19 on 12 March 2020. Subsequently all Ghanaian borders (air, land, and sea) were closed to international travel and trade on 29 March 2020. TGH was one of the two designated treatment centres for COVID-19 in Ghana at the outset of the COVID-19 response. The other was the Greater Accra Regional Hospital also known as Ridge Hospital. This meant that confirmed cases of COVID-19 were referred to and managed at the treatment centre found at the TGH.

During that time, the ED was partially closed to emergencies, and the regular ED staff was made to stay home for a period, including all research assistants. This life saving directives and prompt intervention from the management of the hospital had the tacit approval of the Ghana

Health Service, the Ghana National Service Secretariat, the Ghana Medical Association and the Ghana Nurses and Midwifery Council among other relevant regulatory bodies. This was aimed at protecting hospital staff and preventing health care worker infection while responding to the COVID-19 cases in Ghana.

The number of stroke patients whose data had been extracted before these changes occurred was found to be sufficient for statistical analysis for a PhD program following discussions with my supervisors at the University of Salford during our monthly supervision meetings. Again, with the uncertainty surrounding the return of routine hospital operations, especially at the ED, the data collection was closed prematurely, and the data analysed with a smaller than hoped for sample. Because of the skills I had acquired as a PhD student, my expertise was needed elsewhere, to help deal with the COVID-19 response in Ghana. The University of Salford as all human related research data collection to be halted until further directives were given. The Ghana Health Service also instructed for all human related data collection studies to be halted till further notice. Consequently, I took an interruption from my study at the University of Salford. My job changed as I was assigned to the National Public Health Emergency Operation Center at the Ghana Health Service, and it became very highly pressured. I was pulled out of the TGH, meaning I was no longer able to observe the current practice in the hospital and continue to embed my innovations. I have since been given permanent role of coordinating Port Health at all the points of entry in Ghana.

3.3 Ethics and ethical considerations for this study

By way of the study design, study population and ethics approval:

1. No patient was recruited or enrolled into the study
2. The data comprised routinely collected clinical records of stroke patients
3. Patient record was anonymised
4. Ethics approval (with reference number HSR 1819-097) was received from the School Research Ethics Panel of the University of Salford.
5. Ethics approval was also granted by the Ghana Health Service Ethics Review Committee (GHS-ERC Number: GHS-ERC 012/08/19)
6. Permission to enter the study area and permission to conduct the research was granted by the Tema General Hospital
7. These approval letters are presented in the appendices

3.4 Ethical framework adopted for this study

1. The Declaration of Helsinki which was developed by the World Medical Association as a statement for ethical principles for medical research involving human subject (World Medical Association, 2001) was used. The declaration encapsulates the following principles:
    a. General principles of human studies
    b. Risk, burden, and benefits to humans
    c. Vulnerable groups and individuals being studied
    d. Scientific requirements and research protocol to be fulfilled
    e. Research ethics committee approval
    f. Privacy and confidentiality guaranteed to the human subjects
2. Research governance framework for health and social care of the University of Salford
3. Ghana Health Service Ethics Review Committee protocols and guideline

I adopted, ensured, and adhered to the recommendations from The Health Research Ethical Approval Panel (Guidance Notes for Completing the School Research Ethical Approval Application Form accessed on 20/02/19). The following protocols were adhered to:

1. The original clinical routine records with the biodata of the stroke patients remained exclusively in the hospital.
2. During extraction of demographic and clinical data of the stroke patients their names and dates of birth were excluded. Individuals were given a unique code.
3. An excel primary sheet with the research code and the participant's name was created and this stayed with the hospital administration in case records needed to be relinked to verify information.
4. Other biodata was coded and anonymised by the research assistants before they were delivered to me for the purposes of the study.
5. I received the extracted data that was codified and did not have the identity of the stroke patients to whom the data corresponded. This was to ensure privacy, confidentiality, and anonymity.
6. The electronic patient flow data that were managed by the ED clerk as part of routine daily work had a password to the information and the computer also had a

secured password. This double security verification password was known to the ED clerk and the head of the department.

7. Data that was downloaded from the online website hosting the electronic data extraction tool were personally stored by me during the study.
8. The data set were encrypted end to end on a password-protected computer, password protected F drive and my university OneDrive, which was only accessible to me and the supervisory team/statistician once I granted permission.
9. Currently I am the only one with access to the website that stores the data from the electronic data collection tool that was developed as part of this current study. The developer only accesses the site based on the direction I provide, especially when I need clarity on some aspects of the tool.
10. All protocols of data protection were adhered to, and all ethical protocols and procedures of scientific research were strictly followed.
11. I ensured that stroke patients at the ED at the time of the study did not have their medical care altered for any reason. I did this by regularly engaging and encouraging the ED staff to do their routine work without any discrimination, exceptional favour or consideration as determined by the code of ethics and work discipline of the Ghana Health Service.
12. The modified clinical recording forms were piloted during non-busy times to ensure that they do not add to the burden of the doctors and nurses. Indeed, by structuring the information and use of tick boxes, it was expected that the routine data would be collected more efficiently. The piloting was conducted in the third and fourth week of September 2019.

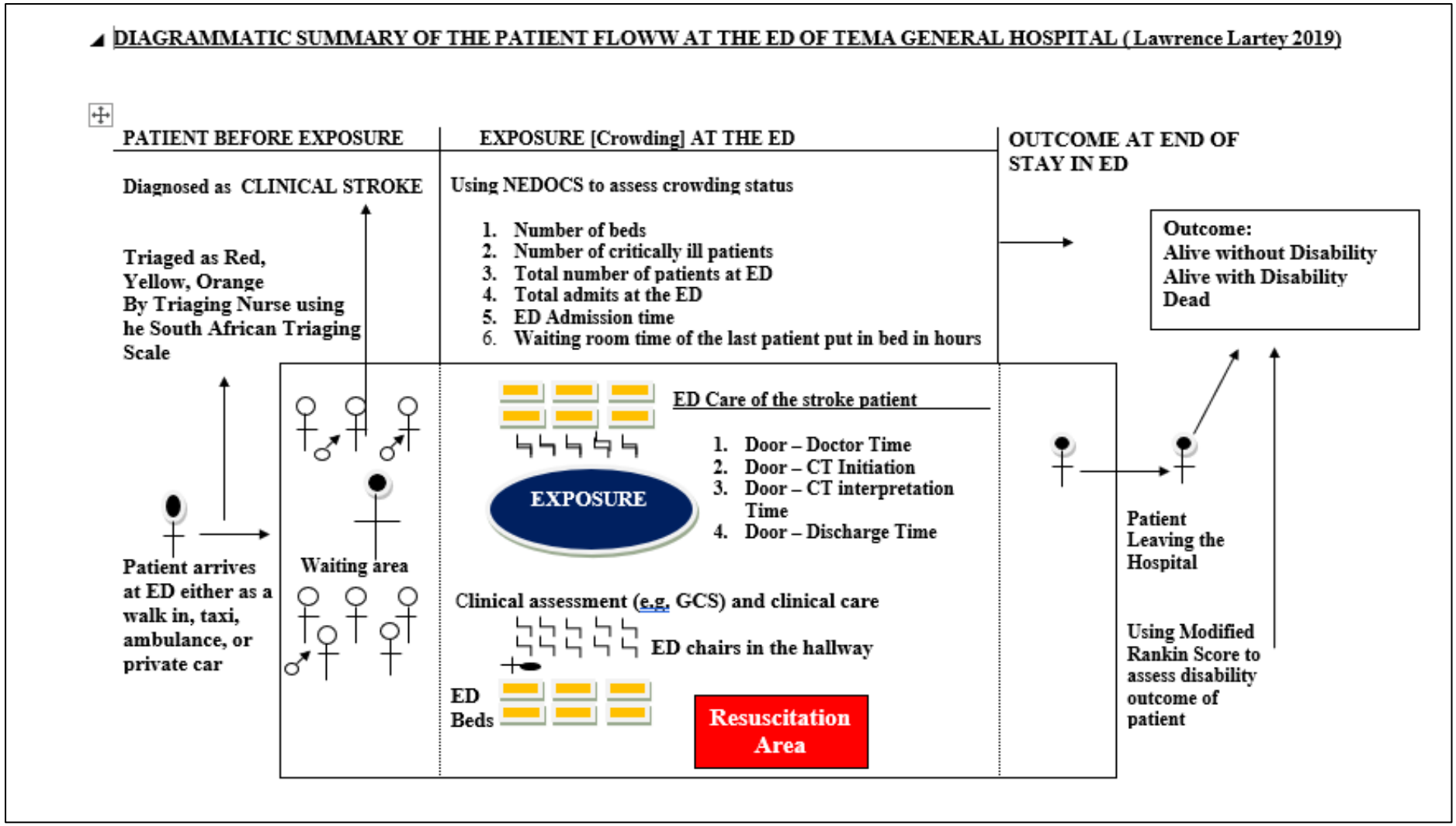


Figure 3.4 Journey of patient flow from arrival to discharge at the ED of Tema General Hospital

Chapter 4 RESULTS

The results analysed the relationship between emergency department variables that potentially affected clinical outcomes of patients and this is presented in this chapter. The presentation focuses on the descriptive statistics, univariate, bivariate and multivariate analysis.

4.1 Summary description of the sociodemographic, clinical presentation and other characteristic features of all the stroke patients that visited the emergency department

The next few paragraphs present findings and analysis on the sociodemographic characteristics, clinical presentation, and other relevant features of the stroke patients.

4.1.1 Age and gender distribution of stroke patients

There was a total of 175 stroke patients that visited the ED during the period of 14 October 2019 and 16 March 2020. Of these, 89 (50.9%) were males and 86 (49.1%) were females. The mean age of all the patients was 59.9 ± 13.9 years. The ages of the 86 females ranged from 15 – 110 years with a mean age of 61.5 ± 15.1 years. The mean age of the 89 males was 58.4 ± 12.6 years and it ranged from 16 – 92 years. The modal age group for the females was 55 – 59 years compared to 60 - 64 years for the males. There were 8 (1 male and 7 females) stroke patients who were above the age of 85 years. The oldest stroke patient was a 110-year-old female followed by 96 years also a female. The youngest stroke patient was a 15-year-old female followed by a 16-year-old male. The highest number of stroke patients for any single day was 5, which was recorded on the 18 October 2019. The various age groups and their gender is presented in the pyramid Figure 4.1 below.

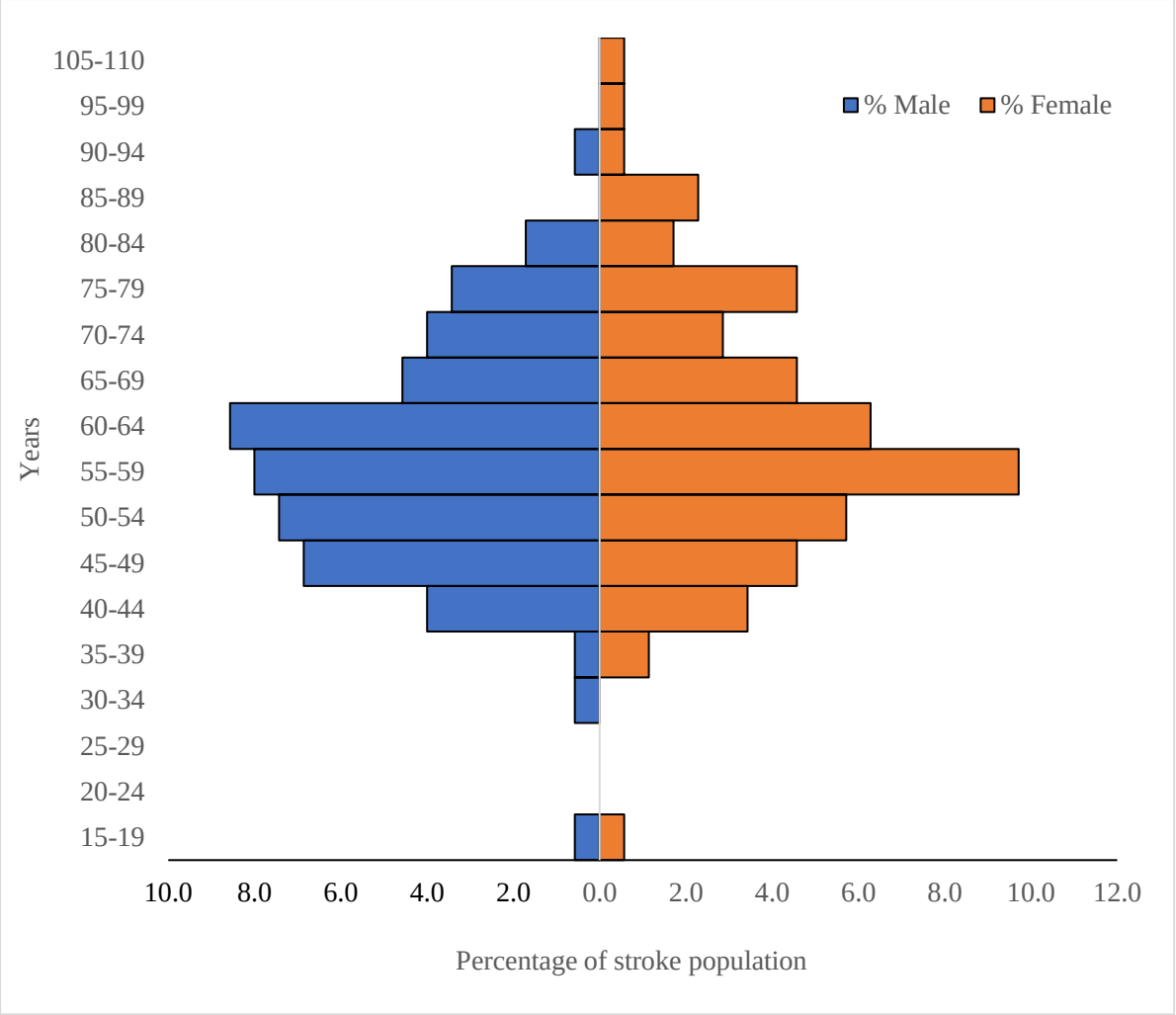


Figure 4.1 Population pyramid of the 175 stroke patients who visited the emergency department of the Tema General Hospital

There were 100 (57.9%) of the patients that had an active National Health Insurance status, 113 (64.6%) married, 83 (47.4%) had some form of employment, 158 (90.3%) of them lived in urban areas and 94 (53.7%) lived within the Tema metropolis where TGH is situated. The farthest patients came from distant location of about 2 hours' drive to the hospital. The sociodemographic characteristics distributed by gender is presented in the Table 4.1 below.

Table 4.1 Sociodemographic characteristics of the 175 stroke patients

		Male	Female
Sociodemographic characteristics	**n (%)**	**n (%)**	**n (%)**
Age	175	89	86
Mean ± SD (years)	59.9 ± 13.9	58.4 ± 12.6	61.5 ± 15.1
Sex			
Male	89 (50.9)		
Female	86 (49.1)		
Marital Status			
Married	113 (64.6)	66 (74.2)	47 (54.7)
Widowed	27 (15.4)	5 (5.6)	22 (25.6)
Single	24 (13.7)	16 (18.0)	8 (9.3)
Divorced	11 (6.3)	2 (2.2)	9 (10.5)
Religion			
Other Christian	91 (52.0)	52 (58.4)	39 (45.3)
Anglican/Methodist/Presbyterian	39 (22.3)	19 (21.3)	20 (23.3)
Pentecostal/Charismatic	29 (16.6)	11 (12.4)	18 (20.9)
Moslim	13 (7.4)	6 (6.7)	7 (8.1)
Catholic	2 (1.1)	1 (1.1)	1 (1.2)
No Religion	1 (0.6)	0 (0.0)	1 (1.2)
Employment Status			
Self employed	56 (32.0)	27 (30.3)	29 (33.7)
Unemployed	52 (29.7)	18 (20.2)	34 (39.5)
Retired	35 (20.0)	16 (18.0)	19 (22.1)
Informal	14 (8.0)	13 (14.6)	1 (1.2)
Formal	13 (7.4)	11 (12.4)	2 (2.3)
Student	3 (1.7)	2 (2.2)	1 (1.2)
Other	2 (1.1)	2 (2.2)	0 (0.0)
Residence			
Within Tema Metropolis	94 (53.7)	51 (57.3)	43 (50.0)
Outside Tema Metropolis	81 (46.3)	38 (42.7)	43 (50.0)
Neighbourhood			
Urban	158 (90.3)	78 (87.6)	80 (93.0)
Peri-urban	15 (8.6)	10 (11.2)	5 (5.8)
Rural	2 (1.1)	1 (1.1)	1 (1.2)
National Health Insurance Status			
Active	100 (57.1)	48 (53.9)	52 (60.5)
Not Active	75 (42.9)	41 (46.1)	34 (39.5)

4.1.2 Triaging of stroke patients at the emergency department

The median (IQR) triage score was 6 (5-7) and the triage scores distribution by gender is highlighted in the Table 4.2 below. The were 79 (45.1%) and 61 (34.9%) patients triaged coded as emergent and very urgent, respectively. The worst proportion of triage scores 7 or more was recorded among males (47.2% vs 43.25) compared to females.

Table 4.2 Triage scores distributed according to gender of the stroke patients

SAT score	Colour Code	Target time	Male (%)	Female (%)	Total (%)
0-2 routine)	Green	< 4 hours	0 (0.0)	1 (1.2)	1 (0.6)
3-4 (urgent)	Yellow	< 1 hour	18 (20.2)	16 (18.6)	34 (19.4)
5-6 (very urgent)	Orange	< 10 mins	29 (32.6)	32 (37.2)	61 (34.9)
7 or more (emergent)	Red	Immediate	42 (47.2)	37 (43.0)	79 (45.1)
Total (%)			89 (100%)	86 (100.0)	175 (100.0)

There were 13 (41.9%), 14 (45.2%) and 4 (12.9%) of the 31 stroke patients in the modal age group (55 – 59 years) that were triaged as emergent, very urgent, and urgent, respectively. A graphical representation of the various age groups and their assigned triaged score and colour code is displayed in the Figure 4.2 below.

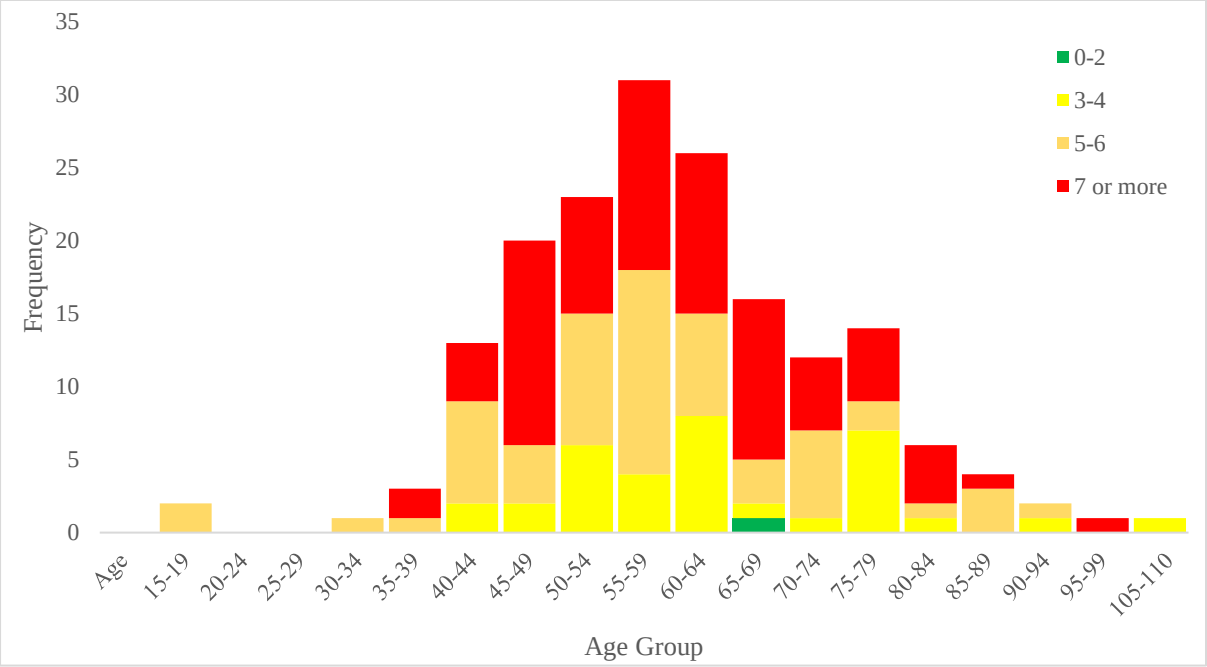


Figure 4.2 Triage scores distribution according to the various age groups of the stroke patients

4.1.3 Blood pressure measurement of stroke patients at presentation (triage)

Among the 175 stroke patients, 39 (22.3%) presented with normal systolic blood pressure (SBP < 120 mmHg), 70 (40.0%) with hypertensive crisis (SBP ≥ 180 mmHg) and the remaining 66 (37.7%) reported with Stage 1 or II hypertension as displayed in Table 4.3 below. A higher proportion of males presented with abnormal values of SBP, 72 (80.9%) compared to females 64 (74.1%). Patients with haemorrhagic stroke presented with higher proportion of abnormal SBP, 70 (98.6%) compared with ischaemic strokes 66 (63.5%). A higher proportion of patients who experienced deaths had higher SBP at triage, 109 (78.4%) compared to stroke patients who survived 27 (75.0%).

Table 4.3 Classification of patients BP statuses at presentation by gender, type of stroke and mortality outcome

BP status at triage	BP (mmHg)	Male (%)	Female (%)	HS (%)	IS (%)	Dead (%)	Alive (%)
Normal BP	< 120	17 (19.1)	22 (25.6)	1 (1.4)	38 (36.5)	30 (21.6)	9 (25.0)
Elevated BP	120 – 129	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Hypertension stage I	130 – 139	3 (3.4)	5 (5.8)	0 (0.0)	8 (7.7)	7 (5.0)	1 (2.8)
Hypertension stage II	140 – 179	30 (33.7)	28 (32.6)	13 (18.3)	45 (43.3)	44 (31.7)	14 (38.9)
Hypertensive crisis	≥ 180	39 (43.8)	31 (36.0)	57 (80.3)	13 (12.5)	58 (41.7)	12 (33.3)
Total		89 (100.0)	86 (100.0)	71 (100.0)	104 (100.0)	139 (100.0)	36 (100.0)

The median SBP and mean arterial pressure (MAP) at triage was 160 (130 – 200) mmHg and 117 (100 – 134) mmHg respectively for all stroke patients as shown in the Table 4.4 below. The MAP which is the average pressure in a patient artery during one cardiac cycle calculated as (2 x diastolic BP + systolic BP)/3. The mean SBP was higher among males (173 ± 55 vs 160 ± 49 mmHg) compared to females, among haemorrhagic strokes (209 ± 40 vs 138 ± 39 mmHg) than ischaemic strokes and among the mortality group (168 ± 53 vs 161 ± 51 mmHg) compared to stroke patients who survived.

Table 4.4 Summary of the various BP variables measured by gender (HS – haemorrhagic stroke; IS – ischaemic stroke)

BP category	Males (mmHg)	Female (mmHg)	HS (mmHg)	IS (mmHg)	Dead (mmHg)	Alive (mmHg)	All (mmHg)
IQR SBP	170 (140 – 220)	150 (120 – 200)	210 (180 – 230)	140 (110 – 160)	160 (130 – 203)	149 (123 – 200)	160 (130 – 200)
IQR MAP	114 (102 – 131)	119 (94 – 138)	127 (114 – 147)	106 (90 – 124)	117 (99 – 134)	112 (101 – 130)	117 (100 – 134)
Mean SBP	173 ± 55	160 ± 49	209 ± 40	138 ± 39	168 ± 53	161 ± 51	167 ± 52
Mean MAP	117 ± 23	116 ± 26	130 ± 23	109 ± 21	161 ± 51	117 ± 26	117 ± 25

4.1.4 Motor function of the limbs assessed at presentation

The motor function for each of the limbs of stroke patients were measured and graded at presentation. Among the 175 stroke patients, 52 (29.7%) had no visible movement in their right upper limb (RUL), 57 (32.6%), 74 (42.3%) and 75 (42.9%) had no motor function in the right lower limb (RLL), left upper limb (LUL) and left lower limb (LLL) respectively. The detailed breakdown of the graded motor function of the limbs as assigned to the stroke patients are presented in the Figure 4.3 below. This gave a sign of motor neurological deficit which aligns with the definition of stroke.

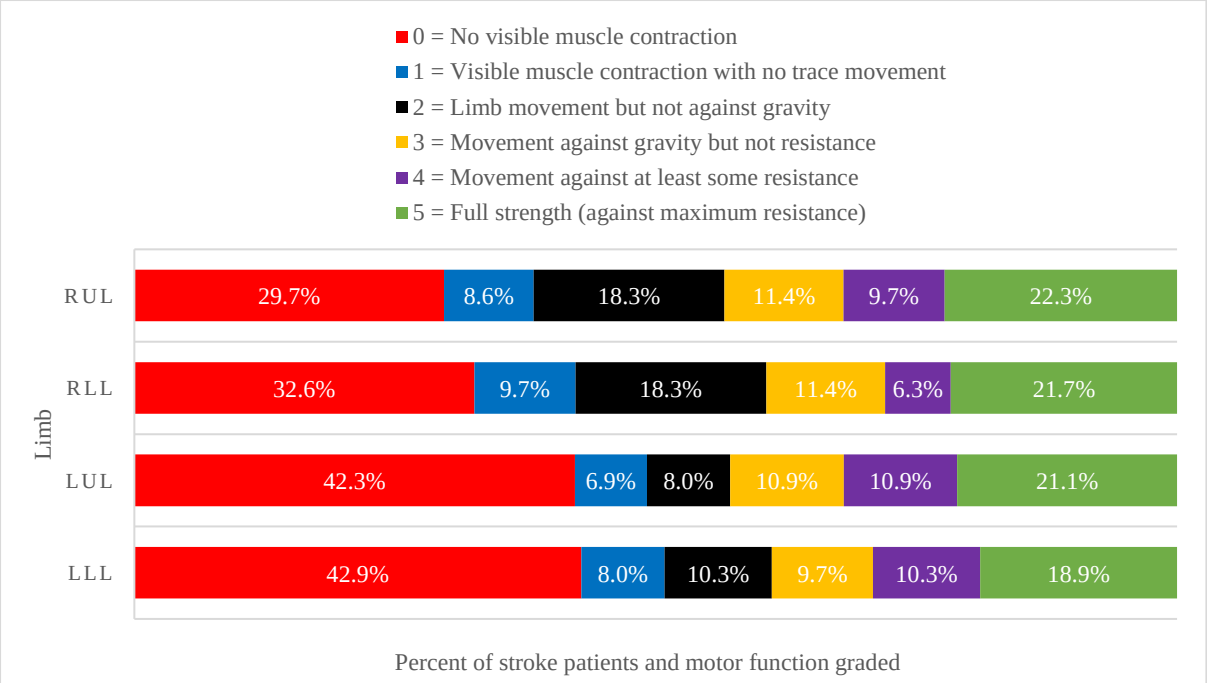


Figure 4.3 Motor function of the stroke patients at presentation to the ED (LLL – left lower limb; LUL – left upper limb; RLL – right lower limb; RUL – right upper limb)

Overall, 21 (12.0%) of the stroke patients presented with quadriplegia (no motor function in all four limbs), 29 (16.6%) with right hemiplegia, 51 (29.1%) with left hemiplegia and 11 (6.4%) had normal function in all four limbs and the remaining 63 (36.0%) had one form of limb weakness or the other.

4.2 Stroke diagnosis at the emergency department

Diagnosis of stroke at the emergency was clinical and or by head CT imaging. Clinical diagnosis was based on history and physical examinations that was suggestive of either a bleed or an ischaemia. There were 105 clinically diagnosed stroke patients with no CT scan. Of these

105 stroke patients, 63 (60.0% were ischaemic and 42 (40.0%) were haemorrhagic. There were 70 (40.0%) of the 175 stroke patients that had a head CT scanning done whiles on admission at the ED. Out of the 70 stroke patients that had a CT scan, 41 (58.6%) were diagnosed with ischaemic stroke and 29 (41.4%) were haemorrhagic strokes. The commonest imaging stroke diagnosis using the ICD 10 classification was unspecified cerebral infarction (31/70) followed by nontraumatic haemorrhage with intraventricular involvement stroke (14/70). The breakdown of the specific imaging diagnosis is detailed in the Table 4.5 below. Overall, there were 104 (59.4%) stroke patients diagnosed with ischaemic stroke and 71 (40.6%) with haemorrhagic stroke.

Table 4.5 ICD 10 CT scan stroke diagnosis of the patients at the emergency department

ICD-10 Code	Stroke diagnosis	Freq	Percent (%)
I61.2	Nontraumatic intracerebral haemorrhage in hemisphere, unspecified	2	2.9
I61.3	Nontraumatic intracerebral haemorrhage in brain stem	3	4.3
I61.5	Nontraumatic intracerebral haemorrhage, intraventricular	14	20.0
I61.6	Nontraumatic intracerebral haemorrhage, multiple localised	1	1.4
I61.8	Other nontraumatic intracerebral haemorrhage	6	8.6
I61.9	Nontraumatic intracerebral haemorrhage, unspecified	3	4.3
I63.519	Cerebral infarction due to unspecified occlusion or stenosis of unspecified middle cerebral artery	8	11.4
I63.529	Cerebral infarction due to unspecified occlusion or stenosis of unspecified anterior cerebral artery	1	1.4
I63.9	Cerebral infarction, unspecified	31	44.3
Total		**70**	**100.0**

4.2.1 Other clinical features of the stroke patients

Among eight other neurological manifestations, urine incontinence was the most frequent occurring in 132 (75.4%) of the stroke patients followed by stool incontinence, 127 (72.6%). The least frequent manifestation was seizures occurring in 14 (8.0%) of the stroke patients followed by signs of raised intracranial pressure, 41 (23.4%). The frequency of the other manifestations is presented in Table 4.6 below. At arrival at the ED, the blood glucose level of

every stroke patient was recorded. The median blood glucose was 9.7 (8 .0 – 12.5) mmol/l (normal should be < 11.0 mmol/l). Other laboratory tests conducted on the patients were also recorded. The mean haemoglobin level was 13.2 ± 2.6 g/dl (normal range = 11.5 – 16.5 g/dl). Kidney function test among 52 of the patients revealed a mean of 91.1 ± 24.7 mmol/L for plasma urea and 5.4 ± 2.4 µmol/L for plasma creatinine. Lipid profile test done among 45 of the patients revealed mean high-density lipoprotein (HDL) cholesterol levels of 2.0 ± 2.3 mmol/L (normal values are > 1.68 mmol/L), low density lipoprotein (LDL) cholesterol level was 3.4 ± 1.1 mmol/l (normal values are < 3.0 mmol/l). Liver function test done among 50 of the patients showed a median Aspartate transaminase (AST) value of 27 (19.8 – 40) u/L and the median Alanine transaminase (ALT) values as 25 (19 – 35) u/l. The median door to doctor time was 5 (5 – 10) minutes and that of the door to CT scan results time was 12.13 (23.0 – 24.3) hours. The mean symptoms onset to ED arrival time was 1.83 (1.3 – 3.83) hours and the median length of stay at the ED was 30.25 (14.0 – 75.75). The specific features and their values are presented in the summary Table 4.6 below.

Table 4.6 Summary descriptive statistics of special characteristic features

Specific features	**Value**	**Freq.**
Age (years), mean ± SD	59.9 ± 13.9	175
Sex		
Male, n (%)	89 (50.9%)	175
Female, n (%)	86 (49.1)	
National Health Insurance Status		
Active, n (%)	100 (57.1%)	175
Not active, n (%)	75 (42.9%)	
Common medical risk factors		
Hypertension, n (%)	162 (92.6%)	
Diabetes Mellitus, n (%)	45 (25.7%)	175
Physical inactivity, n (%)	18 (10.3%)	
Alcohol use, n (%)	9 (5.1%)	
Clinical presentation		
Urine incontinence, n (%)	132 (75.4%)	
Stool incontinence, n (%)	127 (72.6%)	
Altered speech, n (%)	103 (58.9%)	
Aspiration, n (%)	84 (48.0%)	175
Facial palsy, n (%)	71 (40.6%)	
Difficulty swallowing, n (%)	44 (25.1%)	
Raised intracranial pressure, n (%)	41 (23.4%)	
Seizure, n (%)	14 (8.0%)	
Triage findings		
Systolic blood pressure (mmHg), median (IQR)	160 (130 – 200)	
Heart rate (beats per minute), median (IQR)	94 (78 – 110)	
Respiratory rate (cycles per minute), median (IQR)	24 (22 – 28)	175
Oxygen saturation (%), median (IQR)	96 (92 – 96)	
Temperature (^{0}C), mean ± SD	37.0 ± 1.1	

Clinical presentation scores		
Triage score, Median (IQR)	6 (5-7)	
Glasgow coma score on admission, median (IQR)	8 (5-11)	175
Modified Rankin scale on admission, median (IQR)	6 (6 – 6)	
Mean BP values during stay at the ED		
Systolic blood pressure (mmHg), median (IQR)	161 (136 – 184)	175
Mean arterial pressure (mmHg), median (IQR)	117 (100 – 134)	
Stroke diagnosis		
Ischaemic stroke, n (%)	105 (60.0)	
Haemorrhagic stroke, n (%)	70 (40.0)	175
Blood parameters (count)		
Blood glucose on arrival (mmol/L), median (IQR)	9.7 (8 .0 – 12.5)	138
Haemoglobin (g/dl), mean ± SD	13.2 (2.6)	147
White blood cell (WBC) ($x10^9$/L), median (IQR)	9.5 (7.5 – 9.5)	147
Platelet ($x10^9$/L), median (IQR)	214 (163 – 283)	147
Kidney function parameters		
Urea (mmol/l), mean ± SD	91.1 ± 24.7	52
Creatinine (µmol/l), mean ± SD	5.4 ± (2.4)	52
Sodium (Na) (mmol/l), median (IQR)	141.5 (139 – 143)	52
Potassium (K) (mmol/l), mean ± SD	4.2 ± 0.5	52
Blood cholesterol levels		
High density lipoprotein (HDL) (mmol/l), mean ± SD	2.0 ± 2.3	45
Low density lipoprotein (LDL) (mmol/l), mean ± SD	3.4 ± 1.1	45
Very low-density lipoprotein (VLDL) (mmol/l), mean ± SD	3.2 ± 0.7	45
Triglycerides (mmol/l), mean ± SD	5.4 ± 1.5	45
Total Cholesterol (mmol/L), mean ± SD	1.3 ± 0.7	45
Liver function parameter		
Aspartate transaminase (AST) (u/l), median (IQR)	27 (19.8 – 40)	50
Alanine transaminase (ALT) (u/l), median (IQR)	25 (19 – 35)	50
Alkaline phosphatase (ALP) (u/l), median (IQR)	102 (82.5 – 128.3)	50
Gamma-glutamyl transferase (GGT) (u/l), median (IQR)	43 (32.5 – 60)	50
Albumin (g/l), median (IQR)	37 (35 – 38.2)	50
Time measurements		
Door to doctor time (minutes), median (IQR)	5 (5 – 10)	175
Door to CT results time (hours), median (IQR)	12.13 (23.0 – 24.3)	70
Length of stay (hours), median (IQR)	30.25 (14.0 – 75.75)	175
Symptoms onset and ED arrival time (hours), median (IQR)	1.83 (1.3 – 3.83)	175
ED crowding status		
NEDOCS at triage, median (IQR)	185 (163 – 200)	
Average NEDOCS during ED stay, median (IQR)	184 (176 – 193)	175
ED occupancy rate (%), median (IQR)	96 (89 – 109)	
< 100% (Mortality)	79 (75.2%)	105
=>100% (Mortality)	60 (85.7%)	70

4.3 Emergency department crowding status using the national emergency department overcrowding score (NEDOCS)

The next few paragraphs present the crowding status of the ED as the patient met either at arrival or during their entire stay at the ED.

4.3.1 Daily emergency department crowding status for the study period

The average daily NEDOCS between 14 October 2019 to 24 March 2020 was 103 – 200, and therefore was always either 'overcrowded' (101 -140), 'severely overcrowded' (141 – 180) or 'dangerously overcrowded' (181 – 200). The ED was severely overcrowded for 42.2% of the 154 days and dangerously overcrowded for 53.9% over the same period. There was no single time that the ED was 'not busy,' 'busy' or 'extremely busy but not overcrowding.' Figure 4.4 below shows the distribution of the average daily NEDOCS for the period of 154 days of data collection.

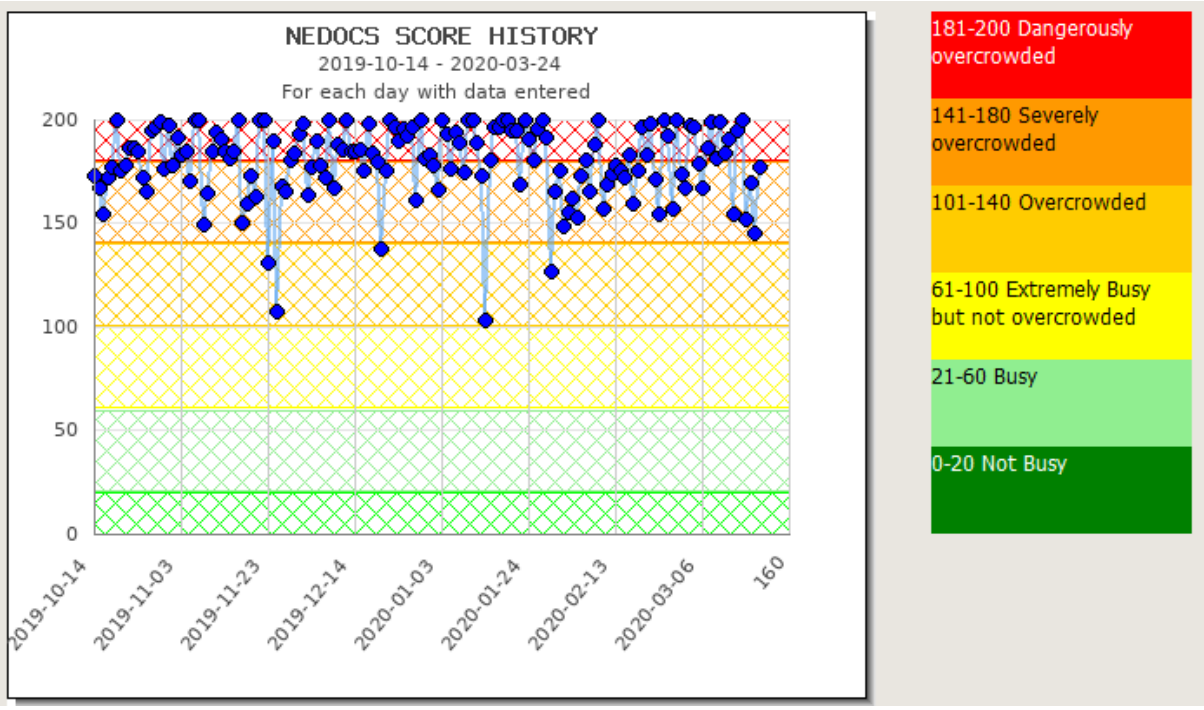


Figure 4.4 Daily emergency department crowding status using NEDOCS

4.3.2 Patient arrival and the emergency department crowding status

When the patient arrived at the ED, at the time of triaging, the NEDOCS was assigned to the patient as the triage NEDOCS. The triage NEDOCS indicated that for 93 (53.1%) of the

patients, the ED was dangerously overcrowded at the time of presentation and for 73 (41.7%) of the patients, the ED was severely overcrowded at the time of presentation. For the remaining 9 (5.1%) of the patients, the ED was overcrowded at the time of presentation. There was no single triage NEDOCS that indicated that the ED was not busy at the time of presentation for any of the patients.

4.3.3 ED overcrowding status for the stroke patients during their stay

The average NEDOCS was calculated for each of the 175 patients during their entire stay at the ED. For 108 (61.7%) patients, on the average, the ED was dangerously overcrowded during their entire stay at the ED, 66 (37.7%) of the patients experience a severely overcrowded ED during their entire stay and for 1 (0.6) patient, the ED was overcrowded for the period spent at the ED. Table 4.7 below provides a summary statistic of the NEDOCS calculated at triage and during the stay of the patient at the ED. It is instructive to note for all the NEDOCS variables calculated, there was no single day, time, or period that the ED was not overcrowded.

Table 4.7 Summary of various national emergency department overcrowding score (NEDOCS) calculated

Variable	Daily Average NEDOCS (days)	Triage NEDOCS (patient)	Average NEDOCS (days)	
Mean	180 ± 18	179 ± 23	180 ± 16	
Range	103 - 200	104 - 200	107 - 200	
NEDOCS				**Crowding status**
0-20	0 (0.0)	0 (0.0)	0 (0.0)	Not busy
21-60	0 (0.0)	0 (0.0)	0 (0.0)	Busy
61-100	0 (0.0)	0 (0.0)	0 (0.0)	Extremely busy but not overcrowded
101-140	6 (3.9)	9 (5.1)	1 (0.6)	Overcrowded
141-180	65 (42.2)	73 (41.7)	66 (37.7)	Severely overcrowded
181-200	83 (53.9)	93 (53.1)	108 (61.7)	Dangerously overcrowded
Total	**154 (100.0)**	**175 (100.0)**	**175 (100.0)**	

4.4 Stroke mortality outcomes and special characteristic features

The outcome variable was stroke mortality, and this is presented alongside other variables of interest in the next few paragraphs.

4.4.1 Stroke mortality by gender and stroke type

Out of the 175 stroke patients, there were 139 stroke related deaths constituting 79.4% of the stroke population. There were 89 stroke males out of which 70 (78.7%) died compared to the 86 stroke females out of which 69 (80.2%) died at the ED. There were 104 ischaemic strokes out of which 78 (75.0%) died compared to 71 haemorrhagic strokes out of which 61 (85.9%) died at disposition. There were 70 patients who had CT scans done whiles on admission out of which 52 (74.2%) died. For both clinical and CT scan diagnosis, proportions of haemorrhagic deaths were higher. Death rates among the 36 CT scan diagnosed strokes in males was 26 (72.2%) compared to 26 (76.5%) deaths among the 34 female stroke patients diagnosed by CT scan. Breakdown of the type of stroke deaths and their gender is highlighted in the Table 4.8 below.

Table 4.8 Stroke diagnosis done clinically and by head CT scan imaging

Sex	**Male (n = 89)**		**Female (n = 86)**		**Total**	**Percent (%)**
Clinical outcome	**Dead**	**Alive**	**Dead**	**Alive**		
Type of stroke						
Ischaemic stroke (CT scan)	13	7	15	6	41	23.4
Ischaemic stroke (clinical)	22	7	28	6	63	36.0
Haemorrhagic stroke (CT scan)	13	3	11	2	29	16.6
Haemorrhagic stroke (clinical)	22	2	15	3	42	24.0
Total	70 (50.4%)	19	69 (80.2%)	17	175	100.0

4.4.2 Risk factors, length of stay and clinical presentation of stroke patients

Patients who were less than 65 years of age had worse clinical presentations as demonstrated by the triage score (5.8 ± 1.3 vs 5.7 ± 1.5), the triage SBP (177 ± 48 vs 144 ± 54 mmHg) and the GCS (8.1 ± 3.6 vs 8.8 ± 3.4) compared to patients who were 65 years and above as shown in Table 4.9. Patients who were less than 65 years had shorter length of stay at the ED (41.6 ± 42.0 vs 69.4 ± 62.6 hours).

Table 4.9 Clinical parameters of stroke patients distributed by age and stroke type

Variable	**< 65 years**	**65 years and older**	**HS**	**IS**
N	119	56	71	104
Age (mean ± SD years)	52.5 ± 8.7	75.7 ± 9.0	55.3 ± 12.6	63.1 ± 14.1
Triage score	5.8 ± 1.3	5.7 ± 1.5	6.3 ± 1.1	5.5 ± 1.4
Triage Systolic BP (mmHg)	177 ± 48	144 ± 54	209 ± 40	138 ± 39

Triage mean arterial pressure (mmHg)	119 ± 25	111 ± 23	129 ± 23	109 ± 22
Glasgow coma score	8.1 ± 3.6	8.8 ± 3.4	7.4 ± 3.6	9.0 ± 3.4
Modified Rankin Scale	5.3 ± 1.4	5.4 ± 1.2	5.7 ± 0.9	5.1 ± 1.6
Length of stay (hours)	41.6 ± 42.0	69.4 ± 62.6	47.9 ± 56.3	52.3 ± 47.5
Symptom onset to ED arrival time (hours)	3.1 ± 3.5	3.6 ± 3.7	2.7 ± 2.8	3.7 ± 3.9
Mortality	95 (79.8%)	44 (78.6%)	61 (85.9%)	78 (75.0%)

Similarly, patients with haemorrhagic strokes were younger with a mean age of (55.3 ± 12.6 vs 63.1 ± 14.1 years) and they also presented with worse forms of clinical presentation as displayed by their triage scores (6.3 ± 1.1 vs 5.5 ± 1.4), GCS (7.4 ± 3.6 vs 9.0 ± 3.4), triage SBP (209 ± 40 vs 138 ± 39 mmHg), triage mean arterial pressure (129 ± 23 vs 109 ± 22 mmHg) among others compared to patients with ischaemic strokes. Haemorrhagic strokes had shorter LOS (47.9 ± 56.3 vs 52.3 ± 47.5 hours) at the ED. There were 65 (46.8%) deaths that occurred within 24 hours and within 7 days 134 (96.4%) of deaths had occurred. The proportion of deaths among haemorrhagic stroke patients occurred earlier when compared to ischaemic stroke patients as displayed in the Table 4.10 below.

Table 4.10 Type of stroke and their length of stay at the emergency department

Length of stay (hours)	**Haemorrhagic (%)**	**Ischaemic (%)**	**Mortality (%)**
< 24 hours	33 (54.1%)	32 9 (41.0%)	65 (46.8%)
< 3 days	47 (77.0%)	56 (71.8%)	103 (74.1%)
< 7 days	58 (95.1%)	76 (97.4%)	134 (96.4%)
< 14 days	61 (100.0%)	78 (100.0%)	139 (100.0%)

There were five main stroke risk factors for which information was collected. The proportion of hypertension 112 (94.1%) vs 50 (89.3%) and alcohol use 9 (7.6%) vs 0 (0.0%) was higher among patients less than 65 years while that of diabetes mellitus 18 (32.1%) vs 24 (20.2%) and physical inactivity 14 (25.0%) vs 4 (3.4%) were higher among patients 65 years and above. Also, hypertension 69 (97.2%) vs 93 (89.4%) was prevalent among haemorrhagic strokes than ischaemic strokes. The proportion of hypertension 84 (94.4%) vs 78 (90.7%) and alcohol use 9 (10.1%) vs 0 (0.0%) was prevalent among males than females while diabetes mellitus 26 (30.2%) vs 16 (18.0%) and physical inactivity 10 (11.6%) vs 8 (9.1%) were common among females than males as detailed in the Table 4.11 below.

Table 4.11 Modifiable risk factors of the stroke patients distributed by age, type of stroke and gender

Modifiable risk factor	< 65 Years	65 years and older	HS	IS	Males	Females
N	119 (%)	56 (%)	71 (%)	104 (%)	89 (%)	86 (%)
Hypertension	112 (94.1)	50 (89.3)	69 (97.2)	93 (89.4)	84 (94.4)	78 (90.7)
Diabetes mellitus	24 (20.2)	18 (32.1%)	4 (5.6)	38 (36.5)	16 (18.0)	26 (30.2)
Obesity	0 (0.0%)	1 (1.8%)	0 (0.0)	1 (1.0)	0 (0.0)	1 (1.2)
Physical inactivity	4 (3.4%)	14 (25.0%)	1 (1.4)	17 (16.3)	8 (9.1)	10 (11.6)
Alcohol use	9 (7.6%)	0 (0.0%)	5 (7.0)	4 (3.8)	9 (10.1)	0 (0.0)

4.5 Special patient and emergency department features distributed by mortality outcomes among strokes patients

The baseline demographic features, clinical presentation, ED crowding status and relevant time variables distributed by discharge outcome is summarised in Table 4.12. Patients who died were older (61.19 ± 15.43 vs 59.60 ± 13.54 years) though not significantly so ($p = 0.541$). The mortality group significantly presented with higher proportions of urine incontinence ($p < 0.001$), stool incontinence ($p < 0.001$), aspiration ($p < 0.001$), difficulty in swallowing ($p < 0.001$) and had signs of raised intracranial pressure ($p < 0.001$. The triage scores (7 (5 – 9) vs 5 (4-5) ($p < 0.001$)), the modified Rankin scale (6 (6-6) vs 3 (2-4); $p < 0.001$)) and the GCS (7 (5-9) vs 12 (10-14); $p < 0.001$)) were significantly worse among patients who died.

The values of kidney function, liver function and lipid profile among other blood test parameters were similar between patients who died and those who were alive at the time of discharge. The average NEDOCS calculated during the entire stay of each patient was found to be significantly higher among patients who died (186 (177-193) vs 181 (171-187); $p < 0.042$)). There was no statistically significant difference ($p > 0.05$) between gender, having a risk factor of hypertension, diabetes mellitus, having a CT scan done, type of stroke, time of onset of symptoms and arrival time at the ED among the mortality and survival groups.

Table 4.12 Summary statistics of special patient and ED characteristic features distributed by mortality outcomes

Specific features	Alive	Dead	P value
Age (years), mean ± SD	61.19 ± 15.43	59.60 ± 13.54	0.541
Sex			
Male, n (%)	19 (10.9)	70 (40.0)	0.853
Female, n (%)	17 (9.7)	69 (39.5)	0.796
National Health Insurance Status			
Active, n (%)	26 (14.9)	74 (42.3)	0.058
Not active, n (%)	10 (5.7)	65 (37.1)	
Marital status			0.923
Married	23 (20.4%)	90 (79.6%)	
Non married	13 (21.0%)	49 (79.0%)	
Educational status			0.793
Employed	14 (19.7%)	57 (80.3%)	
Not employed	22 (21.4%)	81 (78.6%)	
Common medical risk factors			
Hypertension, n (%)	32 (18.3)	130 (74.3)	0.473
Diabetes Mellitus, n (%)	6 (3.4)	36 (20.6)	0.248
Physical inactivity, n (%)	4 (2.3)	14 (8.0)	0.767
Alcohol use, n (%)	4 (2.3)	5 (2.9)	0.088
Other clinical presentation			
Urine incontinence, n (%)	10 (5.7)	122 (69.7)	**<0.001**
Stool incontinence, n (%)	8 (4.6)	119 (68.0)	**<0.001**
Altered speech, n (%)	22 (12.6)	81 (46.3)	0.758
Aspiration, n (%)	5 (2.9)	79 (45.1)	**<0.001**
Facial palsy, n (%)	22 (12.6)	49 (28.0)	**0.005**
Difficulty swallowing, n (%)	1 (0.6)	43 (24.6)	**<0.001**
Raised intracranial pressure, n (%)	1 (0.6)	40 (22.9)	**<0.001**
Seizure, n (%)	4 (2.3)	10 (5.7)	0.490
Triage findings			
Systolic blood pressure (mmHg), median (IQR)	148 (123 – 200)	160 (130 – 203)	0.348
Heart rate (beats per minute), median (IQR)	91 (78 – 110)	95 (78 – 110)	0.969
Respiratory rate (cycles per minute), median (IQR)	22 (20 – 26)	25 (22 – 28)	0.065
Oxygen saturation (%), median (IQR)	97 (95 – 98)	96 (91 – 98)	**0.007**
Temperature (^{0}C), mean ± SD	36.53 ± 0.96	37.14 ± 1.11	**0.003**
Clinical presentation scores			
Triage score, Median (IQR)	5 (4 – 5)	7 (5 – 7)	**<0.001**
7 or more (emergency)	4 (5.1%)	75 (94.9%)	
5-6 (very urgent)	14 (23.0%)	47 (77.0%)	
3-4 (urgent)	18 (52.9%)	16 (47.1%)	
1-2 (routine)	0 (0.0%)	1 (100.0%)	
Glasgow coma score on admission, median (IQR)	12 (10 – 14)	7 (5 – 9)	**<0.001**
3-8 (severe)	4 (4.2%)	92 (95.8%)	
9-12 (moderate)	19 (37.3%)	32 (62.7%)	
13-15 (mild)	13 (46.45)	15 (53.6%)	
mRS on admission, median (IQR)	3 (2 – 4)	6 (6 -6)	**<0.001**
1-2	14 (38.9%)	0 (0.0%)	
3-4	22 (62.9%)	0 (0.0%)	
5-6	0 (0.0%)	139 (100.0%)	

Mean BP values during stay at the ED			
Systolic blood pressure (mmHg), median (IQR)	158 (137 – 170)	164 (132 – 187)	0.422
Mean arterial pressure (mmHg), median (IQR)	112 (101 – 130)	117 (99 -134)	0.747
ED crowding status			
NEDOCS at triage, median (IQR)	179 (157 – 200)	188 (165 – 200)	0.157
Average NEDOCS during ED stay, median (IQR)	181 (171 – 187)	186 (177 – 193)	**0.042**
ED occupancy rate (%), median (IQR)	95 (90 – 103)	96 (88 -110)	0.439
< 100% (not overcrowded)	26 (24.8%)	79 (75.2%)	0.579
=/> 100% (overcrowded)	10 (14.3%)	60 (85.7%)	**0.012**
Stroke diagnosis			
CT scan use, n (%)	18 (25.7%)	52 (74.3%)	0.173
Ischaemic stroke, n (%)	13 (31.7%)	28 (68.3%)	
Haemorrhagic stroke, n (%)	5 (17.2%)	24 (82.8%)	
Clinical diagnosis	18 (17.1%)	87 (82.9%)	0.245
Ischaemic stroke, n (%)	13 (20.6%)	50 (79.4%)	
Haemorrhagic stroke, n (%)	5 (11.9%)	37 (88.1%)	
Blood parameters			
Blood glucose on arrival (mmol/L), median (IQR)	8.9 (8.1 – 10.1)	9.8 (8 – 13)	0.337
Haemoglobin (g/dl), mean ± SD	13.42 ± 2.22	13.17 ± 2.71	0.652
White blood cell ($x10^9$/L), median (IQR)	9.5 (5.5 – 11.2)	9.5 (7.6 – 11.9)	0.303
Platelet ($x10^9$/L), median (IQR)	211 (150 – 283)	214 (166 – 284)	0.916
Kidney function parameters			
Urea (mmol/l), mean ± SD	5.52 ± 2.54	5.30 ± 2.40	0.288
Creatinine (µmol/), mean ± SD	91.29 ± 23.04	91.05 ± 25.45	**0.030**
Sodium (mmol/l), median (IQR)	142 (137 -146)	141 (139 – 143)	0.785
Potassium (mmol/l), mean ± SD	4.20 ± 0.64	4.13 ± 0.48	0.404
Blood cholesterol levels			
High density lipoprotein (mmol/l), mean ± SD	1.93 ± 0.32	2.07 ± 2.62	0.864
Low density lipoprotein (mmol/l), mean ± SD	3.98 ± 0.79	3.25 ± 1.08	0.055
Triglycerides (mmol/l), mean ± SD	1.30 ± 0.88	1.29 ± 0.72	0.967
Total Cholesterol (mmol/L), mean ± SD	5.47 ± 1.90	5.35 ± 1.42	0.822
Liver function parameter			
Aspartate transaminase (u/l), median (IQR)	30 (18 – 36)	27 (20 – 43)	0.847
Alanine transaminase (u/l), median (IQR)	26 (20 – 31)	25 (19 – 36)	0.892
Alkaline phosphatase (u/l), median (IQR)	92 (80 – 126)	105 (88 – 134)	0.892
Gamma-glutamyl transferase (u/l), median (IQR)	45 (35 – 60)	43 (31 – 60)	0.407
Albumin (g/l), median (IQR)	38 (35 – 44)	37 (35 – 38)	0.442
Time measurements			
Door to doctor time (minutes), median (IQR)	8 (5 – 11)	5 (4 – 10)	**0.034**
Door to CT results time (hours), median (IQR)	10.25 (5.67–41.07)	12.57 (3.20–22.92)	0.060
Length of stay (hours), median (IQR)	42.36 (23.79–84.14)	29.22 (11.60–72.67)	**0.046**
Symptoms onset and ED arrival time (hours), median (IQR)	1.92 (1.27 – 4.14)	1.83 (1.30–3.83)	0.865

4.6 Bivariate correlation and association of some sociodemographic and special variables

Pearson's, Point Biserial and Spearman's correlation analysis and Chi^2 association test were run to show the relationship between various variables as presented below.

4.6.1 Relationship between age and some relevant clinical features

Bivariate correlation and association analysis showed that there was a significant negative correlation between age and triage Systolic BP ($r = -0.319$; $p < 0.001$), mean arterial pressure ($r = -0.196$; $p < 0.001$) and the type of stroke ($r = -0.275$; $p < 0.001$). Implying that increasing SBP and mean arterial pressure correlated with younger age and haemorrhagic stroke correlated with younger ages. There was a significant positive association between age and diabetes mellitus ($Chi^2 = 0.222$; $p = 0.003$). Older patients were likely to experience longer length of stay at the ED ($r = 0.164$; $p = 0.030$) and this was found to be statistically significant. These are highlighted in the Table 4.13 below.

Table 4.13 Correlations and associations between age and other clinical features of stroke patients

Specific features	Correlation and associations	P value
Triage SBP vs Age	-0.319	<0.001
MAP vs Age	-0.196	0.009
Age vs onset to arrival time	0.132	0.081
Age vs DM	0.222	0.003
Age vs Hypertension	-0.128	0.092
Type of stroke vs Age	-0.275	<0.001
LOS vs Age	0.164	0.030

4.6.2 Relationship between stroke type and some relevant clinical features

There was a positive and significant correlation between the type of stroke and the triage SBP ($r = 0.687$; $p < 0.001$) as well as with mean arterial pressure (0.417; $p < 0.001$). However, the type of stroke was statistically significantly associated negatively with the GCS ($r = -0.235$; $p = 0.002$), LOS ($r = -0.042$; $p < 0 .001$), diabetes mellitus ($Chi^2 = -0.355$; $p < 0.001$) and the onset of symptoms and arrival to the ED ($r = -0.156$; $p < 0.001$). These relationships are highlighted in Table 4.14 below.

Table 4.14 Correlations and associations between the type of stroke and other clinical features of the stroke patients

Specific features	Correlation and associations	P value
Type of stroke vs LOS	-0.042	0.582
Type of stroke vs GCS	-0.235	0.002
Type of stroke vs DM	-0.355	<0.001
Type of stroke vs Hypertension	0.145	0.055
Type of stroke vs onset to arrival time	-0.156	0.040
Type of stroke vs triage SBP	0.687	<0.001
Type of stroke vs MAP	0.417	<0.001
Type of stroke vs mortality	-0.133	0.079

4.6.3 Relationship between stroke mortality and other variables

There was a statistically significant positive correlation between stroke mortality and the time it took for a physician to attend to a patient who arrived at the ED ($r = 0.240$; $p < 0.001$). Mortality was negatively associated with hypertension and diabetes mellitus as risk factors, symptoms onset and arrival to the ED, as well as the crowding status of the ED using NEDOCS and ED occupancy rate at triage. These variables were found not be statistically significant as shown in Table 4. 15 below.

Table 4.15 Stroke related mortality and its correlates and associates with patients and emergency department characteristic variables

Specific features	Correlation and associations	P value
Mortality vs age	0.047	0.541
Mortality vs hypertension	-0.071	0.344
Mortality vs diabetes mellitus	-0.087	0.248
Mortality vs NEDOCS at triage	-0.118	0.121
Mortality vs average NEDOCS during stay	-0.148	0.051
Mortality vs length of stay	0.087	0.254
Mortality vs ED occupancy at triage	-0.061	0.425
Mortality vs door to doctor time	0.240	0.001
Mortality vs plasma creatinine	0.004	0.976
Mortality vs urea	0.041	0.775
Mortality vs arrival to CT results time	0.127	0.292
Mortality vs symptoms onset to arrival time	-0.480	0.530

4.6.4 ED crowding and its correlation with some stroke care parameters

The average NEDOCS of stroke patient was negatively correlated to having a head CT scan and this was found to be statistically significant ($r = -0.219$; $p = 0.004$). Indicating that fewer patients were likely to have head CT scan done when they encountered severely crowded periods during their stay at the ED. Patients who had CT scan had a positive correlation with their length of stay at the ED ($r = 0.173$; $p < 0.022$) as well as their Glasgow coma score ($r = 0.246$; $p = 0.001$) and they were statistically significant as shown in Table 4.16 below. There was a high positive significant correlation between NEDOCS and ED occupancy rates ($r = 0.420$; $p < 0.001$) as they both measured the crowding status of the ED.

Table 4.16 Emergency department crowding and its correlations and associations with patients and emergency department variables

Specific features	Correlation and associations	P value
Triage NEDOCS vs CT done	-0.097	0.233
Average NEDOCS vs CT done	-0.219	0.004
Triage NEDOCS vs Arrival to CT results time	0.003	0.979
Average NEDOCS vs Arrival to CT results time	0.168	0.161
Triage NEDOCS and ED occupancy at triage	0.420	<0.001
Triage NEDOCS vs Door to doctor time	-0.020	0.975
NEDOCS at triage vs Length of stay	0.107	0.160
Door to CT results time vs Length of stay	0.483	<0.001
CT done vs LOS	0.173	0.022
CT done vs GCS	0.246	0.001

4.7 Prediction of death among stroke patients

Univariate and multivariate logistic regressions were performed to analyse the predictors of stroke mortality at the ED. Using the univariate analysis; not having an active national health insurance status (COR = 2.402; 95% CI: 1.045 – 5.521; p = 0.039), triage score (COR = 2.539; 95% CI: 1.802 – 3.578; p < 0.001), mRS (COR = 95.977; 95% CI: 8.726 – 1005.608; p < 0.001), Glasgow coma score (OCR = 0.686; 95% CI: 0.597 – 0.787; <0.001), patient average NEDOCS (COR = 1.028; 95% CI: 1.001 – 1.005; p = 0.045), difficulty swallowing (COR = 14.937; 95% CI: 1.978 – 112.801; p = 0.009), facial palsy (COR = 0.373; 95% CI: 0.173 – 0.804; p = 0.012), raised intracranial pressure (AOR = 13.000; 95% CI: 1.718 – 98.357; p = 0.013), aspiration (COR = 7.540; 95% CI: 2.754 – 20.640; p < 0.001), urine incontinence (COR = 17.082; 95% CI: 6.978 – 41.827; p < 0.001) and stool incontinence (COR = 19.175; 95% CI: 7.616 – 48.277; p < 0.001) were found to be statistically significant in crudely predicting mortality outcomes among stroke patients in the absence of covariate. Further details are presented in the Table 4.17 below.

Table 4.17 Univariate predictors of stroke mortalities

Variables	Univariate COR	95% CI	P value
Age	0.992	0.966 – 1.019	0.586
Sex (female)	1.125	0.531 – 2.385	0.759
Not married	1.009	0.460 – 2.213	0.981
Not employed	0.988	0.460 – 2.119	0.975
National Health Insurance (not active)	2.402	1.045 – 5.521	0.039
Hypertension	1.911	0.551 – 6.624	0.307
Diabetes mellitus	1.647	0.631 – 4.302	0.308
Triage score	2.539	1.802 – 3.578	<0.001
mRS	95.977	8.726 – 1005.608	<0.001
Glasgow coma score	0.686	0.597 – 0.787	<0.001
Triage SBP	1.003	0.996 – 1.011	0.419
Triage NEDOCS	1.013	0.997 – 1.028	0.110
Average NEDOCS	1.028	1.001 – 1.005	0.045
Difficult swallowing	14.937	1.978 – 112.801	0.009
Facial palsy	0.373	0.173 – 0.804	0.012
Altered speech	0.966	0.451 – 2.069	0.928
Seizures	0.586	0.172 – 1.996	0.393
Raised intracranial pressure	13.000	1.718 – 98.357	0.013
Aspiration	7.540	2.754 – 20.640	<0.001
Urine incontinence	17.082	6.978 – 41.827	<0.001
Stool incontinence	19.175	7.616 – 48.277	<0.001
Symptoms onset to ED arrival time	1.001	0.999 – 1.003	0.530
Stroke diagnosis (haemorrhagic)	2.500	1.057 – 5.913	0.037
CT scan not done	1.470	0.690 – 3.132	0.318

Binary logistic regression analysis was performed to predict the probability of death from stroke. The categorical groups were mutually exclusive and exhaustive as dependent variables. There were multiple independent variables, some of which were categorical and some of which were continuous in character. It was assumed that the independent variables needed not be interval, nor normally distributed, nor have a linearly relationship, nor the error terms (residuals) normally distributed nor of equal variance within the groups. To avoid creating an overfit model, adequate number of observations for each independent variable in the dataset was assured. It has been recommended that a minimum of 30 observations per independent variable can be applied. The influence of outlier data points which had the potential to distort the outcome and the accuracy of the logistic model was checked using the Mahalanobis distance (where < 0.001 were excluded).

There were 8 independent predictor variables (5 were categorical variables and 3 were continuous) included in the model. The predictor variables were average NEDOCS assigned each stroke patient whiles on admission at the ED, type of stroke suffered, having a CT scan done to confirm diagnosis and systolic BP (these four variables were selected from the priori aims of the study). The other four variables based on the literature review were past medical

history of hypertension, diabetes mellitus, age, and gender. The categorical groups were mutually exclusive and exhaustive as dependent variables. The cases selected and included in the analysis was 172 with no missing cases and three cases excluded because they were influential outliers. The dependent variable encoding classified dead as 1 and alive as 0.

An omnibus test of the full model versus the null model with intercept only was statistically significant, χ^2 (8, N = 172) = 121.767; p = 0.047 (p > 0.05). The Hosmer and Lemeshow test indicated a good fit and that the model adequately fitted the data and there was no difference between the observed and the predicted model as they were almost equal χ^2 (8, N = 172) = 8.871; p = 0.353 (p > 0.05) The Nagelkerke's R^2 which is a pseudo-R squared, and an adjusted Cox and Snell R-square approximates variation in the criterion variable. It showed that 13.8% change in the criterion variable could be accounted to the predictor variables in the model. The model was able correctly to classify 99.3% of stroke patients who died showing good sensitivity and an overall percentage accuracy in classification (PAC) which was good at 80.2%.

Table 4.18 shows the logistic regression coefficient, Wald test, odds ratio, and significance for each of the predictors. Adopting a 0.05 criterion of statistical significance, average patient NEDOCS (AOR = 1.033; 95% C1: 1.003 – 1.064; p = 0.033), type of stroke (AOR = 3.834; 95% CI: 1.184 – 12.416; p = 0.025) and a medical history of diabetes mellitus (AOR = 3.001; 95% CI: 1.006 – 8.951; p = 0.049) had significant partial effects. The AOR for the average patient NEDOCS showed that when holding all other variables constant, with one unit increase in the average patient NEDOCS the odds of death increased by 3.3%. Therefore a 10 unit increase of NEDOCS from 150 to 160 was associated with 33.0% chance of death. Likewise, from overcrowded (101) to dangerously overcrowded (200) gives 326.7% increase odds of dying. The AOR for the type of stroke shows that, when holding all other variables constant, a patient with haemorrhagic stroke is 3.8 times more likely to experience death than if the patient had ischaemic stroke. The AOR for diabetes mellitus showed that a patient with diabetes mellitus is 3.0 times likely to die from stroke as opposed to a patient with no diabetes mellitus as a medical risk factor. Although there were increased odds of death among the age (inverted AOR = 1.558), being a female (AOR = 1.342), not having a CT scan done (AOR = 1.307), SBP at triage (AOR = 1.004) and the presence of hypertension (AOR = 2.916) as a medical risk factor they were partially found not to significantly predict death among stroke patients who were admitted at the ED of the TGH.

Table 4.18 Binary logistics regression model output from SPSS indicating significant predictors of mortality outcome among stroke patients who visited the emergency department.

Variables in the Equation									
								95% C.I. for EXP(B)	
		B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Step 1[a]	Average patient NEDOCS	.033	.015	4.566	1	.033	1.033	1.003	1.064
	Stroke diagnosis (1)	1.344	.600	5.026	1	.025	3.834	1.184	12.416
	Diabetes mellitus (1)	1.099	.558	3.881	1	.049	3.001	1.006	8.956
	Hypertension (1)	1.070	.726	2.174	1	.140	2.916	.703	12.099
	Age	-.007	.015	.216	1	.642	.993	.964	1.023
	Sex (1)	.295	.417	.499	1	.480	1.342	.593	3.040
	CT scan done (1)	.267	.422	.403	1	.526	1.307	.572	2.985
	Triage systolic BP	-.004	.006	.407	1	.523	.996	.986	1.007
	Constant	-5.440	3.162	2.960	1	.085	.004		

a. Variable(s) entered on step 1: Average patient NEDOCS, stroke diagnosis, diabetes mellitus, hypertension, age, sex, CT scan done, triage SBP.

Chapter 5 DISCUSSION

5.1 Background and novelty of the study

This was the first hospital based retrospective study of prospectively collected data on stroke mortality and ED overcrowding in the era of CT scan use in sub-Saharan Africa. The study was conducted in the TGH in the Greater Accra Region of Ghana. The electronic data extracting tool was purposefully created for this study. TGH is a district hospital, one of the very few with a functional ED. It is worth noting that having functional EDs are new to Ghana. This was also the first study in West Africa that looked at ED overcrowding and its impact on the mortality among stroke patients. This is the first study that used the NEDOCS to quantitatively assess ED overcrowding in Ghana. Lastly, this is the first time an electronic data extraction tool has been developed and used for stroke studies in an ED in Ghana using SQLite and PHP scripting language. Electronic systems in hospitals are restricted to basic administrative functions and this is one of the rare occasions where efforts have been made to extract followed up data for outcomes assessment in any department in any district or regional hospital in Ghana.

The overall aim of this study was to evaluate the levels of overcrowding and predictors of mortality outcomes among stroke patients at the ED of TGH in the Greater Accra Region of Ghana, a LMIC in sub-Saharan Africa. The research objectives were: 1) To measure the levels of ED overcrowding using the NEDOCS, 2) To establish the case fatality among stroke patients who visit the ED, 3) To establish stroke specific mortality outcomes by stroke subtypes, 4) To evaluate whether there was an association between CT scan diagnosis and stroke specific mortality, 5) To evaluate whether there was an association between admission BP levels and stroke specific mortality, and 6) To evaluate ED overcrowding and other predictors of stroke specific mortality

Summary of the key findings were as follows: a total of 175 (89 males and 86 females) stroke patients visited the ED during the period of data collection. The ED was always overcrowded, with the NEDOCS greater than 100. There were 93 (53.1%) of the stroke patients who arrived at a time when the ED was ‘dangerously overcrowded’ (score of 181-200). Another 73 (41.7%) of the stroke patients arrived when the ED was ‘severely overcrowded’ (score of 141-180) and the remaining 9 (5.1%) arrived when the ED was ‘overcrowded’ (score of 100 – 140).

The most prevalent medical risk factors were hypertension, 162 (92.6%) and diabetes mellitus, 42 (24.0%). Only 70 (40.0%) stroke patients had a CT scan done during admission at the ED. There were 139 deaths representing ED stroke mortality rate of 79.4%. Sex specific stroke mortality rate was higher among females (80.2%) than males (78.7%). Overall, there were 104 (59.4%) patients with ischaemic strokes of whom 78 (75.0%) died. There were 71 (40.6%) haemorrhagic strokes of whom 61 (85.7%) died at the ED. Age ($p = 0541$), being a male ($p = 0.853$), female ($p = 0.798$) and triage BP ($p = 0.419$), not having a head CT scan ($p = 0.318$) for the diagnosis of stroke were not significantly associated with stroke mortality in the univariate analysis.

However, worse scores on the Glasgow coma score ($p < 0.001$), worse triage scores ($p < 0.001$), average overcrowding status of the ED ($p = 0.045$), not having an active national health insurance status ($p = 0.039$) and having haemorrhagic stroke ($p = 0.037$) were significantly associated with stroke mortality. After multivariate adjustment, there were three statistically significant stroke predictors; average patient NEDOCS (AOR = 1.033; 95% C1: 1.003 – 1.064; $p = 0.033$), type of stroke (haemorrhagic stroke) (AOR = 3.834; 95% CI: 1.184 – 12.416; $p = 0.025$) and a medical history of diabetes mellitus (AOR = 3.001; 95% CI: 1.006 – 8.951; $p = 0.049$).

This study promotes the need for qualitative based study of care quality and patient experience. The quality care challenges identified included but not limited to the absence of an in-hospital CT scanner or MRI machine, the non-existence of a comprehensive stroke unit and lack of stroke specialist including neurologist, and the lack of an ED pharmacy and pharmacist. The inability of the hospital to perform stroke specific laboratory tests such as cardiac markers and EEG imaging studies. There was a lack of adequate staff at the ED, delays in patients arriving at the ED at the outset of stroke, high levels of ED overcrowding, boarding and access block throughout the period of data collection. There were poor data collection mechanisms at the ED, lack of use of time-stamped documentation in patients' clinical records, challenges with the use of paper-based patient medical records and frequency of missing records, and the absence of an electronic patient data management system.

Other quality care related issues were the lack of use of the recommended rTPA for thrombolysis, lack of use of NIHSS for neurological assessment, and the lack of-use of the modified Rankin scale for disability assessment. An inability to accurately validate patients medical risk factors was prevalent, as was an inability to carry out all the pharmacological and

non-pharmacological interventions at the appropriate time and expected times. There were delays in receiving care, financial inaccessibility of patients and inability to self-fund recommended investigations and procurement of medications, and inability to electronically predict the overcrowding status of the ED at all times. These were quality care related issues observed and identified at the ED. There is therefore a strong need to conduct qualitative based studies that will assess the quality of care and patients' experience in the future. Most especially, attention should be paid to the issue of poor data management systems and its attendant implications on quality care outcomes.

5.2 Outline of the discussion

An outline of the discussion is as follows: 1) observations of stroke services in the hospital and reflections on the Theory of Care; 2) general mortality outcomes among stroke patients; 3) non-modifiable risk factor and stroke mortality; 4) clinical risk factors and stroke mortality; 5) clinical presentation and stroke mortality; 6) stroke etiology and association with mortality outcomes; 7) CT scan use and stroke mortality laboratory findings and stroke mortality; 8) stroke care and mortality outcome; 9) ED and its impact on stroke mortality outcome; 10) critical evaluation of the findings on the predictors of stroke mortality outcomes; 11) limitations of the study; 12) contributions of this study to literature; 13) conclusion; and 14) recommendations.

5.3 State of stroke services at the Tema General Hospital

There were 175 stroke patients who arrived at the ED of the hospital either as a direct walk-in, 143 (81.7%) or as a referral from another health facility, 32 (18.3%). The mode of transportation at arrival was mostly by a taxi, 154 (88.0%) or in an ambulance, 15 (8.6%) or by a private vehicle, 6 (3.4%). At the ED, the patient was triaged by the triage nurse who then assigned a triage score with colour coding. The triage code (red, orange, yellow, green, or blue) gave an indication of the time needed for physician care to be instituted. Per protocol patients triaged red were to receive attention immediately, those triaged orange were to be attended to within 10 minutes and those triaged yellow were to be attended to within 60 minutes by the physician at the ED.

Every patient that arrived at the ED, was given a patient's clinical record folder (with an identity number) where all the patient information was documented. For this study, the Glasgow Coma

score, modified Rankin scale and blood pressure monitoring sheets were affixed to the folder for ease of structured data capture. Patients' sociodemographic information was recorded in the folder which was also electronically registered in a computer stationed at the ED and assigned an electronic patient identification number. After the physician attended to the patient, the nurses conducted the necessary interventions including taking of blood samples for laboratory test, administration of medications and positioning of the patient in a bed at the ED.

Patients with an active national health insurance status benefitted from minimal laboratory services including full blood count, urine and stool analysis done at the hospital laboratory. Electrocardiogram and chest X-rays services are provided at the hospital, though the machines broke down intermittently. Blood glucose test was conducted for every patient at a cost to the patient. Laboratory tests including liver function, kidney function, international normalised ration (INR), lipid profile and cardiac enzymes among others are performed at a cost to the patient.

For this study, 148 (84.6%) had a full blood count, 138 (78.9%) had blood glucose, 53 (30.3%) had a kidney function test, 51 (29.1%) had a liver function test, 49 (28.0%) had a liver function test, 15 (8.6%) had an electrocardiogram and only 3 (1.7%) had a chest X-ray conducted whiles on admission at the hospital. No patient had an international normalised ratio test, no patient had arterial blood gases done, and none of the patients had cardiac enzymes conducted on them. These findings highlight the dire state of laboratory testing services on stroke patients who accessed care at the ED of TGH.

Appropriate management of stroke patients is dependent on the etiology of the stroke assisted by confirmation findings on a head CT scan and MRI (Morgenstern et al., 2021). All clinically diagnosed stroke patients were required to have a head CT scan to confirm or rule out the diagnosis of stroke. Unfortunately, there was no CT scan or MRI machines or electroencephalogram machine at the TGH at the time of the study and the situation remains unchanged. For this study, only 70 (40.0%) of the patients had a head CT scan done outside the TGH and none had an electroencephalogram conducted on them whiles on admission. Patients who could afford (between $40-$100) had their CT scan conducted outside the hospital usually about 45 minutes to an hour drive to the scanner location.

The cost of CT scan equipment and the cost of individual use of CT scan is high for LICs and LMICs. In India for example, to have a plain CT scan costs about $90 in the context of an

average monthly middle class income of $500 (Yan et al., 2016). A study at the Regional Hospital Limbe in the South-West Region of Cameroon found that 104 (28%) out of 370 patients who had a CT scan could not afford and had to negotiate for direct cost reduction formally through the hospital administration or illegally through staff directly related with service provision (Tambe et al., 2020). According to Tambe et al. (2020), the direct cost of CT scan at the time of their study was between $42-$175 and about 40% of the population of Cameroon lived below the poverty line. In South Africa, head CT scan ranges from R3,600 to R5,500 ($196-$300) and this was found to be financially burdensome patients who needed this imaging service and hospitals that provide these services in poly traumatic patients (Bashir et al., 2019).

According to the Ghana 2020 earnings inequality in the public sector, the average monthly net salary of public sector employees is currently GH₵2,594 approximately £183 (Ghana Statistical Service, 2023). In Ghana, the minimum daily wage for the during the study (2019 and 2020) was GH₵10.65 and GH₵11.82 approximately £0.7 and £0.83 respectively (Ministry of Finance (Ghana), 2019). CT scan cost was between $20-$50 (£16.11-£40.28) in Ghana at the time of the study anecdotally. This placed a huge financial burden on a stroke patient who earned the lower margins of the minimum wage in Ghana. For all stroke patients, supportive care is dependent on a successful evaluation process which includes blood glucose, markers of cardiac enzymes, prothrombin time (international normalised ratio), activated partial thromboplastin time, echocardiograph and for some selected patients, liver and kidney function, pregnancy test, arterial blood gases, chest radiography, electroencephalogram (Jauch et al., 2013; Morgenstern et al., 2021). Interestingly, except for CT scan, MRI, arterial blood gases and electroencephalography most of the investigations were conducted at the TGH at a cost of the patient.

Medications prescribed for the patients were usually provided by the hospital pharmacy at a cost to the patients and in instances where the prescribed medications were not available, patient relatives had to purchase them outside the hospital. Supportive intervention included airways support and ventilatory assistance for patients with decreased consciousness. This was done by providing supplemental oxygen to maintain oxygen saturation at levels greater than 94%. Other interventions included management of elevated temperature (hyperthermia), low temperature (hypothermia), cardiac monitoring for at least the first 24 hours (especially in patients with atrial fibrillation), adequate provision of nutrition and management of seizures.

Blood pressure monitoring and control for both high blood pressure (hypertension) or low blood pressure (hypotension), provision of adequate hydration through the administration of intravenous fluids in stroke patients who are euvolemic or hypovolemic were within the spectrum of stroke care at the ED. Monitoring and control of low blood glucose (hypoglycaemia) and high blood glucose (hyperglycaemia) were key aspects of stroke care. Intravenous fibrinolysis using intravenous recombinant tissue plasminogen activator (rtPA) and endovascular interventions including intra-arterial fibrinolysis, mechanical clot retrieval with the mechanical embolus removal in cerebral ischaemia retrieval system, mechanical clot aspiration with the penumbra system, and acute angioplasty and stenting are part of the advance care provided to stroke patients (Berkowitz, 2016; Jauch et al., 2013; Meschia et al., 2014; Morgenstern et al., 2021). At the TGH, most of these interventions were provided except for the use of intravenous fibrinolysis (using recombinant tissue plasminogen activator) and endovascular interventions. This is because the expertise, skills and the needed equipment to undertake these interventions and monitor the safety of the patients were not readily available and they were also not instructed in the standard treatment guidelines for stroke management in a district hospital (Standard Treatment Guidelines, 2017).

When patients were admitted, the determining factor for transfer of the patient to an in-hospital bed was the availability of the bed. In all instances, there were no available in-patient bed and that meant that the patient had to remain (board) at the ED till a bed become available. It is important to note that the TGH does not have a specialised stroke unit, therefore patients who needed stroke specialist care were referred mostly to the highest referral hospital in Ghana, the Korle Bu Teaching Hospital, which was about an hour and an hour and half drive from the TGH. Again, it is important to mention that a successful transfer to the Korle Bu Teaching Hospital with a resultant admission of the patients was based on the availability of a bed at the referral hospital. In instances, where Korle Bu Teaching Hospital did not have an available admission bed, the patient had to wait (board) at the ED of the TGH to such a time when a bed became available. Secondly, the transportation of the patient to the Korle Bu Teaching Hospital was by an ambulance at the cost of the patient $20-$50 (£16.11-£40.28).

Establishing best practices in stroke care remains a challenge in LICs and LMICs (Berkowitz, 2016). Owolabi et al. (2021) compared data on stroke services in 84 countries (34 countries from HICs, 23 from UMICs, 21 from LMICs and 6 from LICs) across the World Health Organization regions and economic strata. They found that stroke units were statistically

significantly present in 91% of HICs in contrast to 18% of LICs and acute stroke treatments were offered in approximately 60% of HICs compared to 26% of LICs (Owolabi et al., 2021). A survey of hospital services towards the best practice of stroke care in Ghana in 11 major referral hospitals (including regional and tertiary teaching hospitals) found limited evidence based services for acute stroke care (Baatiema et al., 2017). They found that thrombotic therapy using recombinant tissue plasminogen activator for acute stroke care was not available in any of the study hospitals. None of the hospitals had an occupational or a speech pathologist to support stroke care and only 4 out of the 11 hospitals had a neurologist specialist (Baatiema et al., 2017).

Task sharing such as the physician-led and non-specialist-led models of care for stroke patients is largely practiced in LMICs such as India, Armenia and Malaysia (Sebastian et al., 2023). Stroke management in LICs and LMICs is usually complicated by the unavailability of resources, unavailability of the full diagnostic set and therapeutic modalities, limited specialist healthcare facilities which are usually present in HICs (Kaseke et al., 2020; Tilo et al., 2020). At discharge, the patient was either alive or dead. The TGH has a mortuary to accommodate dead patients till relatives followed administrative procedures to claim the corpse for burial.

5.3.1 Reflections on the moral ethics and the Theory of Care

Reflecting on stroke services at the TGH (described in Chapter 5, section 5.3), the moral ethics and the Theory of Care (Busse et al, 2019; Hankivsky, 2014, 2014, 2014; Kaufman-Osborn et al., 2018; Sander-Staudt, 2021; Tronto, 1993) as presented in Chapter 1 (section 1.16), there was a moral and professional obligation on the staff of the ED to care about, take care of and provide actual, adequate, and effective care for the stroke patients. This category of patients were vulnerable, dependent and had expectations of receiving care that will help them to survive the 'attack.' Unfortunately, the barriers of care as explained in the preceding paragraphs made the realisation of the full components of the Theory of Care practically impossible.

This was reflected in the high proportions of mortality among the stroke patients that were recorded during the study period as will be detailed in section 5.5. As enthusiastic as the staff may be in desiring to provide effective and efficient care, the lack of resources and lack of implementation of evidence-based policies will continue to hinder care and lead to undesired patient outcomes. In the recommendations (section 5.19) it is suggested that it would be useful

to carry out qualitative research using the Theory of Care within the context of the ED in a low resource setting.

5.4 Settings for data collection at the emergency department

Data for this study was extracted from the patients' clinical record folders. Data for all stroke patients were collected and entered in the electronic data extraction tool once the information became available to the research team. Once the patient entered the ED and a patient identity number was provided, this was captured using the structured electronic data extraction tool by the research assistants. The health information officer at the ED assisted the research assistants with relevant patient sociodemographic information that has been captured in the administrative records at the ED and in the patient's folder. The healthcare staff were all aware of this study as they had been engaged and oriented on the aim and objectives of the study. They assisted the research team with the relevant patient information where necessary. This did not interfere in anyway with their routine work. Patients' records were prospectively followed during their entire stay at the ED. Data was collected for 6 months from October 2019 to March 2020.

5.5 Mortality outcomes among stroke patients

Out of the 175 stroke patients, there were 139 (79.4%) stroke deaths of which 70 (50.4%) were males and 69 (49.6%) were females. An in-hospital stroke case fatality of 79.4% for this study is considered extremely high when compared to rates in other studies conducted in Ghana. One of the earliest stroke study in Ghana was conducted at the Korle Bu Teaching Hospital, where the proportion of stroke deaths among all 9,760 natural adult deaths between 1994 to 1998 was found to be 1,086 (11.13%) (Wiredu & Nyame, 2001).. In that study by Wiredu & Nyame (2001), stroke deaths were confirmed by autopsies. A recent study at the Korle Bu Teaching Hospital in Ghana also found a high stroke case fatality of 52.0% among 68 stroke patients at the ED and 35.0% among 182 stroke patients at the medical inpatient ward (Ofei-Palm et al., 2022). Stroke case fatality rate in a hospital at the Komfo Anokye Teaching Hospital in Ghana has been reported to be 5.7% at 24 hours, 32.7% at 7 days and 43.0% at 28 days among 1,054 admitted stroke patients (Agyemang et al., 2012). Stroke case fatality rates in other low resource settings have been found to be lower compared to the rates for this current studies. For example, stroke mortality rates have been reported for studies in Sierra Leone (34.8%) (Russell et al., 2020), Madagascar (30.0%) (Stenumgård et al., 2017), Zambia (40.0%)

(Atadzhanov, 2012), Nigerian (23.8%) (Desalu et al., 2011), Kenya (5.0%) (Jowi & Mativo, 2008), Democratic Republic of Congo (31.7%) (Kamabu et al., 2020), Ethiopia (12.0%) (Gebremariam & Yang, 2016), Sri Lanka (11.7%) (Shalini Ranasingheid et al., 2023), and Burkina Faso (39.1%) (Dabilgou et al., 2020).

In-hospital stroke mortality among 220 stroke patients in a Namibian tertiary level hospital was found to be 26.4% (Neshuku et al., 2023) relatively lower than what was found in this current study. Relatively, lower stroke mortality rates of 11.6% among 825 stroke patients was reported in a study in a university teaching hospital in Grenada, Spain (Maestre-Moreno et al., 2017). In an ED in Queensland, Australia where 921 adults presented between 2010 to 2015 with stroke, relatively very low stroke mortality rates of 1.4% were reported (Bernaitis et al., 2019).

In a HIC like the UK, a prospective registry-based study of 6,923 adult patients admitted to various hospitals with acute stroke registered a 7 day in-hospital stroke mortality rate of 9.4% (Douiri et al., 2021) extremely lower compared to the 7 day stroke mortality rate of 74.9% for this current study. These hospitals in the UK have stroke units, acute medical admission units, critical care unit among others and interventions like intravenous thrombolysis for ischaemic stroke patients were carried out for 14% of them, of which 59.8% was effected within 1 hour (Douiri et al., 2021). Also, within 4 hours, 66.6% of the stroke patients were directly admitted to stroke units with 93.0% receiving stroke specialist nurse assessment within 24 hours, 88.1% receiving stroke specialist physician assessment within 24 hours and 96.4% who received stroke specialist assessment within 72 hours (Douiri et al., 2021). The extent of care and availability of evidence-based interventions might be the gap that explains the high stroke mortality rates experienced for this current study that was conducted at the TGH where there is no stroke unit, no stroke specialist nurse, no stroke specialist physician, and no intravenous thrombolysis available for ischaemic stroke patients.

5.6 Non-modifiable stroke predisposition risk factors

Non-modifiable risk factors including age and sex were examined for this study and how that predisposed patients to stroke and mortality outcomes.

5.6.1 Age and predisposition to stroke and mortality outcome

Stroke remains a common acute medical emergency in most hospitals including Italy (Salvadori et al., 2021), Ghana and Nigeria (Kumi et al., 2022; Sarfo et al., 2018), South Africa (Feris et al., 2020; O'Meara et al., 2022), Australia (Middleton et al., 2019), United Kingdom (Grunwald et al., 2020; Haworth & McClelland, 2019; McClelland et al., 2022), other European countries (Aguiar de Sousa et al., 2019) and in many parts of Africa (Roushdy et al., 2022). There are known risk factors with predisposition to stroke. These risk factors are categorised as modifiable (clinical and behavioral) or non-modifiable (Boehme et al., 2017). Some of the non-modifiable risk factors include age, sex, ethnic group, and genetic predisposition to stroke. For this study, age and sex were studied as risk factors and their association with stroke mortality was analysed.

Among the 175 patients recorded in this study, 89 (50.9%) were males and 86 (49.1%) were females. The overall mean age was 59.9 ± 13.9 years. The mean age for the 89 males (58.4 ± 12.6 years) was lower compared to the mean age of the 86 females (61.5 ± 15.1 years). A younger population (less than 65 years for this study) constituted the majority (119, 68.0%) of the stroke patients. The youngest stroke patient identified in this study was a 15-year-old female. The predominance of stroke among younger people in Ghana has been documented in previous studies (Agyemang et al., 2012; Edzie et al., 2021).

High stroke burden of stroke among the youth is potentially worrying (Smajlović, 2015) especially as they form the majority of the working class in Ghana (Aryeetey et al., 2021). Stroke among young people has emerged as an important public health concern as it leads to a long term DALYs, physical and psychosocial dependency on the family and the society (Murray, et al., 2020) with long term economic effect on the country. The gradual increase in the global incidence of strokes among younger people have been demonstrated to be due potentially to the increase in modifiable life style risk factors (Kissela et al., 2012), and medical risk factor including hypertension and diabetes mellitus among this age bracket (George et al., 2017).In Karela India, higher incidence of stroke among the younger population with a mean age of 65.30 ± 12.80 years (Subha et al., 2015) has been recorded. On the contrary, other studies have also found increased incidence of stroke among ageing populations, example in the USA, Singapore, Thailand, Hong Kong and Korea among other HICs (Teh et al., 2018). Interestingly, countries in sub-Saharan Africa including Ghana, Mozambique, Democratic Republic of Congo among others are currently witnessing demographic transitions with attendant ageing

population, urbanisation, and improved sociodemographic characteristics. The incidence and prevalence of stroke is therefore expected to be higher among the ageing populations in these countries in the future (Sanuade et al., 2019).

There has been increased incidence and hospitalization of young people with stroke in the USA (George et al., 2017), in Tanzania (Matuja et al., 2020) among others. As a proposed explanation, younger people have been reported to have increased vascular risk factors that predisposes them to stroke resulting from increasing incidences of hypertension, diabetes mellitus, dyslipidaemia, alcohol consumption and smoking among this age group (Boehme et al., 2017). Young adults with first-ever ischaemic stroke were found to have relatively high rates of smoking and a lower rate of hospital arrival by ambulance compared to older patients with stroke in a national acute stroke Israeli registry study (Shuaib et al., 2017).

These predisposing factors which is increasingly becoming prevalent among the younger population may be contributing to the eventual worse severity outcomes among that population (Smajlović, 2015). Geographically, the higher incidence of stroke among the younger population in LICs and LMICs compared to HICs has be worsened by the differences in the risk factors including infections like HIV, lesser detection of vascular risk factors due to resource constraint, sociocultural difference in health seeking behaviour among others (Boot et al., 2020). Also, with the increasing life expectancy in Ghana, coupled with improvement in stroke care though not at the most desired level, the expectations are that the number of stroke survivors and recurrent strokes will increase (Béjot et al., 2019). This foreseeable epidemiological projection needs some attention so that the needed comprehensive services for stroke survivors will be adequately provided.

For this study, there were 139 (79.4%) stroke deaths and 36 (20.6%) survivors. Among the 119 patients who were less than 65 years, 95 (79.8%) of them died representing a higher mortality rate compared to 44 deaths among 56 patients who were 65 years and above. Also, the mean age of the mortality group (59.60 ± 13.54 years) was lower than the surviving group (61.19 ± 15.43 years; $p = 0.541$), although this was not statistically significant. Increase in stroke related mortalities has been reported among younger people in other LMICs (Gedefa et al., 2017; Greffie et al., 2015). For this current study, younger stroke patients reported with significant higher systolic blood pressure (177 ± 48 vs 144 ± 54 mmHg), significant higher mean arterial pressure (119 ± 25 vs 111 ± 23 mmHg), significant worse Glasgow coma score (8.1 ± 3.6 vs 8.8 ± 3.4), significant worse mRS (5.3 ± 1.4 vs 5.4 ± 1.2) and significant shorter length of stay

at the ED (41.6 ± 42.0 vs 69.4 ± 62.6 hours). This is indicative of significant increase of stroke severity among young people in this current study which eventually correlated with mortality outcomes.

Younger people less than 45 years with stroke in a study in Tanzania were found to be associated with a new diagnosis of hypertension, use of hormonal contraceptives among females, plasma lipid abnormalities, thrombocytosis and stroke severity (Matuja et al., 2020). Younger patients with severe stroke will need advanced intensive care services, longer and more intensive hospitalisation, and rehabilitation services (Salvadori et al., 2021) which were barely present at the TGH. This could partially explain the high case fatality among stroke patients in general at the ED of the TGH. The younger age distribution for this study needs consideration when explaining higher mortality outcomes among that group. Among the 36 stroke survivors, 23 (62.9%) of them at the time of discharge had severe disability using the modified Rankin scale (mRS of 3-4). This was similar to findings of the extent of disability among stroke patients in studies carried out in Ethiopia, Sierra Leone, Spain and Madagascar among others (Deresse & Shaweno, 2015; Kortazar-Zubizarreta et al., 2019; Russell et al., 2020; Stenumgård et al., 2017; Salvadori et al., 2021).

5.6.2 Gender and predisposition to stroke and mortality outcome

There was no significant sex bias in the number of strokes among the 89 males 86 females (86) who reported with stroke at the ED. This was similar to findings in a study carried out in a referral hospital in Ethiopia (Temesgen et al., 2018). On the contrary other studies that found stroke to be common among females in some parts of Ghana (Akpalu et al., 2019), Gambia and Sierra Leone (Awad et al., 2014) and Northwest Ethiopia (Greffie et al., 2015). In this current study, males were more likely to be married (74.2% vs 54.7%) and more likely to be employed (57.3 vs 37.2%) whereas females were more likely to have active national health insurance enrolment status (60.5% vs 87.6%). From the literature, it is known that risk factors for getting stroke differ between males and females. For example males might be more likely to drink (Smyth et al., 2023).

Among the 89 males in this current study, only 10.0% were found to consume alcohol as against none among the 86 female stroke patients. Findings from the INTERSTROKE study in 32 countries (from Asia, America, Europe, Australia, the Middle East and Africa) (O'Donnellet al., 2016) showed that high levels of alcohol was consistently associated with increased odds

(OR 1.14; 95% CI 1.04–1.26) for all stroke (Smyth et al., 2023). Another study on population drinking and gender gap in stroke mortal mortality in Russia between 1980 to 2015 found that the overall levels of alcohol consumption was significantly associated with the gender disparities in the mortality rate of stroke (Razvodovsky, 2020). To the extent that an increase in the gender levels of alcohol consumption by one litre lead to an increase in the gender difference in the mortality rate by 6.1% (Razvodovsky, 2020). In that study alcohol was found to be responsible for 55.3% of the gender gap in the rate of stroke death (Razvodovsky, 2020). As part of the international alcohol control study carried out in Australia, England, Scotland, New Zealand, St Kitts and Nevis (high income), Thailand, South Africa, Mongolia and Vietnam (middle income), high frequency drinking was found to be greater in HICs especially in the older groups with less frequent drinking among the MICs though heavier typical quantities (Chaiyasong et al., 2018). Also, the percentages of high frequency, heavier typical quantity and higher risk drinking were greater among men than in women in all the nine survey countries (Chaiyasong et al., 2018).

In contrast, for females, oral contraceptive is a risk factor for stroke (Reddy et al., 2022). Previous studies have shown that higher dosages of oestrogen use and prolonged duration of oral contraceptive use significantly increases the risk of total stroke, ischaemic stroke and haemorrhagic stroke whiles cessation of use significantly decreases the risk of total stroke (Carlton et al., 2018; Li et al., 2019). The prevalent use of oral contraceptives especially among younger females have also been found to be associated with increased incidence of especially ischaemic stroke among younger females (Correia et al., 2021; Reddy et al., 2022). Alcohol and oral contraceptive use as risk factors for stroke were not variables assessed for this study as the clinical data set already collected as part of routine clinical records did not detail information on these variables.

5.7 Modifiable stroke predisposition risk factors

Risk factors like hypertension, diabetes mellitus, smoking, alcohol use, dyslipidaemia, vascular risk factors, physical inactivity and obesity are known to contributed close to 90% of stroke and subsequent clinical outcomes (Benjamin et al., 2019; Boot et al., 2020; GBD 2019 Stroke Collaborators, 2021; Pandian et al., 2018). For an individual, a risk pathway might look like this Alcohol > obesity > diabetes mellitus > hypertension > stroke.

5.7.1 Clinical risk factors and predisposition to stroke and mortality outcome

The two commonest proximate clinical stroke risk factors for this current study were found to be hypertension and diabetes mellitus. This is similar to the findings in the previous SIREN and INTERSTROKE studies in Ghana and Nigeria, Sierra Leone and other LMICs (Akinyemi et al., 2021; Fekadu et al., 2019; Lisk et al., 2020; Owolabi et al., 2018; Sarfo et al., 2018). Since 1965, publications from the Framingham trial has identified high blood pressure (both systolic and diastolic) as an important precursor to cardiovascular diseases and the leading risk factor for all stroke (Wolf, 2012). In this current study, history of hypertension was recorded among 162 (92.6%) patients and history of diabetes mellitus among 45 (25.7%) patients. This is similar to findings in a study in Nigeria by Desalu et al. (2011) where hypertension prevalence was 85.2% and diabetes mellitus 23.8%, in Kenya, a prevalence of 80% was found for hypertension and 33.7% for diabetes mellitus (Jowi & Mativo, 2008), in Sri Lanka, hypertension prevalence was 56.1% (Shalini Ranasingheid et al., 2023).

In the current study, the proportions of hypertensive history were higher among patients less than 65 years (94.1% vs 89.3%) and diabetes mellitus were higher among patients 65 years and above (32.1% vs 20.2%). Male stroke patients presented with a higher burden of hypertension (94.4% vs 90.7%) whiles the females presented with higher burden of diabetes mellitus (30.3% vs 18.0%). Lower rates of pre-existing hypertension (33.8%) and diabetes mellitus (4.9%) were however recorded among 142 stroke patients in a tertiary teaching hospital in Ethiopia (Gebremariam & Yang, 2016).

Another study in South East Nigeria also showed hypertension and diabetes mellitus as the commonest risk factors for stroke (Eze et al., 2013) in variance to the findings of this study at the TGH. For this current study, patients and their relatives gave history of the presence or absence of risk factors like hypertension and diabetes mellitus. In some instances, a few patients or their relatives provided samples of antihypertensives or anti-diabetic medications or treatment prescriptions to indicate the presence of these risk factors. Assessing the duration of these risk factors was difficult as most of the patients were in poor clinical condition and unable to adequately communicate as their level of consciousness was compromised and patient relatives could not be certain on the duration of the existence of these risk factors. It was also difficult to determine whether patients with these risk factors had them controlled or

uncontrolled. These issues with data quality could explain the variations found in this study regarding stroke risk factors and how they impacted the overall outcome of the patients.

For this study, the proportion of hypertension (97.2%) was higher among patients with haemorrhagic stroke than the proportion among patients with ischaemic stroke (89.4%). In contrast, the proportion of diabetes mellites (36.5%) was higher among ischaemic stroke than the proportion among patients with haemorrhage stroke (5.6%). There were 32 (18.3%) of the stroke patients who had both hypertension and diabetes mellitus. These findings are similar to a study a study at the ED of the Yalgado Ouedraogo University Hospital in Burkina Faso among 302 ischaemic stroke patients (Dabilgou et al., 2020). In that study, Dabilgou et al. found hypertension to be the commonest risk factor in 54.2% of stroke deaths. A study in the Tamale Teaching Hospital in Ghana among 105 stroke patients also found hypertension (88.6%) as the commonest medical risk factor followed by diabetes mellitus (38.1%) (Kumi et al., 2022), similar to the findings in this current study. Ischaemic strokes in general have been found to have better prognosis compared to haemorrhagic strokes (Balami & Buchan, 2012; Woo et al., 2022). Risk factors that support the incidence of ischaemic stroke such as atrial fibrillation, previous myocardial infarction and intermittent claudication (Andersen et al., 2009) could not be determined among the stroke patients who reported to the ED as they had no prior knowledge of such medical conditions and hence their impact on stroke mortality could not be established.

Among the 139 stroke patients that died per this current study, 130 (93.5%) had hypertension and 36 (25.9%) had diabetes mellitus as a risk factors. Alternatively, 130 (80.2%) out of the 162 with hypertension as a risk factor died and 36 (85.7%) out of the 42 stroke patients with diabetes mellitus died. Out of the 32 patients who had both hypertension and diabetes mellitus, 30 (93.8%) died. This gives an indication of high proportions of mortality among patients with a risk factor of hypertension and or diabetes mellitus. The presence of hypertension and diabetes mellitus was however found not be statistically significant among the mortality group. Other lifestyle risk factors could not be assessed as there was no patient who admitted to smoking and only a few patients admitted to physical inactivity (28 out of 175 patients) and alcohol use (9 who were all males out of 175 patients). Albeit a study by Sanuade et. al (2019) found no significant correlations between lifestyle factors and the prevalence of stroke.

5.8 Clinical presentation and stroke mortality

At presentation, higher bodily temperatures and lower blood oxygen saturation were found to correlate significantly to death among stroke patients. However, patients' heart rate, respiratory rate and systolic blood pressure were not significantly associated with mortality. Surprisingly, the time taken between the onset of symptoms to arrival at the ED did not correlate significantly with mortality outcomes. However, the door to doctor time had a significant association with stroke mortality outcomes. In other studies, shorter time from stroke onset to admission has been indicated to improved clinical outcomes at discharge (Ayehu et al., 2022; Harari et al., 2020). Patients with worse clinical presentation who were immediately attended to did not show marked difference in their mortality outcome compared to those who had an extended door to doctor time.

Stroke mortality is generally associated with stroke severity (Andersen et al., 2009; Ekeh et al., 2015; Nakibuuka et al., 2015; Namale et al., 2020). Patients with haemorrhagic stroke presented with worse severity as determined by the GCS (7.4 ± 3.6 vs 9.0 ± 3.4) and modified Rankin scale (5.7 ± 0.9 vs 5.1 ± 1.6) as well as the systolic BP (209 ± 40 vs 138 ± 39 mmHg) and MAP (129 ± 23 vs 109 ± 22 mmHg) at presentation. The triage scores ($p < 0.001$), GCS ($p < 0.001$), and the mRS ($p < 0.001$) correlated significantly with mortality outcomes. For example, the proportion of mortality was high among patients with patients whose triage scores were graded as emergent (94.9% of whom died) than patients whose triage scores were graded as urgent (5.1% mortality). Again, proportions of stroke mortality were higher among patients with severe brain injury (95.8% vs 47.1%) showed by an admission Glasgow Coma Score of 3 – 8 compared to patients with Glasgow coma score suggestive of mild brain injury (13 – 15). It is worth noting that some studies have found haemorrhagic stroke to have worse clinical presentations and associated mortality outcomes (Balami & Buchan, 2012; Salvadori et al., 2021; Zarean et al., 2021).

Other clinical presentations like urine incontinence (69.7% vs 5.7%; $p < 0.001$) and stool incontinence (68.0% vs 4.6%; $p < 0.001$), which were highly prevalent among the mortality group, was statistically significant. The same was true for patients who had aspiration pneumonitis (45.1% in the mortality group vs 2.9% in the survivors; $p < 0.001$), facial palsy (28.0% vs 12.6%; $p = 0.005$), difficulty in swallowing (24.6% vs 0.6%; $p < 0.001$) and signs of raised intracranial pressure (22.9% vs 0.6; $p < 0.001$). These clinical presentations also

highlight the severity of stroke presentations, and it stands to explain the higher case fatality among patients who presented with these symptoms (Nakibuuka et al., 2015; Woo et al., 2022).

5.9 Stroke etiology and association with mortality outcomes

Clinical diagnosis of stroke is based on history and physical examination of the patient and confirmatory diagnosis is based on the CT scan or MRI imaging findings. Ischaemic stroke patients usually present with classical history of acute onset, focal weakness and speech disturbance (Nor et al., 2005). Patients with haemorrhagic stroke (intracerebral or subarachnoid bleed) usually present with severe headache with other symptoms such as vomiting, seizures, meningismus and depressed consciousness (Suarez et al., 2006). Severe hypertension has been found to be commonly associated with haemorrhagic stroke (Kitagawa, 2022). Overall, the accuracy of physician diagnosis of stroke is good with lower reliability among less experienced and less confident examiners (Hand, et al., 2006).

Majority of the patients reported with ischaemic strokes 104 (59.4%) and haemorrhagic stroke patients were younger (55.3 ± 12.6 vs 63.1 ± 14.1 years). The incidence of ischaemic stroke is generally higher compared to haemorrhagic stroke as evidenced from studies in Czech Republic; (subarachnoid haemorrhage, 6.9; intracerebral haemorrhage, 26.4; and ischaemic stroke, 180 cases per 100,000) (Sedova et al., 2021), and Sri Lanka (79.7%) (Shalini Ranasingheid et al., 2023) among others. Haemorrhagic stroke usually contributes 10 – 20% of all strokes (An et al., 2017; S. Chen et al., 2014) and in the USA, UK and Australia 8-15%, and 18-24% in Japan and China (Unnithan et al., 2023). Similar higher incidence ischaemic stroke (86.3%) have been reported in a UK hospital where 6,923 acute stroke patients were studied (Douiri et al., 2021).

Out of the 105 stroke patients diagnosed clinically, 63 (60.0%) were ischaemic and 42 (40.0%) were haemorrhagic. Among the 42 patients with haemorrhagic stroke, 37 (88.1%) died representing a higher proportion of death compared to 50 (79.4%) deaths that occurred among 63 clinically diagnosed ischaemic stroke patients. High case fatality among haemorrhagic stroke patients have been supported by studies in Uganda (Namale et al., 2020) and South Korea (Choi et al., 2022). Summarily (71 haemorrhagic and 104 ischaemic strokes), the overall proportion of haemorrhagic deaths (both clinical and CT scan diagnosis) were higher, 61 (85.9%) out of compared to 78 (75.0%) ischaemic deaths. These findings were similar to that

of the SIREN study where higher proportions of haemorrhagic deaths than ischaemic deaths were reported (Fekadu et al., 2019; Gedefa et al., 2017; Zewudie et al., 2020).

Overall, 65 (46.8%) deaths occurred within 24 hours, 103 (74.1%) within 3 days, 134 (96.4%) within 7 days and 139 (100.0%) within 14 days. Also, 15 (10.8%) of the 139 deaths occurred in the first 6 hours upon arrival at the ED. The median length of stay was found to be significantly shorter among the mortality group (29.22 vs 42.36 hours; $p = 0.046$). These high early stroke mortalities recorded for this current study were found to be higher when compared to other studies in LIC and LMICs. For example, a related study at Jos University Teaching Hospital in Nigeria recorded a 7 day stroke mortality rate of 76.2% among 120 admitted stroke patients (Ekeh et al., 2015). Also in Mulago National and Teaching Hospital, Uganda, the 7 days in-hospital stroke deaths was found to be 6.3% among 127 admitted stroke patients (Nakibuuka et al., 2015). These mortality rates were lower compared to what was recorded in this current study.

The proportion of death among patients with haemorrhagic stroke within the first 24 hours at the ED was higher (54.1% vs 41.0%) than the proportion of deaths among patients with ischaemic strokes. Again, the proportion of death among patients with haemorrhagic stroke within the first 3 days at the ED was higher (77.0% vs 71.8%) than the proportion of deaths among patients with ischaemic strokes. However, by day 7 the proportion of death was higher among patients with ischaemic strokes deaths (97.4% vs 95.1%) than patients with haemorrhagic stroke. Empirically, as described in the earlier in the discussion session, haemorrhagic deaths occurred earlier than ischaemic strokes, due to the severity of their presentation and the absence of advanced stroke care and related life-saving intervention, such as hematoma evacuation and endovascular interventions which are not performed at the TGH.

This observation is however different from what has been seen in HICs where the standard of stroke care is better and advanced. For example, a study of 5,790 stroke patients admitted in an inner city area in South London between 1995 to 2015 recorded an increase in stroke unit admission from 32.2% to 86.3% respectively (Emmett et al., 2019). This observation was accompanied by a corresponding increase in brain imaging rates from 92.4% to 100% between 1995 and 2015 respectively and a resultant in-hospital mortality rates decreasing from 34.1% to 13.7% over the same period (Emmett et al., 2019). These improvements were attributed to the implementation of evidence-based stroke guidelines (Royal College of Physicians UK, 2017). In another study in Greater Manchester, UK, the number of patients treated in a

hyperacute stroke unit witnessed a sustained significant increase from 39% in 2010-12 to 86% in 2015/16 with a corresponding significant reduction in in-hospital stroke mortality by 1.8% and shorter length of acute hospital stay by 1.5 days (Morris et al., 2019). This goes to show that when stroke care improves, in-hospital mortality rates decline, and stroke survival increases.

5.10 CT scan use and stroke mortality

Early diagnosis of stroke influences treatment appropriate interventions and the overall impact on mortality outcomes (Ayehu et al., 2022). CT scan imaging is the basic and simplest diagnostic method to differentiate the etiology of stroke (Weichet et al., 2022). As recommended, a suspected stroke patient is expected to have a CT scan within 3 hours of symptoms onset to guide appropriate intervention and limit the impact on brain damage (Sacco et al., 2013). In this current study, only 70 (40.0%) of the 175 stroke patients were able to have a CT scan done whilst on admission at the ED. This brain imaging rate is generally and comparatively low. In a middle income country, for example, the Proyecto Investigación de Stroke en Chile: Iquique Stroke Study (PISCIS) in Latin America found that 91.0% of 380 stroke patients had head CT scan carried out whilst admission (Lavados et al., 2005) as far back as two decades ago.

In Ghana, a study at the Tamale Teaching Hospital showed that, about 25.0% of 105 stroke patients had a CT scan performed on them within 24 hours whiles on admission in the hospital (Kumi et al., 2022). The Tamale Teaching Hospital has a CT scan machine though reports from Kumi et al. (2022) showed that for the period of their study, the CT scan machine was intermittently non-functional as some of the patients had to undergo CT imaging at a private health facility outside the hospital. At the Yaoundé Central Hospital, the largest hospital in the capital city of Cameroon, another LMIC, CT brain images were conducted among 1,048 (62.1%) out of 1,688 stroke patients on admission (Lekoubou et al., 2016) relatively higher than the 40% recorded for this current study. Interestingly, the medical department in Cameroon had a better human resource capacity when their study was done (four emergency physicians, two intensivists, three neuro-radiologist, three neurosurgeons among others) (Lekoubou et al., 2016) when compared to the staffing situation at the ED of the TGH that had only one emergency physician and no other stroke specialist at the time of this current study. This limited

human resource capacity and limited CT scan diagnosis in this current was consistent with reports in an earlier study in 11 hospitals in Ghana (Baatiema et al., 2017) .

However, the 40% CT scan brain imaging rates for this current study was found to be relatively higher when compared to findings in a teaching hospital in Nigeria (Ogbole et al., 2015). In that study, 30.6% of 271 stroke patients with CT scans had full retrievable results for evaluation during their stay in the hospital and a recorded a mean CT imaging results time of about 70 hours (Ogbole et al., 2015). In an ED in Burkina Faso, 1.5 days was recorded as the CT scan results availability time (Dabilgou et al., 2020). For this current study, the door to CT results time was 9.5 hours shorter time than the findings from the study in Nigeria and Burkina Faso stated above. This raises the challenge of not having access to CT scan results even in instances where the scans are even conducted in LICs and LMICs. Poor documentations in poor resource settings have compounded the challenged of quality of stroke care the need to improve on documentation where stroke care in involved using standardised clinical record gathering tool has been advocated (Patel, 2015).

The median CT results time for this current study was 12.6 hours which is a longer time than a median CT results time of 4 hours in a study in 14 public hospitals in Malaysia (Hwong et al., 2016). The situation is better in UK hospitals, where for example 58.9% of 6,923 admitted stroke patients had brain CT scan within 1 hour where CT scan imaging are readily available in hospitals (Douiri et al., 2021). It is important to note that some of the barriers identified as possible reasons for the low penetration and usage of CT scan machines in LICs and LMICs include among others, the lack of investment plans and prioritization, high cost of CT scan machines, maintenance and safety and lack of human resource capacity to operate the scanners (Frija et al., 2021). In a qualitative study in a major referral hospital in Ghana, 75.0% out of 114 CT scan confirmed stroke patients were reported to have had delayed scans (Duodu et al., 2022). The reasons identified according to Duodu et al. (2022) were late request of CT scan by the emergency physician (35.0%), delay in transporting patient to the scan facility by health worker (25.0%), financial constraints (16.7%), unavailability of CT scan services (13.3%) and lack of radiographers (10.0%) (Duodu et al., 2022). To overcome these challenges, there is a need to proffer sustainable, cost effective, efficient, effective technical solutions.

There were 70 patients in this current study who had confirmatory head CT scans and the remaining 105 were only clinically diagnosed. The proportion of patients diagnosed as ischaemic stroke without CT scan were 63 (60.0%) and those with ischaemic stroke confirmed

by CT scan, 41 (58.6%) were higher compared to haemorrhagic strokes without CT scan, 42 (40.0%) and haemorrhagic stroke with CT scan confirmation, 29 (41.4%). This is consistent with other studies where CT scan confirmation of ischaemic stroke were more than haemorrhagic stroke (Lisk et al., 2020; Russell et al., 2020; Temesgen et al., 2018). The proportions of death among patients with haemorrhagic stroke with CT scan confirmation was 24 (82.8%) which was higher than ischaemic stroke patients confirmed by CT scan who recorded 28 (68.3%) deaths. Overall, mortality rate among the 105 patients who did not have a CT scan was 87 (82.9%) and this was higher when compared to a mortality rate of 74.3% among the 70 stroke patients who had a CT scan done.

The primary reason for the low usage of CT scan was the non-availability of a CT scan imaging machine at the TGH and the cost of access to CT scan imaging services. This posed accessibility challenges, coupled with the challenge of having to move the patient to distant location of about an hour or more outside the hospital to have a head CT scan done. The availability or unavailability of an ambulance to transport the patient at his or her own cost was another accessibility barrier. This was because CT scan and ambulance services were not covered by the national health insurance scheme. However, it is interesting to note that the possession of an active national health insurance status was not significantly associated with stroke mortality outcomes. Even for the few patients who had a CT scan done and stroke subtypes determined, there was no statistically significant association with mortality outcome. In effect several other factors must synergistically work to establish causality for stroke mortality.

5.11 Laboratory findings and stroke mortality

The mean admission blood glucose was higher (11.5 ± 5.9 mmol/L) among the mortality group compared to the survival group (10.2 ± 4.3 mmol/l) though it was not statistically significant. There was no significant difference in the mean admission blood glucose levels among patients with haemorrhagic stroke (11.3 ± 5 mmol/l) and patients with ischaemic stroke (11.3 ± 6.1 mmol/l). This is contrary to other studies that have found severe neurological deficit (Zhao et al., 2017) and mortality outcomes among stroke patients with high blood glucose at admission (El-Gendy et al., 2021; Zarean et al., 2021). In another study involving 2,839 acute intracerebral haemorrhage stroke patients, hyperglycaemia was found to be significantly associated with poor outcomes (Saxena et al., 2016). Also, hyperglycaemia was found to be

associated with poor neurologic severity among 228 acute haemorrhagic stroke patients (Zhao et al., 2017). Hyperglycaemia has also been found to be associated with poor outcomes among 344 intracerebral haemorrhage stroke patients who underwent neurosurgical interventions (Chen et al., 2021). High admission glucose has also been linked to less favourable outcomes among ischaemic stroke patients after thrombolysis (Desilles et al., 2013). Where for example, persistent hyperglycaemia within 24 hours at admission correlated with an increased risk of mortality within 30 days and haemorrhagic transformation under CT scan imaging within the first 7 days after stroke onset among 91 non-diabetic patients with acute ischaemic stroke (Mi et al., 2018).

Following an acute stroke, stress counter regulatory hormones including glucagon, growth hormones, catecholamines are released and they lead to increased gluconeogenesis among others that results in increased insulin resistance which potentially increases the levels of glucose in the body (Marik & Bellomo, 2013). Secondarily, the high levels of blood glucose during a haemorrhagic stroke may also contribute to exaggerated neuroinflammatory processes and oxidative stress and in some instances may lead to the breakdown of the blood brain barrier as a resultant vasogenic brain oedema, increased brain cell death in the perihaematomal areas (Chiu et al., 2013) and eventual poor outcomes among stroke patients.

Though studies have found associations between high admission glucose and stroke mortality outcomes worse among patients with haemorrhagic strokes, it still is uncertain the causal relationship between high blood glucose at admission and outcome among stroke patients. The blood glucose measured provides insufficient information on glucose haemostasis response dynamic changes with regards to premorbid glycaemic control. Preferably, a better test for evaluating glycaemic control could be the estimated glycated haemoglobin (HBAIc) which gives a measure of the long-term average glucose levels in the blood. There is therefore a glycaemic gap that exist as the difference between admission blood glucose levels and the estimates of the glycated haemoglobin (Zarean et al., 2021). At best, the glycaemic gap will be a more reliable measure of the changes in glycaemic control following a brain injury as it will also provide extra information with higher discriminatory power on the body's haemostatic response in the advent of physical stress on the long term glycaemic control (Zarean et al., 2021). Long term glycaemic control will therefore be beneficial prior to an acute stroke.

The liver function test values for aspartate aminotransferase (AST), alanine transaminase (ALT), alkaline phosphatase (ALP), gamma-glutamyl transferase (GGT) and albumin did not

significantly correlate to the mortality outcome among the stroke patients. Suffice to say that there were only 50 of the 175 stroke patients who had this test conducted. At the TGH, the liver function test is paid for out of pocket and patients without the financial ability would not be able to do the test. Early mortality did not also allow for enough time to conduct some of the requested laboratory tests among some of the patients. There was no correlation between kidney function test values for sodium, potassium and urea and mortality outcome. Interestingly, plasma lipids (high density lipoprotein (HDL), low density lipoprotein (LDL), triglycerides (TGs) and total cholesterol), which are involved in the formation of cholesterol plaques that clog blood vessels and contribute to stroke were found not to be statistically significantly associated with stroke related mortality. Again, at presentation, the haemoglobin levels, white blood cells and platelet counts were found not to correlate statistically significantly to stroke mortality outcomes.

5.12 Stroke care and mortality outcome

After triaging and immediately attending to a patient, the level of multidisciplinary care that is provided the stroke patient impacts on survival. In the absence of advanced stroke care, and the non-existence of a specialised stroke unit at the TGH, there was heavy reliance on patient referral, transfer, and transport to other facilities for further care. This was also dependent on the availability of an ambulance and a bed at the receiving hospital. Blood pressure control is a vital part of stroke care. All the 175 stroke patients had their admission blood pressure recorded at triage. A randomised, controlled systolic blood pressure intervention trial (SPRINT) was conducted at 102 clinical sites in the USA looked at the effect of reducing blood pressure to levels where it reduced cardiovascular morbidity and mortality among persons without diabetes (The SPRINT Research Group, 2015). That study showed that lowering blood pressure to targets below 120 mmHg compared to less than 140 mmHg resulted in lower rates of fatal and non-fatal major cardiovascular events and deaths from any cause (The SPRINT Research Group, 2015). Inadequate blood pressure control could have contributed to the high levels of mortality outcomes for this study.

Anecdotal observations found nursing care to be suboptimal, as patients who had aspirated and needed regular suctioning did not receive this care frequently. Similarly, patients who should have been turned often to the side to avoid the generation of bed sores and aspiration were not frequently attended to. For the few who had the best of care, documentation of the non-

therapeutic interventions was documented sparingly, which made data extraction challenging. On the average, there were two doctors responsible for over 40 patients at the ED, and three nurses responsible for the same number of patients at every *point of time. This hindered the optimisation of care among the generality of patients and not just the stroke patients. The demand for care at the ED, based on my observations, was outstripped by the provision of adequate and satisfactory care. These factors contributed to the high burden of stroke mortality observed at the ED of the TGH. This was clearly demonstrated by the levels of high case fatality rates among stroke patients who visited the ED of the TGH.

In advanced jurisdictions, thrombolysis, and the use of Alteplase has been proven to be vital in the treatment options of stroke with good prognostic outcomes, the same cannot be said for Ghana and other LMICs, as they are not routinely used. At the TGH, there was no evidence of the active application of thrombolytic agents or recombinant tissue plasminogen activator administration. Detailed imaging and results of laboratory studies were not readily available during care provision, and this might have contributed to the high mortality outcome observed in this current study. Endovascular techniques such as coiling, surgical clipping during aneurysmal haemorrhage, which are widespread practice in well-resourced settings, were also not available at the TGH. A study on 1,173 stroke patients with aneurysmal subarachnoid haemorrhage in Mayo clinic Rochester, Minnesota found progressive increase in the overall use of endovascular techniques between 1985 – 1994 and 2005 – 2014, from 5.1% to 65.5% (La Pira et al., 2018). This led to significant reduction in in-hospital mortality from 22.6% to 16.7% within the same period and consecutive good functional outcome among these patients at 3 – 6 months from 64.8% to 78.8% (La Pira et al., 2018). These stroke interventions have been found to improve in-hospital stroke survival and functional recovery (Chua et al., 2016). In the future, policies and investments that will improve stroke care in Ghana in general must be deliberately implemented.

5.13 Emergency department crowding and its impact on stroke mortality outcome

From the results of this current study, the ED was always overcrowded, and this was discovered midway into data collection. The NEDOCS was used to measure ED crowding status. The tool uses the total number of patients in the ED, total number of beds in the ED and in the hospital, total number of admitted patients at the ED, the waiting time from triage to ED bed placement for patients placed in ED beds, the longest boarding time of patients waiting for admission and

the number of patients critically ill/ventilators to calculate the NEDOCS (Weiss et al., 2004). The score ranges from 60 – 200, and any score between 100 – 140 was considered overcrowded and from 141 – 180, severely overcrowded and from 181 – 200 dangerously overcrowded (Weiss et al., 2004). Details of the NEDOCS tool can be found in sections 2.26, 3.10, 4.5, Figure 2.6 and appendix 1 for reference.

It was hoped that there were going to be non-crowding moments using the NEDOCS for clear comparisons to be made between crowded and non-crowded conditions, but this was found not to be the case until data collection ended. Maximum ED overcrowding has been found to be associated with unexpected cardiac arrest (Chang et al., 2019; Kim et al., 2020), increased laboratory test processing and turnaround time (Hwang et al., 2010), reduced patient satisfaction (Tekwani et al., 2013), quality of care (Tsai et al., 2016), medication errors (Kulstad et al., 2010), increased inpatient mortality (Jo et al., 2015; Khubrani & Al-Qahtani, 2021; Ugglas et al., 2020; Ugglas et al., 2021) among others. The median ED occupancy rate at arrival was 96 (IQR: 89 -109%) and for 40% of the time that patients arrived at the ED, the occupancy rate was above 100% indicating the unavailability of an admission bed.

Among the 70 patients who arrived when the ED occupancy was 100% and above, 60 (85.7%) died while 79 (75.2%) who arrived at occupancy below 100% died. ED occupancy was statistically significantly higher among the mortality group ($p = 0.012$). A study in Tehran, Iran found no significant correlates between ED occupancy and timeframe associated with the management of admitted stroke patients (Momeni et al., 2018). Similarly, another study of stroke patients (1,379) in a comprehensive stroke centre in Massachusetts General Hospital found no significant delays in stroke care during overcrowded periods at the ED (Jaffe et al., 2020). This particular hospital had 2 dedicated CT scans, located adjacent to the ED with a less than 2 minutes stretcher transport from high acuity and there was robust continuous quality acute care delivery during periods of increased capacity burden (Jaffe et al., 2020). To put this into perspective, the Jaffe et al. (2020) study was among ischaemic stroke patients only in an academic hospital where CT scanners, neurology teams and stroke code activation systems for team members was available 24 hours a day. This was not the case for the ED at the TGH, and hence the findings are likely to be at variance and contextual interpretation will be cautiously needed.

The crowding status of the ED potentially affects aspects of the input, throughput, and output factors at the ED, which directly or indirectly affects the mortality outcome of patients. A case

in point is a throughput factor known as the door to CT results time. The median door to CT results time was higher among the mortality group (12.57 vs 10.25 hours; p = 0.060) though not statistically significantly so. The median patient NEDOCS was significantly (p = 0.042) higher among the morality group, at 186 (IQR: 177 – 193) vs 181 (IQR: 171 – 187) than the group during their stay at the ED. Chatterjee et al. (2011) conducted a study in two hospitals in the USA, where one urban hospital had a stroke centre, a readily available stroke team and a CT scan machine on the same floor adjacent to the ED and a community ED with no stroke centre, no stroke team and the CT scan machine located 3 floors above the ED which required the use of an elevator.

Their study found that for patients in the academic hospital and the community hospital who presented after 3 hours of onset of symptoms, higher levels of ED crowding were associated with longer times to CT order and completion time though the performance was better in the academic hospital (Chatterjee et al., 2011). The reasons adduced was the presence of stroke teams who reduced delays as they stay by the bed side during initial ED care as well as the presence of CT scanners in the academic hospital (Chatterjee et al., 2011). Another study based in an urban regional referral stroke centre hospital in Massachusetts also found poorer performance on door to imaging times with increased ED crowding (Reznek et al., 2017). This clearly shows the relevance of functioning stroke units, in-hospital CT scan and evidence-based interventions which is associated with mortality outcomes of stroke patients care.

In this current study, it should be worthy to note that only 70 out of the 175 patients had CT scan done, and drawing inferences may fall short of statistical power. The absence of a CT scan in the TGH and the absence of a stroke team could well explain the high in-hospital mortality among the 175 stroke patients over a period of 6 months. Secondly, most of the stroke patients did not have various laboratory tests done, such as the full blood count, cardiac enzymes, international normalised ration, liver, and kidney function as well as other blood parameters. This made it difficult to estimate the time variables for when the attending physicians made these requests, and when they were performed, and when the results were made available for interpretation and decision making on patient care. Unfortunately, it was not possible to do a comparison of non-crowded periods with overcrowded periods to see how that affected mortality outcomes.

5.14 Critical evaluation of the findings on the predictors of stroke mortality outcomes

In-hospital mortality is a good indicator for assessing the effectiveness and efficiency of stroke care. An appreciation of the potential predictors of mortality can influence future policies and strategies to improve stroke care. The univariate logistic regression analysis found statistically significant stroke mortality predictors. These included: not having an active national health insurance status ($p = 0.039$), worse triage scores ($p < 0.001$), worse mRS ($p < 0.001$), worse GCS ($p < 0.001$), higher average patient NEDOCS ($p = 0.045$), difficulty in swallowing ($p = 0.009$), facial palsy ($p = 0.012$), raised intracranial pressure ($p = 0.013$), aspiration pneumonia ($p < 0.001$), urine incontinence ($p < 0.001$), stool incontinence ($p < 0.001$), and having haemorrhagic stroke ($p = 0.037$). In some other studies, increased blood pressure elevated the risk of sudden death among patients with haemorrhagic stroke (Lindbohm et al., 2017). In a study by Russell et al. (2020) on the predictors of in-hospital stroke mortality in Sierra Leone, significant univariate predictors included the type of stroke, aspiration pneumonia and seizures. In the same study, the multivariate analysis yielded hypertension, haemorrhagic stroke, Glasgow coma score less than 8, clinical diagnosis in the absence of stroke imaging and aspiration pneumonitis as significant predictors of stroke mortality (Russell et al., 2020). Most of these predictors have been shown to have significant correlations and associations with stroke mortality outcomes. However, fewer studies have looked at the impact of overcrowding on stroke mortality outcome in-hospital or ED.

For this current study, stroke related mortality was partially predicted by three important characteristic variables in the multivariate logistic model conducted using seven predictor variables. The NEDOCS averaged for each patient during their stay at the ED was significant in predicting mortality outcomes among the stroke patients (AOR, 1.033; 95% CI, 1.003 – 1.064; $p = 0.033$). When holding all other variables constant, with every unit increase in the NEDOCS, the odds of a patient experiencing death increased by 3.3%. This meant that patients who encountered the extreme end of dangerously overcrowded periods (NEDOCS of 200) had 326.7% increased odds of death compared to patients who witnessed the lower end of overcrowded (NEDOCS of 101) periods at the ED. ED overcrowding was associated with reduced odds (0.83) of meeting door to imagine time within 25 minutes per 10% absolute ED occupancy rate for 463 stroke patients in a Massachusetts hospital (Reznek et al., 2017).

In a tertiary academic hospital in southern Taiwan, ED crowding was significantly associated with delayed door to assessment time and door to CT completion time among ischaemic stroke patients who needed thrombolysis (Tsai et al., 2016). With regards to how ED crowding correlates with mortality outcomes, a large cohort study in 7 ED in Stockholm Region, Sweden found significant association between high levels of ED crowding and increased 30-day mortality. In that particular study the estimated hazard ration for death was 1.00 within 30 days in a crowding category of 75%-95% and 1.08 in the 95%-100% category (Ugglas et al., 2020). ED crowding have also been associated with in-hospital cardiac arrest occurrence in a registry based cohort study among 629 adults in teaching hospital in Seoul Korea (Kim et al., 2020). In that study, 29.7% of the patients at the ED experienced in-hospital cardiac arrest and this positively correlated with ED crowding levels (Kim et al., 2020). Inasmuch as these studies focused on the general impact of ED crowding on care, and how it potentially affected the quality and timelines of care, none of them specifically focused on the impact of ED crowding on stroke care and mortality outcomes and this is exactly what this current study addressed.

Secondly, the type of stroke was found to be statistically significant in predicting death outcomes among stroke patients. Haemorrhagic stroke was associated with an overall higher odds of death compared to ischaemic strokes (AOR, 3.834; 95% CI, 1.184 – 12.415; p = 0.025). A patient with haemorrhagic stroke had a 3.8 times likelihood of death compared to a patient with ischaemic stroke. Studies in Denmark, Northwest Ethiopia, Uganda have also found higher proportions of death among patients with haemorrhagic stroke compared to ischaemic deaths (Andersen et al., 2009; Ayehu et al., 2022; Namale et al., 2020). A study in Democratic Republic of Congo by Larrey et al. (2020) also found haemorrhagic stroke to be a predictor of stroke mortality. In a recent Sri Lanka study, haemorrhagic stroke was also found to predict stroke mortality with an OR of 5.12 (Shalini Ranasingheid et al., 2023). High mortality among haemorrhagic stroke patients has been attributed to fewer treatment options, mass effect of the bleed, elevated intracranial pressure from the underlying hematoma, cerebral edema from perihematomal neurotoxicity or inflammation and those who survive have severe residual neurological dysfunction (Cordonnier et al., 2018; Fernando et al., 2021).

Thirdly, diabetes mellitus as a risk factor significantly predicted stroke mortality in this current study. Stroke patients with diabetes mellitus had a 3.0 times higher likelihood of death compared to patients without diabetes mellitus, holding all other variables constant (AOR, 3.001; 95% CI, 1.006 – 8.956; p = 0.049). Patients with diabetes mellitus have endothelial

damage as well as challenges with kidney function needed for the metabolism of treatment drugs. Poorly controlled blood glucose could lead to poor outcomes (Koga et al., 2015); indeed, in this current study, the mortality group had a higher blood glucose median (9.8 vs 8.9 mmol/L). High blood glucose was a significant stroke mortality predictor in a study by Dabilgou et al. (2020).

Stroke mortality was also found to be significantly associated with being in the younger age group, high systolic blood pressure, high mean arterial pressure, worse Glasgow coma score, worse modified Rankin scale and shorter length of stay at the ED. These were similar to findings in a 5-year analysis of clinical presentations and predictors of stroke mortality in Southwestern Nigeria, where poor GCS, uncontrolled hypertension, seizures among others were established to be predictors of stroke mortality among 276 patients (Ibrahim et al., 2022). The absence of CT scan for faster diagnosis and the lack of surgical intervention during intracerebral bleeds potentially contributed to the high mortality rates especially among haemorrhagic stroke patients at the ED of TGH.

Other parameters like age, gender, having a CT scan done, SBP at presentation and having hypertension as a risk factor were individually correlated with stroke mortality but were not predictors as covariates in the final multivariate logistic model. Similarly, age, gender, hypertension, and diabetes mellitus were found not to predict stroke mortality in study by Dabilgou et al. (2020) in Burkina Faso. The relevance of these non-predictors to the clinical outcome of stroke patients cannot be underestimated hence the need to further explore how these factors interplay in the resultant outcome of the clinical outcome of stroke patients.

The overall findings of this study was consistent with a study of 178 Sierra Leoneans that looked at risk factors, clinical outcomes and predictors of stroke mortality (Russell et al., 2020). In that study, stroke was prevalent among younger patients, hypertension was the commonest risk factor and an in-hospital mortality rate of 34.5% was reported; lower than the 79.4% of this study at TGH. Russell et al. (2020) found stroke mortality predictors to be worse Glasgow coma score, modified Rankin scale, haemorrhagic stroke, aspiration pneumonia and hypertension among others (Russell et al., 2020). However, they found women to have poorer outcomes than men and they also had 36.0% of patients with no CT scan diagnosis (Russell et al., 2020) compared to the 60.0% for this study at the TGH. Sierra Leone is also a low resource setting and some of the limitations of their study were also encountered during this study in Ghana.

5.15 Strengths of the study

This study was conducted in a challenged ED in a low resource setting where documentation of clinical records and quality care were limited. Despite these problems with data quality, the study was successfully conducted. This study was anchored on sound and clearly stated research objectives which defined the scope of the study. The research questions were feasible, interesting, novel, ethical and relevant. The study was logical, transparent and could be replicated in similar settings especially in a LMIC. This study acknowledged previous research on ED overcrowding and quality care of stroke patients at the ED. A systematic literature review was conducted. This study had an appropriate, systematic, and good research methodology that highlighted systematic processes, procedures, and techniques. Participants were clearly defined with an inclusion and exclusion criteria. This ensured that the findings were valid, reproducible, consistent, and reliable. This study led to the generation of new knowledge within the context of a low resource setting.

There were no falsifications, no fabrications or plagiarism and all the principles of a scientific research were followed. This study used relevant, meaningful, empirical data and proper data analysis methods which generated objective and unbiased evidence in the context of decision-making. Prospectively collected data during the process of stroke care minimised recall bias and the participatory observation brought a qualitative dimension that explained the observations of stroke care at the TGH. This provides the reader a better understanding and an in-depth view of crowdedness and the quality care processes at the ED of the TGH. This was first time a quantitative metric like the NEDOCS has been used to quantify the levels of overcrowding at the ED of the TGH. The findings eliminate doubts about the extent of overcrowding at the ED. The correlational analysis helped to bring to perspective the complex relationships between the variables studied, example: age, sex, medical risk factors, overcrowding, triage scores, BP values, laboratory and CT scan findings, stroke specific mortalities, among others. Despite the strenghts highlighted above, this study acknowledges limitations and provides suggestions for future research.

5.16 Limitations of the study

There were a number of limitations to this study. Firstly, this was a single health facility study and generalisation of the findings must be done with caution. It is however comparable with a number of other single site studies. For example, a single site study in Amrita Institute of

Medical Sciences, Kochi, Kerala, India was conducted among 1,336 stroke patients, however with a low in-hospital stroke mortality of 45 (3.45) (Nambiar et al., 2022). Another example was a study conducted in northern Spain, however in a stroke unit at the Neurological department, where the in-hospital mortality rate was found to be 7.13% among 673 ischaemic stroke patients admitted (Kortazar-Zubizarreta et al., 2019). A different study among 285 stroke patients in an Intermediate Hospital Katutura in the Windhoek, Khomas region of Namibia recorded a relatively lower rates of in-hospital stroke mortality of 26.4% (Neshuku et al., 2023). Similar studies was also conducted among 135 stroke patients where a 30 days in-hospital mortality rate was recorded to be 37% at Bugando Medical Center, a tertiary teaching hospital in North-western Tanzania (Matuja et al., 2023).

A primarily similar study was conducted in Connaught Teaching Hospital in the capital city, Freetown of Sierra Leone where the stroke population was 178 even though the in-hospital mortality outcome of 34.8% was lower compared to the 79.4% of this current study (Russell et al., 2020). Though multisite studies are rare especially in LMIC and LICs, reference can be made to the SIREN study conducted among 16 medical sites in Ghana and Nigeria, where 814 (21.8%) stroke mortalities were recorded among 3,739 stroke patients (Sarfo et al., 2023). In this study, TGH did not have a not stroke unit, as found in hospitals where stroke studies have been conducted. For example, in the UK study, where 114 hospitals were involved with a recorded 7 days in-hospital mortality rate of 9.4% among 5,704 admitted stroke patients (Douiri et al., 2021). However, this study is novel in a LMIC, and it provides scientific evidence and characteristic information on ED constraints in a resource challenged setting and how that impacts mortality outcomes among stroke patients.

Secondly, the ED was always crowded and hence there was no proper comparative non-crowded times. This meant that it was necessary to compare gradations of overcrowding, severely overcrowded and dangerously overcrowded. The ED of the TGH had 33 beds that served the entire population of Tema and beyond at the time of the studies and the situation remains unchanged. At the time of the study, there was only one emergency physician specialist on call, two physicians and three nurses usually on duty. Anecdotally, these numbers of staff were found to be extremely inadequate as one physician managed an average of 20 patients at every point in time and one nurse was responsible for about 15 patients averagely at every point in time. Both referred and walked in patients could access the ED at any point in time and the ED operated 24 hours daily. Stroke patients who were referred to an in-hospital bed mostly

boarded because admission beds were not readily available in the hospital and in instances where they were referred to a facility outside the hospital, again the unavailability of beds at the referral facility posed a challenged. These factors, coupled with physical and financial inaccessibility to CT scan and other laboratory services needed to facilitate early physician decision on treatment options and referral options in a way contributed to most patients boarding at the ED which worsened the crowding state of the ED. These anecdotal observations could have been recorded in a more systematic way using a qualitative approach, to properly characterise the issues at play in the ED. Nevertheless, the study did serve a good purpose in describing, for the first time, the dire state of the ED of the TGH and the urgent need for improvement in the state of diagnostic facilities and stroke care at the ED.

Thirdly, the advent of COVID-19 in Ghana in March 2020 led to the closure of the ED for routine patient care and was designated and used as one of the two sites in the Greater Accra Region for the management of COVID-19 patients. The other site was the Greater Accra Regional Hospital. At this point in March 2020, 175 patients had been admitted with stroke, of whom 139 died. The original aim had been to analyse a dataset with 200 deaths, with the assumption being (by the UK statistician), that deaths were rare events. The aim of the study for the purposes of comparison was to have looked also at about 200 stroke survivors which was rarer for this study. In the thinking of the UK statistician, deaths were supposed to be the rarer outcomes, contrary to what was observed in this current study. None of the other literature cited, registered such extreme in-hospital death rates as seen at the TGH. The University of Salford and the Ghana Health Service halted the conduct of human related research that was going on at the time. This directly affected the sample size and potentially the power of the study. Despite this challenge, there was enough statistical power to derive a useful model, though it would it have been preferrable to have been able to include more predictors in the model.

Fourthly, confirmation of stroke sub-types by CT imaging would have gone a long way to affirm the confidence of stroke diagnosis been analysed. Unfortunately, only a minority of patients successfully had a CT scan done and hence reliance on stroke diagnosis were based on the experience of the clinicians. This thesis has highlighted the substandard of stroke care and the unavailability of stroke diagnosis confirmation at the TGH. The expectations are that these findings when made available to the Ministry of Health in Ghana and the management of the TGH will drive the provision of such important diagnostic facilities in the hospital and provide

some evidence-based stroke care policy directions to the rest of Ghana. Ultimately, these findings put scientific facts to gaps of what has anecdotally been considered as poor outcomes of stroke patients at the TGH, as it also highlights the care gaps in the hospital.

Fifthly, the absence of CT scan machines and the absence of a stroke centre with multidisciplinary set skills and specialist care meant that the level and extent of care was not standardised nor advanced. This potentially could have affected the high mortality rates observed during the study. The relevance of CT scan uses in the diagnosis of stroke as detailed in section 2.16 and 2.18 and the use of tissue plasminogen activator cannot be overemphasised. Efforts should be led by the managers of the healthcare delivery system in Ghana to see to a successful and sustained implementation of the use of this proven lifesaving therapy among stroke patients.

A further limitation is that the long-term impact of stroke on mortality was not assessed beyond the walls of the hospital as that was not the focus of the study. Also, the NIHSS which has been established as a useful tool to determine the severity of stroke patients upon arrival and during follow as referenced in was not used, for reasons explained earlier section 2.17.1. The old age Glasgow coma score with its shortfalls was the main tool used to assess the level of brain injury and consciousness. This is the case for most LMICs (National Department of Health (South Africa), 2020; Sedain & Bhusal, 2019; Standard Treatment Guidelines, 2017). Finally, the non-use of tissue plasminogen activator, which has been established to be beneficial to stroke patients, could have potentially contributed to the high mortality outcomes observed.

5.17 Contributions of this study to literature

Relevant contributions of this study are itemised below:

1. The negative impact of ED overcrowding on stroke mortality in a LMIC
2. Predictors of in-hospital stroke mortality in an ED of a low resource setting
3. ED overcrowding as a predictor of mortality among stroke patients in a LMIC
4. The use of NEDOCS to measure ED overcrowding status in a LMIC
5. High rates on non-use of CT scan in the diagnosis of stroke in a LMIC
6. Clinical diagnosis of stroke in comparison with stroke confirmatory diagnosis with CT scan in an ED in a LMIC
7. High in-hospital mortality rates among non-elderly stroke patients in a LMIC

8. Use of a structured electronic data extraction tool in a stroke prospective study in a LMIC
9. Detailed description of stroke care in a LMIC with limited resources
10. Medical risk factors of hypertension and diabetes mellitus as clinical risk factors for stroke patients in an ED in a LMIC

5.18 Conclusion

The findings of this study have generated evidence of the disproportionate high burden of stroke deaths among patients with certain clinical characteristics and ED exposures. Patients with haemorrhagic strokes, a history of diabetes mellitus and meeting worse forms of overcrowding whilst on admission at the ED predicted stroke mortality. This is similar to what has been found in other LMICs. The single most powerful predictor of stroke mortality in the multivariate analysis was haemorrhagic stroke, as these patients were 3.8 times more likely to die from stroke compared to patients with ischaemic stroke. This was followed by patients with diabetes mellitus who had a 3.0 times likelihood of experiencing death compared to patients without diabetes mellitus. Lastly, with every unit increase in the average patient NEDOCS, the odds of experiencing death were 1.033. Independent predictors of stroke mortality using the crude odds ratio included not having an active national health insurance status, high triage scores, high mRS, depressed GCS, high average patient NEDOCS, difficulty swallowing, presence of facial palsy, raised intracranial pressure, aspiration pneumonia, urine incontinence, stool incontinence and having haemorrhagic stroke.

The ED was for most part of the patient stays at the ED either severely or dangerously overcrowded. The level of crowding negatively correlated with patients having a head CT scan done. Patients with poor GCS were associated with fewer CT scans done who eventually spent shorter stay at the ED as they experienced earlier mortality. Younger patients reported with severe forms of hypertension (systolic blood pressure and mean arterial pressure), and they had early and worse mortality outcomes. Diabetes mellitus was however associated with increasing age and found to be common among patients with ischaemic strokes. Stroke severity, which was reflected by the poor Glasgow coma score, modified Rankin scale, triage score, presence of urine incontinence, stool incontinence, aspiration, facial palsy, difficulty in swallowing and raised intracranial pressure had worse mortality outcomes. Various lab test including the full blood count, blood glucose, kidney function, liver function and lipid profiles conducted among patients did not have any statistical significance on their outcomes.

Evidence of good quality stroke care which improves survival include access to CT scan for diagnosis, reperfusion strategies, intravenous thrombolysis, mechanical thrombectomy, tissue plasminogen activator administration, having a multidisciplinary stroke unit and early rehabilitation (Azkune Calle et al., 2017; Benjamin et al., 2019; Cabral Frade et al., 2022; Harari et al., 2020; Lekoubou et al., 2016; Pop Ovidiu et al., 2021). The lack of access to these local resources, where only 40.0% of the stroke patients had CT scans for confirmatory diagnosis, meant that majority of the patients were managed based on clinical diagnosis without imagery differentiation between haemorrhagic and ischaemic strokes. Given the limitations of the facilities, the clinical team were acting appropriately since the WHO has encouraged the use of clinical diagnosis where CT scans are not readily available especially in low resource settings like Ghana. However, evidence suggests that the use of CT scan improves the quality of stroke diagnosis which eventually impacts on the clinical outcome. The electronic data extracting tool that was developed as an output for this study improved patient record documentation as paper-based records keeping was the main stay at the time of the study.

5.19 Recommendation

In the future a study that will identify the immediate cause of death among stroke patients is recommended to help explain the potential reasons for the extremely high in-patient mortality among stroke patients. Further studies should also examine the potential reasons why patients who are younger with haemorrhagic strokes experience high case fatality than do elderly patients in LMICs. Patients reported with worse GCS and in the future studies should look at the potential reasons why acute stroke patients usually presented in worse clinical states. These should be qualitative in character to examine the health seeking behaviour of patients in low resource settings where self-funding is the main stay for stroke patients.

It was observed that when patients travelled for CT scan outside the hospital, they died faster upon return at the ED. Future studies should explore why this observation and what potentially accounts for the high mortality following CT scans outside the TGH. It is strongly recommended that the leadership of the TGH invest in CT scan machines at the hospital as well as establish a multidisciplinary stroke unit at the hospital. The electronic data extracting tool developed for this study could be adopted and adapted in an integrated manner for bed management as well as for stroke patient data management. As it is only with data collection like this that the poor state of the stroke service at the ED becomes apparent.

This study has demonstrated the need for further research to explore potential reasons for the perennial overcrowding experienced at the ED. In the future, a simpler metric like the ED occupancy rate which correlated strongly with the NEDOCS could be explored during ED crowding studies in low resource setting. Studies on how ED overcrowding impacts the various aspects of ED care should in the future be considered. This study focused on quantitatively measuring ED overcrowding and the predictors of stroke mortality. Qualitative based study of care quality and patients experience is recommended for future studies. This could usefully explore further the Theory of Care and bring out the aspects of quality care at the ED and how that potentially impacts the clinical outcomes of patients specifically stroke patients. In low resource settings like Ghana, ED overcrowding and how that affects quality care metrics such as the door to CT time, door to needle time, door to assessment time should be explored in the future as this current study could not achieve this.

Chapter 6 REFERENCES

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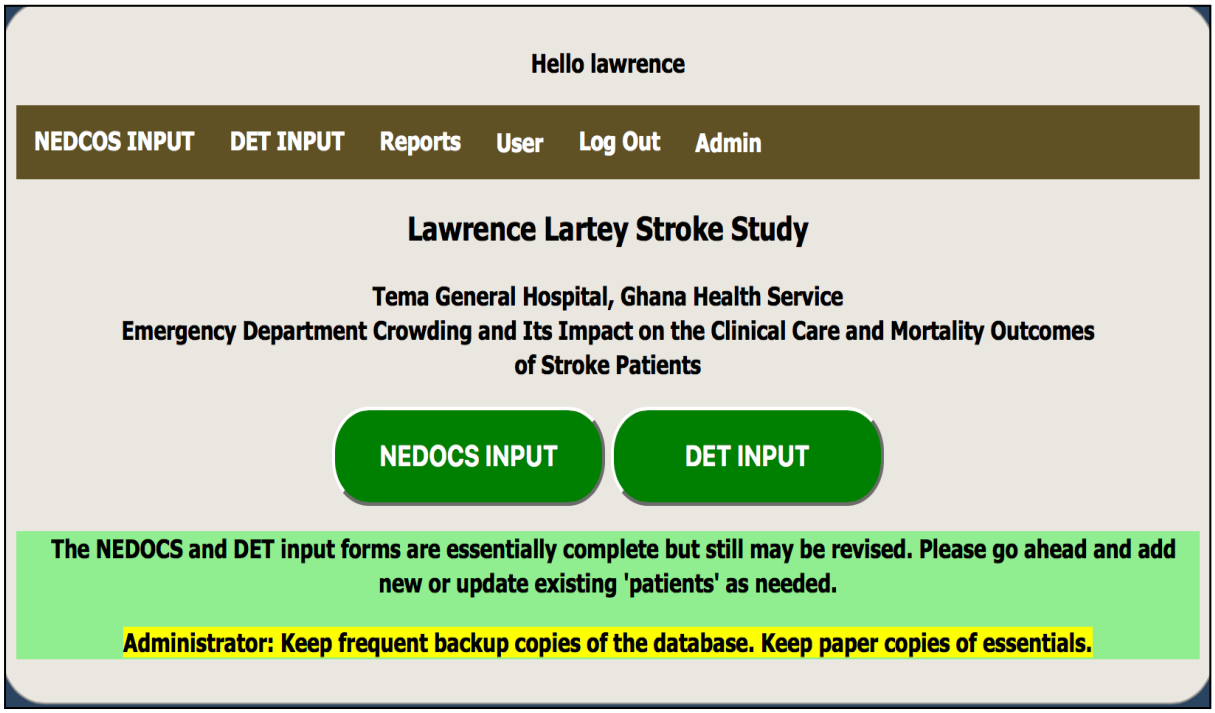
Appendix 1 – Variables of the National Emergency Department Overcrowding Score

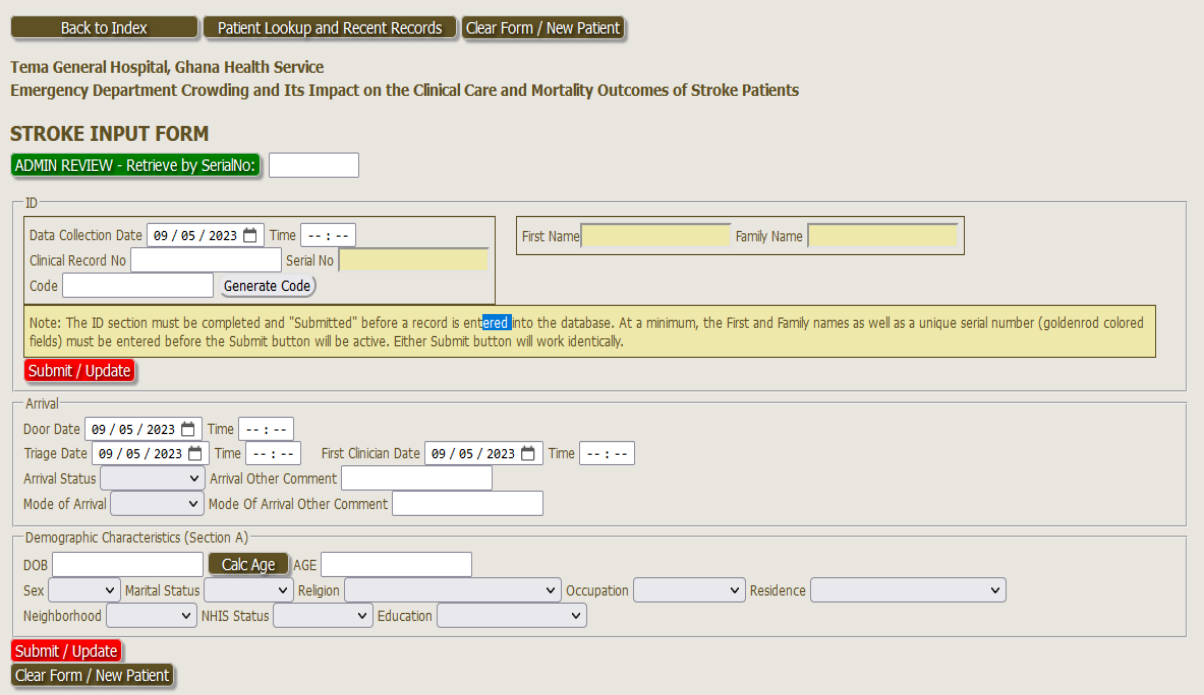
Variables	Categories of ED crowding status
1. Total number of patients in the emergency department which is the number of patients in the ED occupying beds, including hallway beds 2. Number of ED beds, which is the total number of available ED beds 3. Total number of admitted patients in the ED, which is the number of ED patients waiting to be moved from the ED to the hospital 4. Number of hospital beds, which is the total number of occupied and vacant inpatient beds 5. The waiting time from triage to ED bed placement for patients placed in ED beds 6. The longest boarding time of patients waiting for admission 7. The number of ventilators in use in the ED or critically ill	Level 1: Not busy (0 ≤ NEDOCS < 20) Level 2: Busy (20 ≤ NEDOCS < 60) Level 3: Extremely busy but not overcrowded (60 ≤ NEDOCS < 100) Level 4: Overcrowded (100 ≤ NEDOCS < 140) Level 5: Severely overcrowded (140 ≤ NEDOCS <180) Level 6: Dangerously overcrowded (180 ≤ NEDOCS)

Appendix 2 – Electronic stroke input form development and component interface

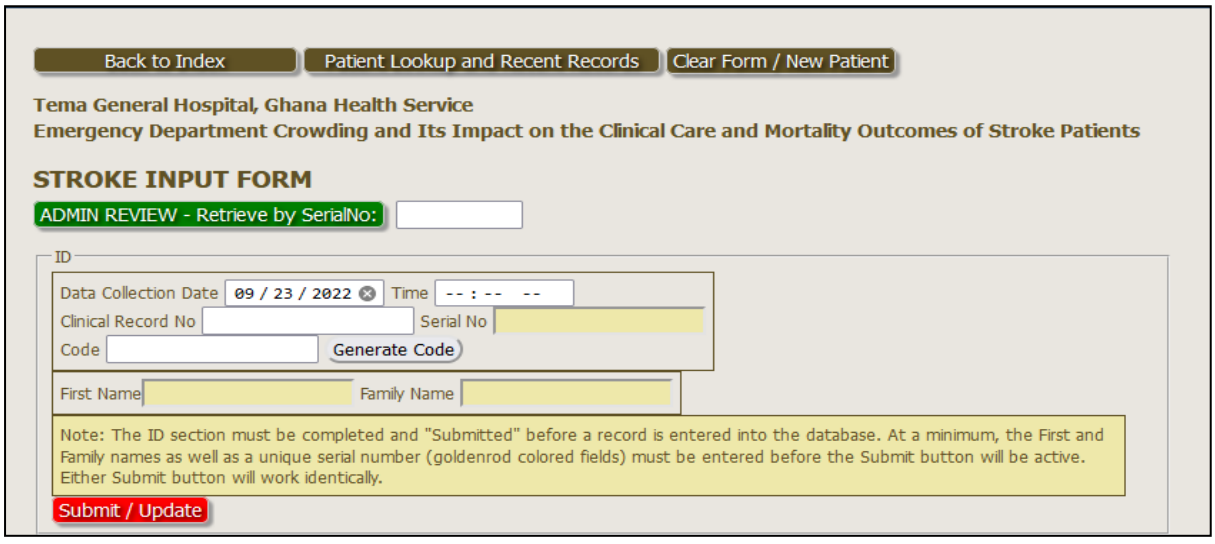
The electronic-based data management system had two main components (NEDOCS and electronic data extraction tool (e-DET) input.



For date-time consistency the input format database storage was 'DD MM YYYY HH: MM: SS.' A date/time 'picker' was used to ensure proper format. The interface was designed to be user friendly and easy to navigate. The entire interface showing the root e-DET input page and links to various component form of the electronic data extraction tool is shown below in Figure. The input form had pop up warning information for the administrator to frequently backup copies of the data base whilst safely storing the paper copies. The input form allowed for edits of the patient information whenever the need arose.



1. Patient identity (ID)
    a. Data collection date (DD MM YYYY)
    b. Data collection time (HH: MM: SS)
    c. Clinical record number
    d. Serial number (automatically generated by the computer)
    e. Code generated for the patient automatically for anonymisation
    f. First name
    g. Family name



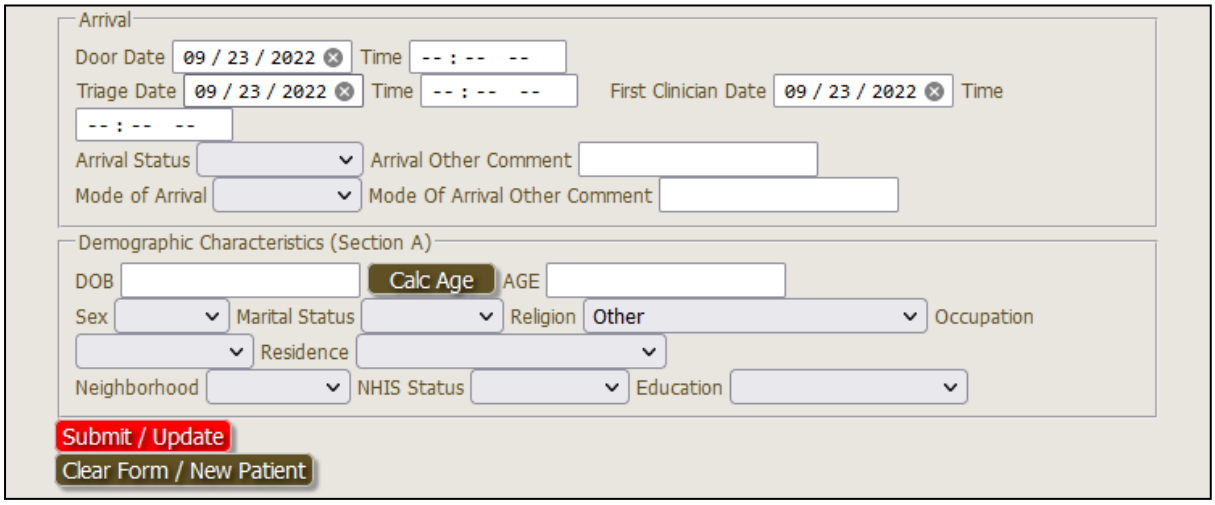
2. Arrival patient record
    a. Door date (DD MM YYYY)
    b. Door time (HH: MM: SS)
    c. Triage date (DD MM YYYY)
    d. Triage time (HH: MM: SS)
    e. First clinician date (DD MM YYYY)

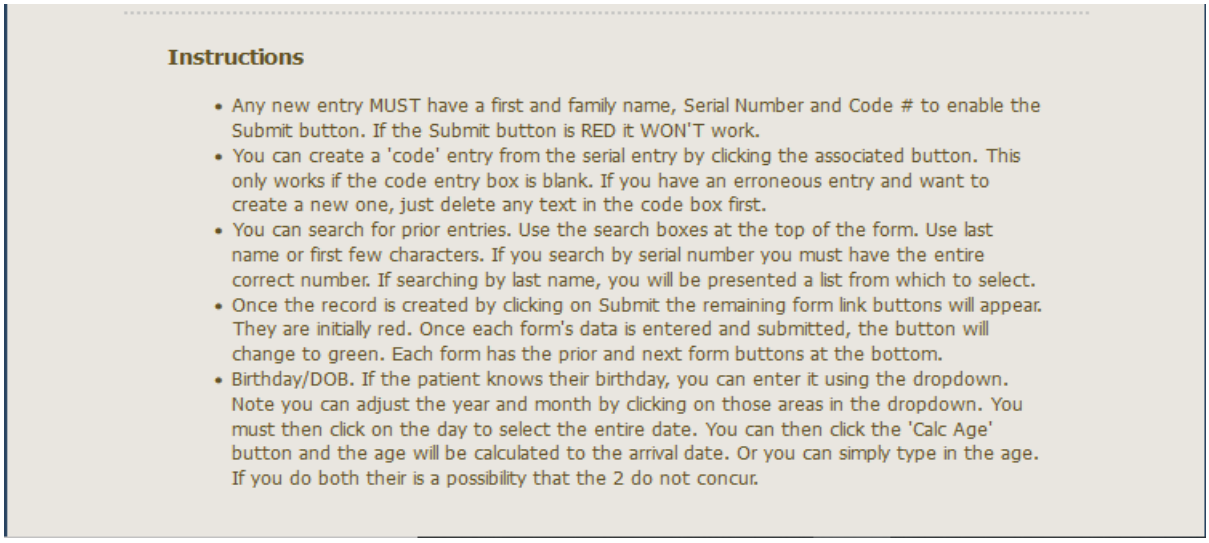
f. First clinical time (HH: MM: SS)
g. Arrival status
    i. Referral
    ii. Walk in
    iii. In patient transfer
    iv. Other
h. Any comment on arrival status
i. Mode of arrival
    i. Ambulance
    ii. Private car
    iii. Taxi
    iv. Uber
    v. Motorcycle
    vi. Walk in
    vii. Other
j. Comment on mode of arrival if any

3. Demographic characteristics
    a. Date of birth (DOB)
    b. Age (automatically calculated by the computer ones the DOB is entered)
    c. Sex
        i. Male
        ii. Female
4. Marital status
        i. Single
        ii. Married
        iii. Divorced
        iv. Widowed
        v. Separated
        vi. Other
5. Religion
    a. Catholic
    b. Anglican/Methodist/Presbyterian (orthodox churches in Ghana)
    c. Pentecostal/Charismatic
    d. Muslim
    e. Traditional/Spiritualist
    f. No religion
    g. Other
6. Occupation
    a. Formal
    b. Informal
    c. Retired (> 60 years as cut off for retirement in Ghana)
    d. Student
    e. Self employed
    f. Unemployed
    g. Other
7. Residence
    a. Within Tema metropolis (where Tema General Hospital is situated)
    b. Outside Tema metropolis
8. Neighbourhood

a. Urban
b. Rural
c. Peri-urban

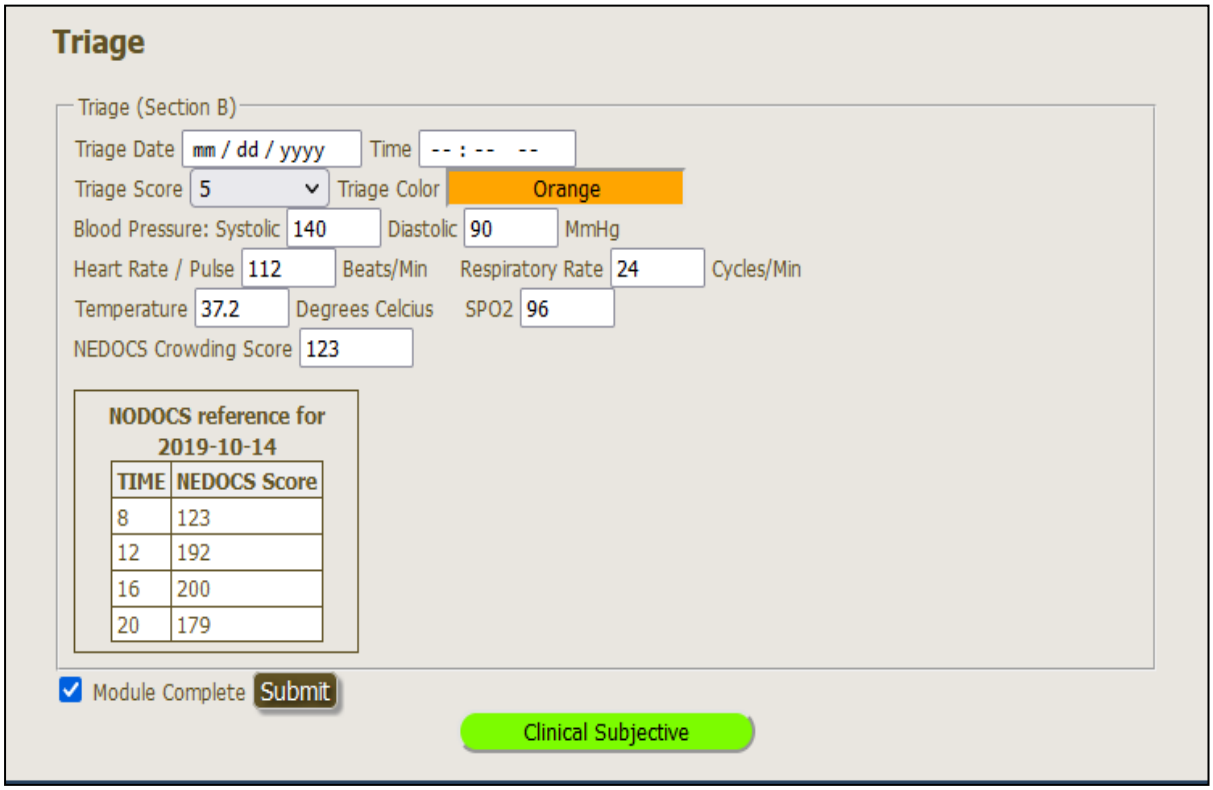
9. National Health Insurance Status (NHIS needed to financially access health care
    a. Active (meaning health care could be accessed)
    b. Not active (meaning renewal of activeness has not been done and hence cannot access health care financially, payment must be done out of pocket
    c. Not enrolled (meaning not a member of the National Health Insurance Scheme)
10. Education
    a. No education
    b. Primary
    c. Middle/ Junior high school
    d. Secondary/Senior high school
    e. Tertiary
    f. Technical/Vocational
    g. Other





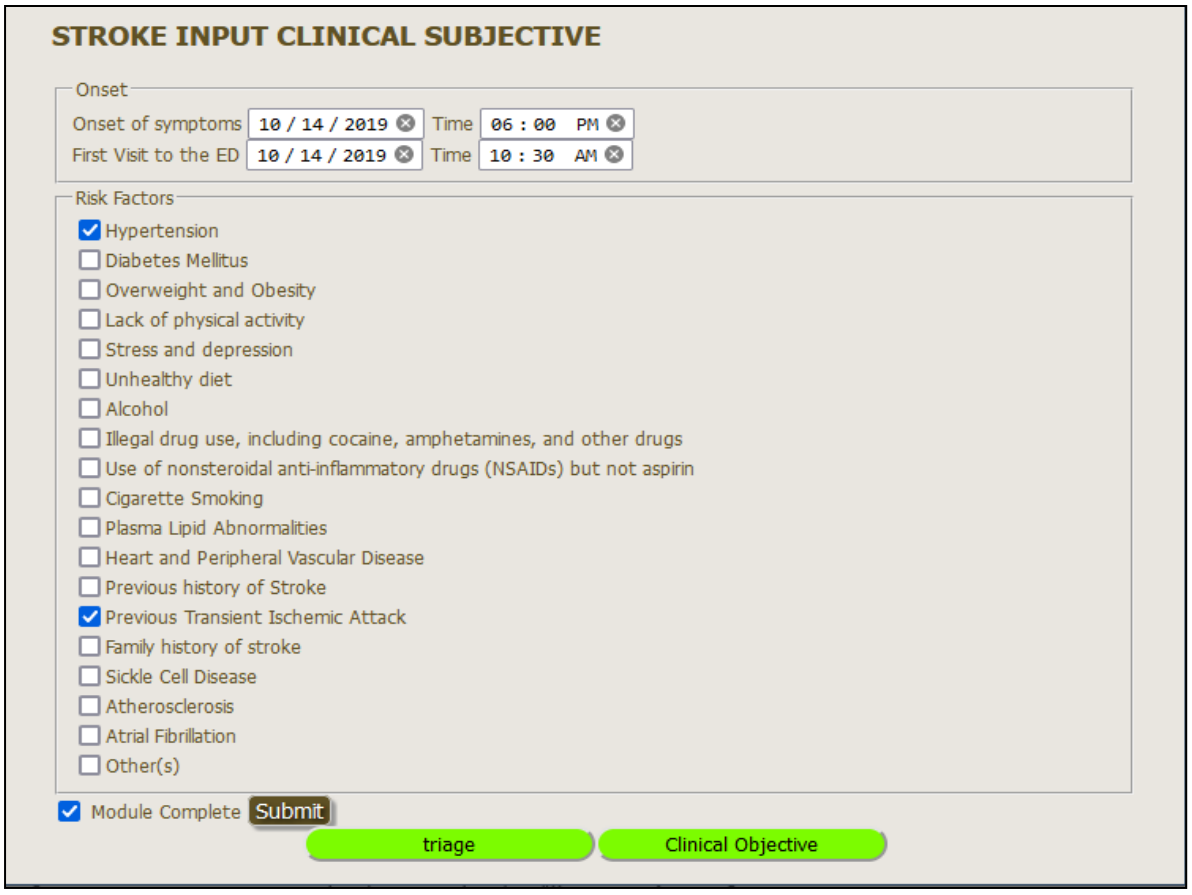
11. Patient triage information and National Emergency Department Overcrowding Score
    a. Triage Date (MM DD YYYY)

b. Triage time (HH: MM: SS)
c. Triage score (0, 1, 2, 3, 4, 5, 6, 7 or more, dead)
d. Systolic blood pressure (mmHg)
e. Diastolic blood pressure (mmHg)
f. Heart rate/pulse rate (beats/mins)
g. Respiratory rate (cycles/min)
h. Temperature (Degree Celsius)
i. SPO2 (the oxygen saturation of the patient (expressed as % (from 0-100))
j. NEDOCS
k. NEDOCS reference as entered earlier (this featured linked the NEDOCS to the patient during the period the patient stayed at the ED and hence allowed for ease of calculating the specific average NEDOCS for the entire duration of the patient at the ED.



12. Initial clinical subjective findings after patient have been taken
    a. Onset
        i. Date of onset of symptoms (DD MM YYYY)
        ii. Time of onset of symptoms (HH: MM: SS)
        iii. Date of first visit to the ED (DD MM YYYY)
        iv. Time of first visit to the ED (HH: MM: SS)
    b. Risk factors (all that applied is ticked in the tick box displayed:
        i. Hypertension
        ii. Diabetes Mellitus
        iii. Overweight and Obesity
        iv. Lack of physical activity
        v. Stress and depression
        vi. Unhealthy diet
        vii. Alcohol
        viii. Illegal drug use, including cocaine, amphetamines, and other drugs

ix. Use of nonsteroidal anti-inflammatory drugs (NSAIDs) but not aspirin
x. Cigarette Smoking
xi. Plasma Lipid Abnormalities
xii. Heart and Peripheral Vascular Disease
xiii. Previous history of Stroke
xiv. Previous Transient Ischaemic Attack
xv. Family history of stroke
xvi. Sickle Cell Disease
xvii. Atherosclerosis
xviii. Atrial Fibrillation
xix. Other(s)

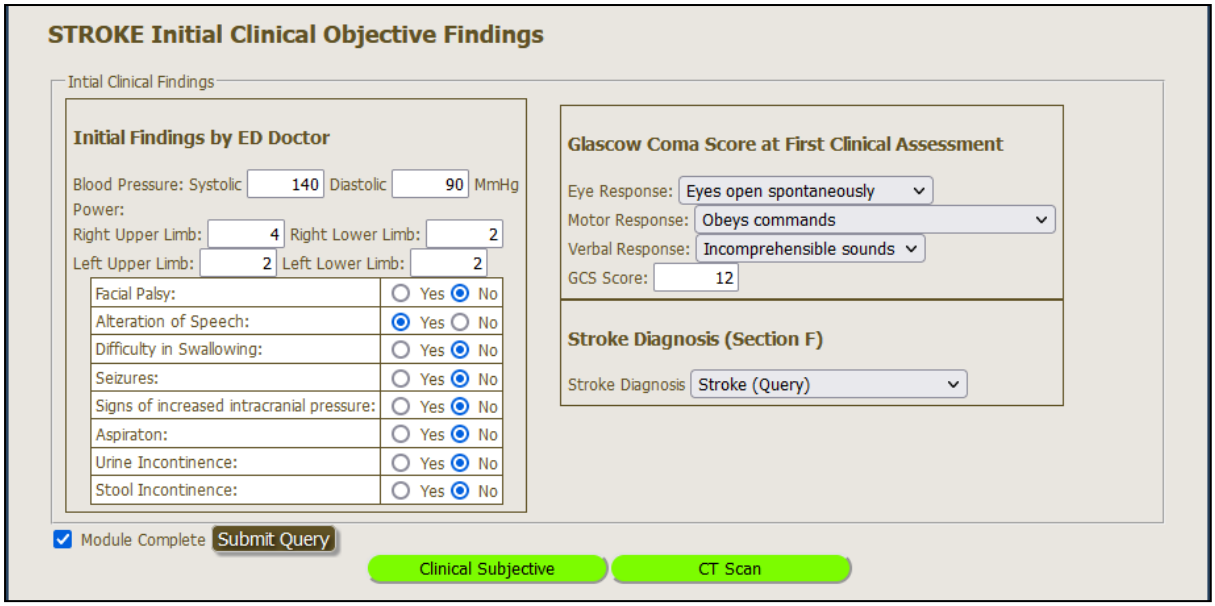


13. Initial clinical objective findings after patient have been examined by ED physician
    a. Systolic blood pressure (mmHg)
    b. Diastolic blood pressure (mmHg)
    c. Power
        i. Right upper limb (0 meaning no power, which is no movement of the limb to 5 where there is maximum power and displayed by movement of the limb against maximum physical force applied by the physician to the limb)
        ii. Right lower limb (0-5)
        iii. Left upper limb (0-5)
        iv. Left lower limb (0-5)
        v. Facial palsy (yes/no)
        vi. Alteration of speech (yes/no)
        vii. Difficulty in swallowing (yes/no)
        viii. Seizures (yes/no)

ix. Signs of increased intracranial pressure (yes/no)
x. Aspiration (yes/no)
xi. Urine incontinence (yes/no)
xii. Stool incontinence (yes/no)

14. Glasgow coma score at first clinical assessment (score of 3-15)
    a. Eye response (score of 1-4)
        i. No spontaneous eye movement (score = 1)
        ii. Eye opening to pain stimulus (score = 2)
        iii. Eye opening to speech (score = 3)
        iv. Spontaneous eye opening (score = 4)
    c. Verbal response (score of 1-5)
        vi. No verbal response (score = 1)
        vii. Incomprehensible sounds (score = 2)
        viii. Inappropriate words (score = 3)
        ix. Confused (score = 4)
        x. Oriented (score = 5)
    d. Motor response (score of 1-6)
        i. No motor response (score = 1)
        ii. Abnormal extension to pain (score = 2)
        iii. Abnormal flexion to pain (score = 3)
        iv. Normal flexion from pain (score = 4)
        v. Localise to pain (score = 5)
        vi. Obeys command (score = 6)

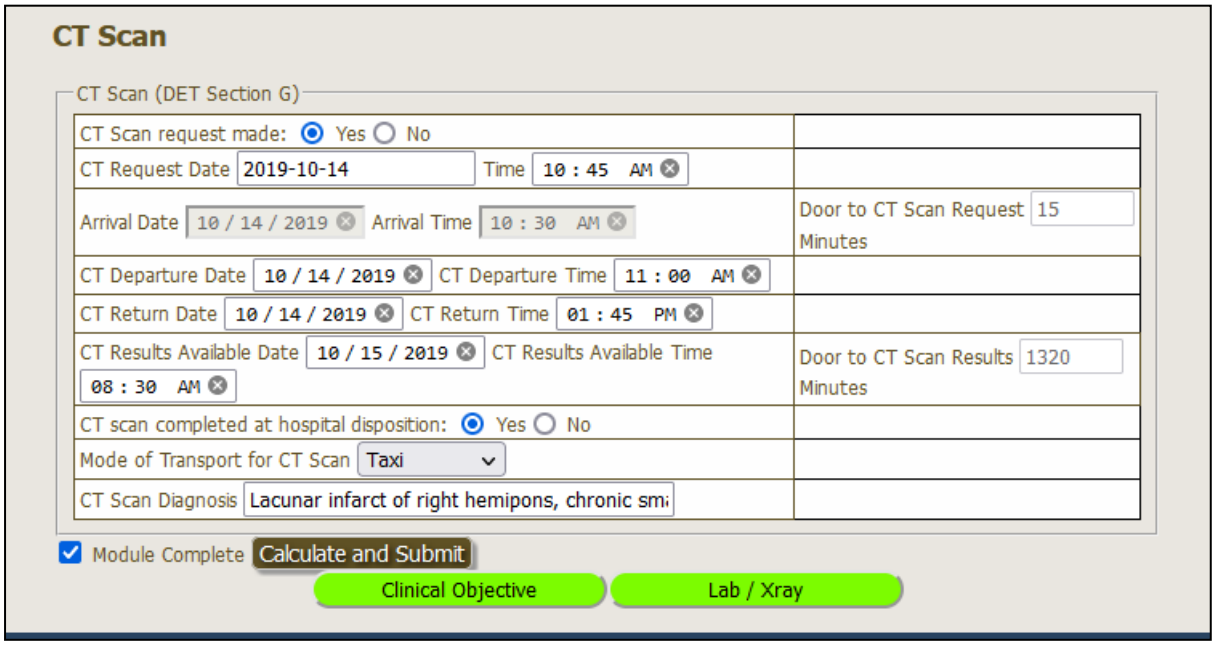
15. Stroke diagnosis
        i. Haemorrhagic stroke (clinical)
        ii. Haemorrhagic stroke (CT scan)
        iii. Ischaemic stroke (clinical)
        iv. Ischaemic stroke (CT scan)
        v. Query stroke (non-specific stroke)



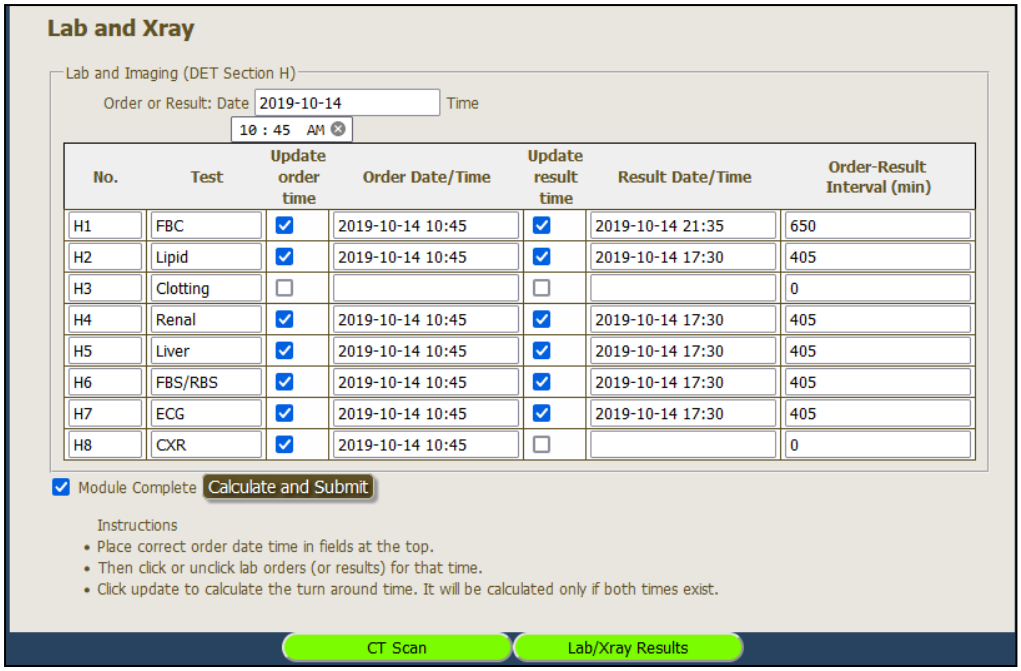
16. CT scan breakout
    a. CT scan request made (yes/no)
    b. CT scan request date (DD MM YYYY)

c. CT scan request time (HH: MM: SS)
d. Arrival date (DD MM YYYY)
e. Arrival time (HH: MM: SS)
f. Door to CT scan request (automatically calculated)
g. CT scan departure from ED date (DD MM YYYY)
h. CT scan departure time (HH: MM: SS)
i. CT return date (DD MM YYYY)
j. CT return time (HH: MM: SS)
k. CT scan results available date (DD MM YYYY)
l. CT scan results available time (HH: MM: SS)
m. Door to CT scan results (automatically calculated)

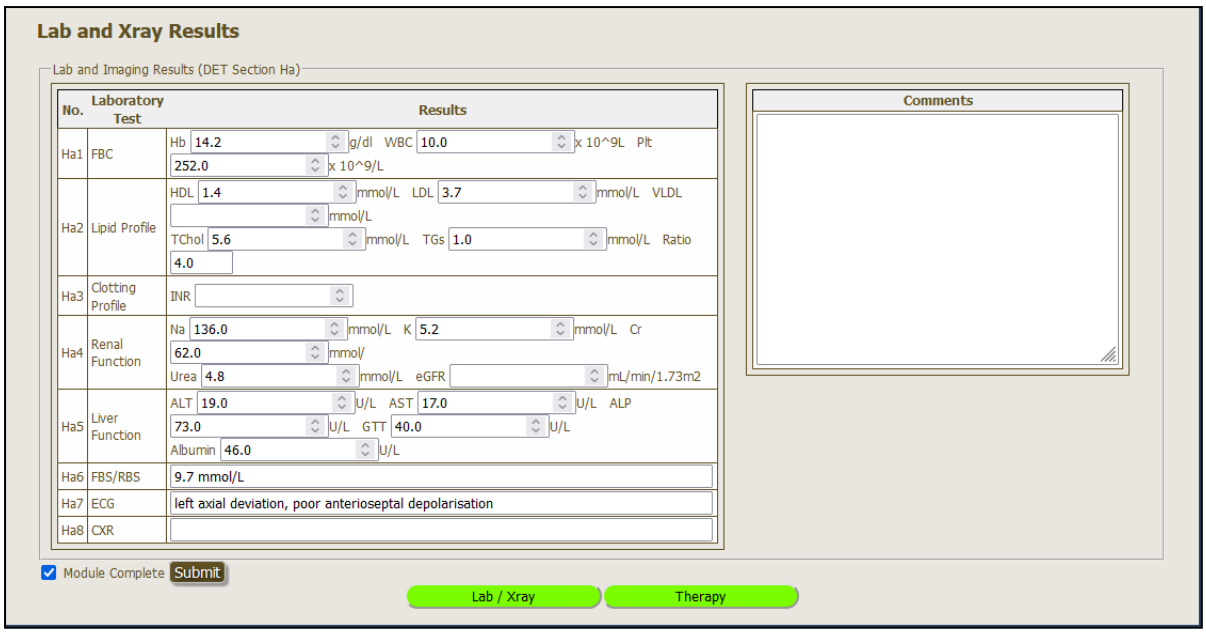
17. CT scan conducted at hospital disposition/discharge (yes/no)
18. Mode of transport for CT scan
    i. Ambulance
    ii. Taxi
    iii. Private car
    iv. Uber
    v. Other



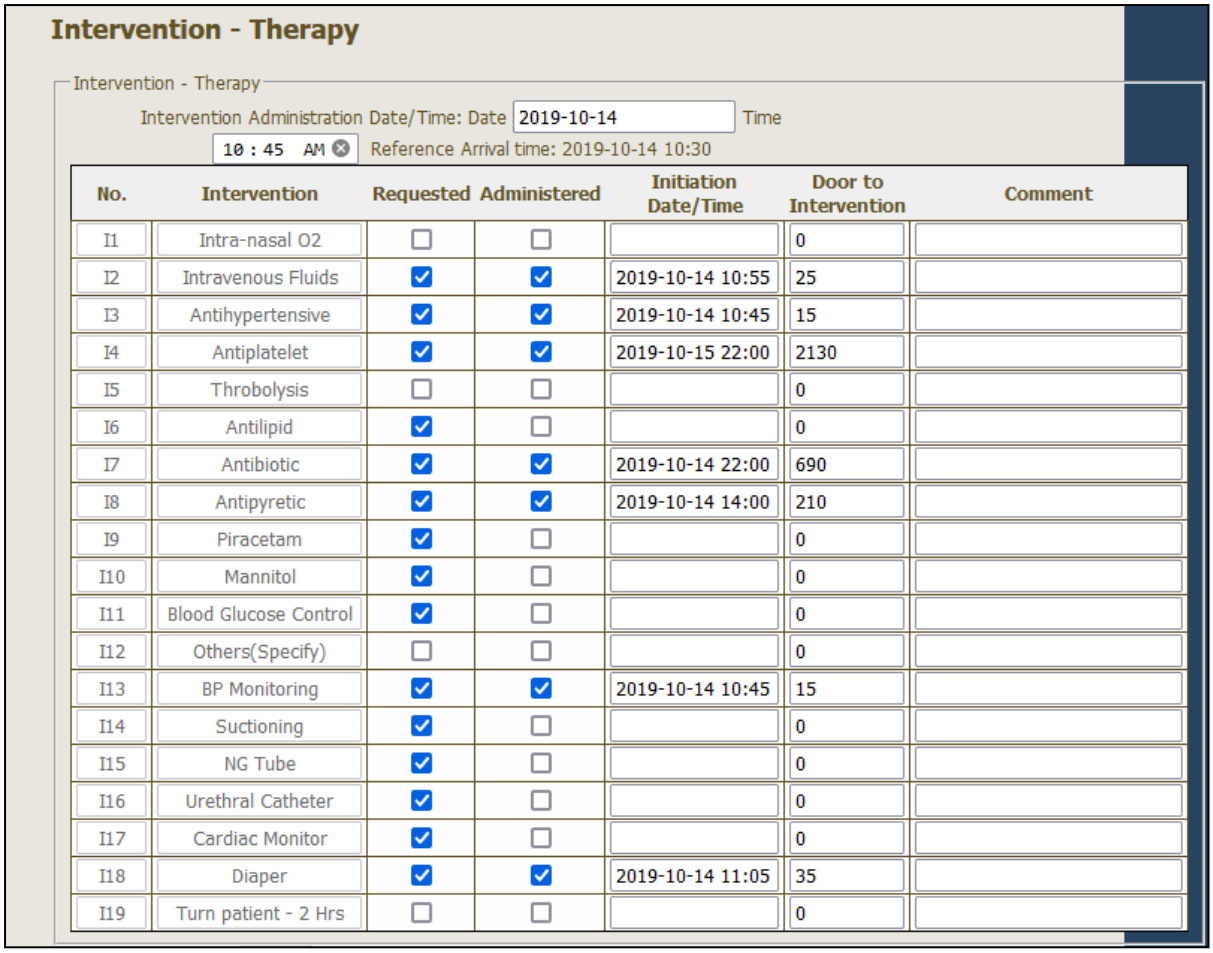
19. Laboratory and X-ray request details
    a. Order or results date (DD MM YYYY)
    b. Order or results time (HH: MM: SS)
    c. Test
        i. Full blood count
        ii. Lipid profile
        iii. Clotting profile
        iv. Renal function test
        v. Liver function test
        vi. Blood glucose
        vii. Electrocardiogram
        viii. Chest x-ray



20. Laboratory and X-ray results
    a. Full blood count
        i. Haemoglobin (Hb in g/dl)
        ii. White blood cell count (WBC in 10 ^ 9 L)
        iii. Platelet (Plt in 10 ^ 9 L)
    b. Lipid profile
        i. High density lipoprotein (HDL in mmol/L)
        ii. Low density lipoprotein (LDL in mmol/L)
        iii. Very low-density lipoprotein (VLDL in mmol/L)
        iv. Total cholesterol (TChol in mmol/L)
    c. Clotting profile
        i. International Normalised Ration (INR)
        ii. Prothrombin time (PT) that is the time it takes for blood to clot
    d. Renal function
        i. Sodium (Na as mmol/L)
        ii. Potassium (K as mmol/L)
        iii. Blood urea (in mmol/L)
        iv. Blood creatinine (in mmol/L)
        v. Estimated glomerular filtration rate (eGFR in mL/min/1.73 m^2)
    e. Liver function
        i. Alanine Aminotransferase (ALT in U/L)
        ii. Alkaline Phosphatase (ALP in U/L)
        iii. Gamma-glutamyl Transferase (GGT in U/L)
        iv. Albumin (in U/L)
    f. Random or fasting blood glucose (RBS/FBS in mmol/L)
21. Electrocardiograph (ECG) findings
22. Chest X ray (CXR) findings.
23. Comments



24. Therapy intervention
    a. Intervention administration date (DD MM YYYY)
    b. Intervention administration time (HH: MM: SS)
    c. Reference Arrival time and date (automatically populated) as it has been captured in the e-DET earlier
    d. Interventions
        i. Intranasal oxygen (requested (yes/no): administered (yes/no))
        ii. Intravenous fluids (requested (yes/no): administered (yes/no))
        iii. Antiplatelet (mostly aspirin per protocol) (requested (yes/no): administered (yes/no))
        iv. Thrombolysis (tPAs are not administered at the ED) (requested (yes/no): administered (yes/no))
        v. Antilipids (atorvastatin per protocol) (requested (yes/no): administered (yes/no))
        vi. Antipyretic (paracetamol per protocol) (requested (yes/no): administered (yes/no))
        vii. Piracetam (requested (yes/no): administered (yes/no))
        viii. Mannitol (osmotic diuretic) (requested (yes/no): administered (yes/no))
        ix. Blood glucose control plan (requested (yes/no): administered (yes/no))
        x. Other medications specify (requested (yes/no): administered (yes/no))
        xi. Blood pressure monitoring chart (requested (yes/no): administered (yes/no))
        xii. Regular suctioning to prevent aspiration (requested (yes/no): administered (yes/no))
        xiii. Nasogastric tube insertion (to decongest the stomach and prevent aspiration) (requested (yes/no): administered (yes/no))
        xiv. Urethral catheter passage (requested (yes/no): administered (yes/no))
        xv. Cardiac monitor set up (requested (yes/no): administered (yes/no))
        xvi. Diaper wearing (requested (yes/no): administered (yes/no))
        xvii. Turn patients every two hours to prevent bed sores acquisition (requested (yes/no): administered (yes/no))



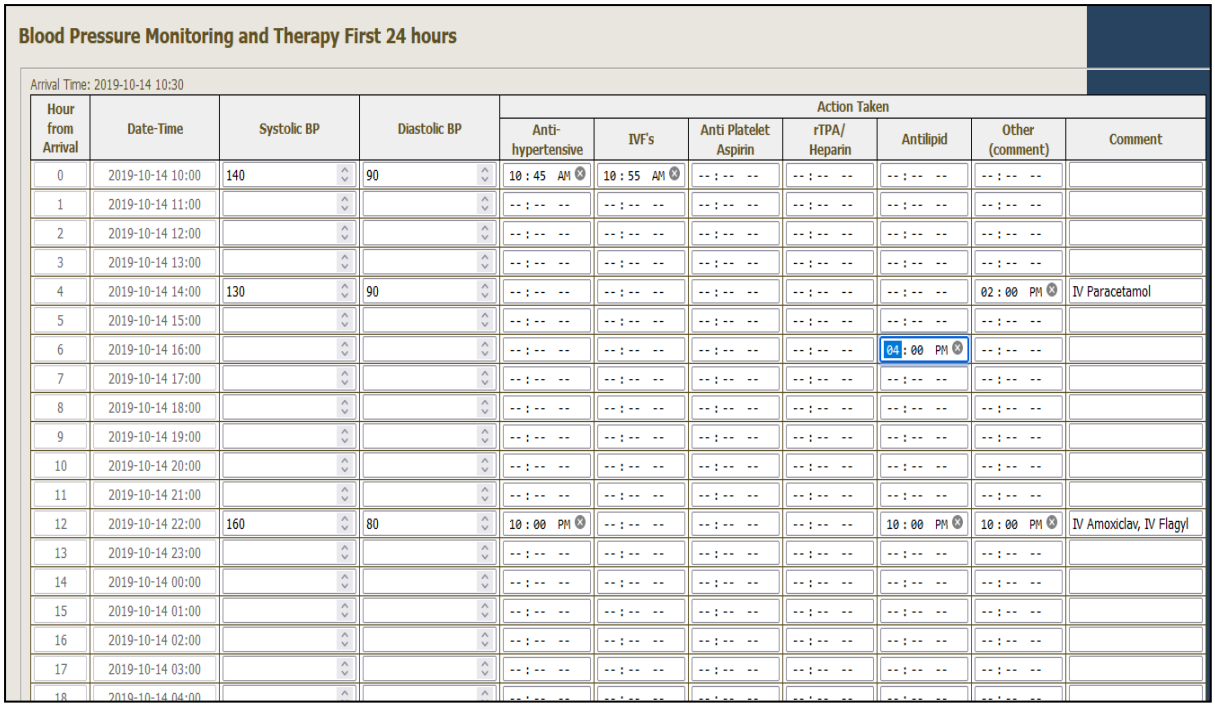
Intervention - Therapy

Intervention - Therapy

Intervention Administration Date/Time: Date 2019-10-14 Time 10 : 45 AM Reference Arrival time: 2019-10-14 10:30

No.	Intervention	Requested	Administered	Initiation Date/Time	Door to Intervention	Comment
I1	Intra-nasal O2	☐	☐		0	
I2	Intravenous Fluids	☑	☑	2019-10-14 10:55	25	
I3	Antihypertensive	☑	☑	2019-10-14 10:45	15	
I4	Antiplatelet	☑	☑	2019-10-15 22:00	2130	
I5	Throbolysis	☐	☐		0	
I6	Antilipid	☑	☐		0	
I7	Antibiotic	☑	☑	2019-10-14 22:00	690	
I8	Antipyretic	☑	☑	2019-10-14 14:00	210	
I9	Piracetam	☑	☐		0	
I10	Mannitol	☑	☐		0	
I11	Blood Glucose Control	☑	☐		0	
I12	Others(Specify)	☐	☐		0	
I13	BP Monitoring	☑	☑	2019-10-14 10:45	15	
I14	Suctioning	☑	☐		0	
I15	NG Tube	☑	☐		0	
I16	Urethral Catheter	☑	☐		0	
I17	Cardiac Monitor	☑	☐		0	
I18	Diaper	☑	☑	2019-10-14 11:05	35	
I19	Turn patient - 2 Hrs	☐	☐		0	

25. Blood pressure control chart within 24 hours of admission at the ED
    a. Arrival date (DD MM YYYY)
    b. Arrival time (HH: MM: SS)
    c. Hour from arrival (0 – 24 hours)
    d. Date/ time of systolic blood pressure measured (DD MM YYYY and HH: MM: SS)
    e. Date/time of diastolic blood pressure measured (DD MM YYYY and HH: MM: SS)
    f. Date/ time of antihypertensive administered (DD MM YYYY and HH: MM: SS)
    g. Date/ time of intravenous fluids administered (DD MM YYYY and HH: MM: SS)
    h. Date/ time of antiplatelet administered (DD MM YYYY and HH: MM: SS)
    i. Date/ time of Antilipids administered) (DD MM YYYY and HH: MM: SS)
    j. Other comments



Blood Pressure Monitoring and Therapy First 24 hours

Arrival Time: 2019-10-14 10:30

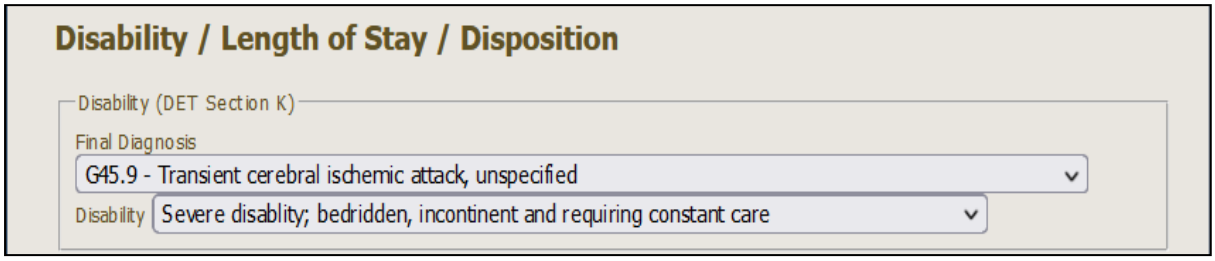
Hour from Arrival	Date-Time	Systolic BP	Diastolic BP	Action Taken						
				Anti-hypertensive	IVF's	Anti Platelet Aspirin	rTPA/ Heparin	Antilipid	Other (comment)	Comment
0	2019-10-14 10:00	140	90	10:45 AM	10:55 AM	--:-- --	--:-- --	--:-- --	--:-- --	
1	2019-10-14 11:00			--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	
2	2019-10-14 12:00			--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	
3	2019-10-14 13:00			--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	
4	2019-10-14 14:00	130	90	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	02:00 PM	IV Paracetamol
5	2019-10-14 15:00			--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	
6	2019-10-14 16:00			--:-- --	--:-- --	--:-- --	--:-- --	04:00 PM	--:-- --	
7	2019-10-14 17:00			--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	
8	2019-10-14 18:00			--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	
9	2019-10-14 19:00			--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	
10	2019-10-14 20:00			--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	
11	2019-10-14 21:00			--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	
12	2019-10-14 22:00	160	80	10:00 PM	--:-- --	--:-- --	--:-- --	10:00 PM	10:00 PM	IV Amoxiclav, IV Flagyl
13	2019-10-14 23:00			--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	
14	2019-10-14 00:00			--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	
15	2019-10-14 01:00			--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	
16	2019-10-14 02:00			--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	
17	2019-10-14 03:00			--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	
18	2019-10-14 04:00			--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	--:-- --	

26. Final CT scan diagnosis at discharge based on ICD – 10

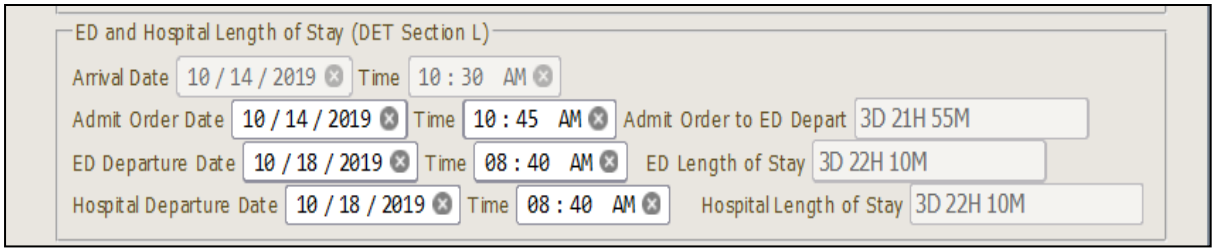
161.0- Non traumatic intracerebral haemorrhage in hemisphere, subcortical
161.1 - Non traumatic intracerebral haemorrhage in hemisphere, cortical
161.2 - Non traumatic intracerebral haemorrhage in hemisphere, unspecified
161.3 - Non traumatic intracerebral haemorrhage in hemisphere, brainstem
161.4 - Non traumatic intracerebral haemorrhage in hemisphere, cerebellum
161.5 - Non traumatic intracerebral haemorrhage in hemisphere, intraventricular
161.6 - Non traumatic intracerebral haemorrhage in hemisphere, multiple localised
161.8 - Other non-traumatic intracerebral haemorrhage
161.9 - Non traumatic intracerebral haemorrhage unspecified
163.50 - Cerebral infarction due to unspecified occlusion or stenosis of unspecified cerebral artery
163.519 - Cerebral infarction due to unspecified occlusion or stenosis of unspecified middle cerebral artery
163.529 - Cerebral infarction due to unspecified occlusion or stenosis of unspecified anterior cerebral artery
163.549 - Cerebral infarction due to unspecified occlusion or stenosis of unspecified cerebellar artery
163.549 - Cerebral infarction due to unspecified occlusion or stenosis of unspecified another cerebral artery
163.9 - Cerebral infarction, unspecified
G45.9 - Transient cerebral ischaemic attack, unspecified

27. Disability levels using the modified Rankin scale
    a. Asymptomatic (score = 0)
    b. No significant disability despite symptoms (score = 1)
    c. Slight disability, unable to conduct all previous activities (score = 2)

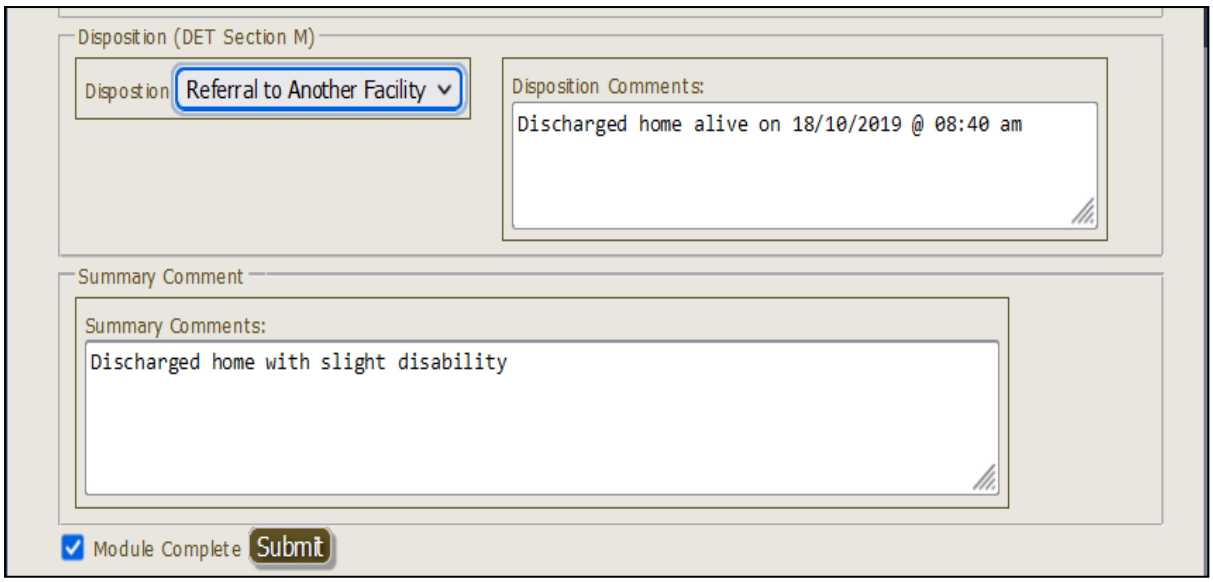
d. Moderate disability, requiring some help, able to walk (score = 3)
e. Moderate to severe disability, unable to walk or attend to bodily needs without assistance (score = 4)
f. Severe disability, bedridden incontinent and requiring constant care (score = 5)
g. Deceased (score = 6)



28. Emergency department and hospital length of stay
    a. Arrival data (DD MM YYYY)
    b. Arrival time (HH: MM: SS)
    c. Admit order date (DD MM YYYY)
    d. Admit order time (HH: MM: SS)
    e. ED departure date (DD MM YYYY)
    f. ED departure time (HH: MM: SS)
    g. Admit order to ED departure time (automatically calculated)
    h. ED length of stay (automatically calculated)
    i. Hospital departure data (DD MM YYYY)
    j. Hospital departure time (HH: MM: SS)
    k. Hospital length of stay (automatically calculated)



29. Decision at disposition of patient
    a. Discharged
    b. Transfer to an inpatient bed
    c. Referral to another facility
    d. Alive
    e. Dead
30. Disposition comments
31. Summary comments



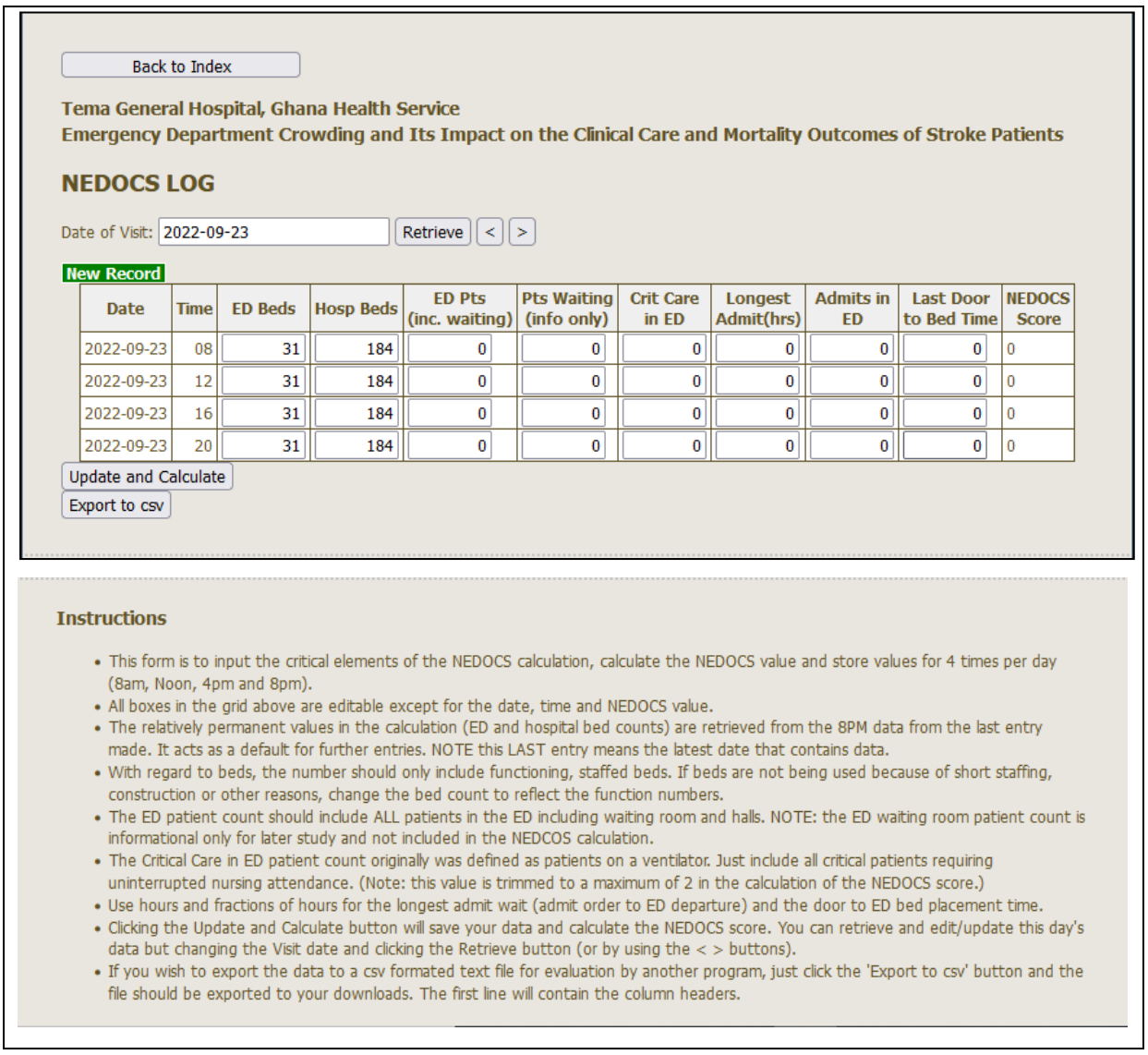
32. NEDOCS input form

The NEDOCS INPUT button allowed access to the NEDOCS calculator which was incorporated into the e-DET. The interface of the NEDOCS calculator developed as part of the online data capture tool is shown in Figure below. On the NEDOCS LOG, there was a space bar that allowed for the date of visit to be entered with a retrieve button that allows for retrieval of patient information using the data of visit. Under the new record tab, a table with 4 rows and 11 columns is available to capture the NEDOCS variables for the day. This is presented below.

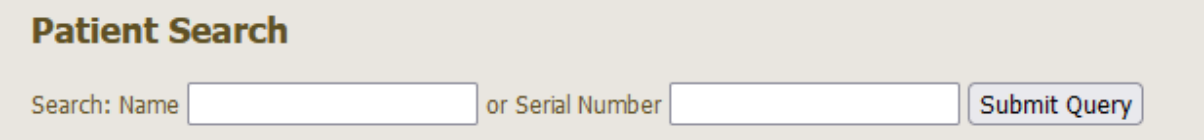
1. The first row has the following date when the variables were to be entered during the same date.
2. The second row has the time when the NEDOCS variables were collected, that is at:
    a. 8:00 am
    b. 12:00 pm
    c. 4:00 pm
    d. 8:00 pm
3. The third row is ED beds count
4. The fourth row has the total number of hospital beds, which was usually a constant figure
5. The fifth row had the total number of ED patients including those waiting to be seen
6. The sixth row had the total number of patients waiting to be seen at the ED
7. The seventh row had the number of patients in critical care at the ED

8. The eight rows had the longest admit patients at the ED (in hours)
9. The nineth row had the total number of patients that have been admitted to inpatients bed in the hospital who were at the ED
10. The tenth row had the last door to bedtime which measure the time between the last patient was seen and the time the patient was admitted into a bed at the ED
11. The eleventh row captures the NEDOCS that is automatically generated.

The NEDOCS could be updated, and a recalculated score automatically effected. This score could be exported to a CSV file format for cleaning and analysis. Embedded in the NEDOCS input form were the instructions that ensured accuracy of data entry. The NEDOCS interface and instructional guide is seen in the Figure below. Embedded were the instructions that ensured accuracy of data entry.



The patient search tab allowed for searching Searches was be done using the name of the patients or the serial number assigned to the patient. A query is submitted, and a list of patient's records pops up enabling the user to select patients. The records that popped up included the name of the patients, date of birth, clinical record number, serial number, the last date, and time records were updated and a select button.



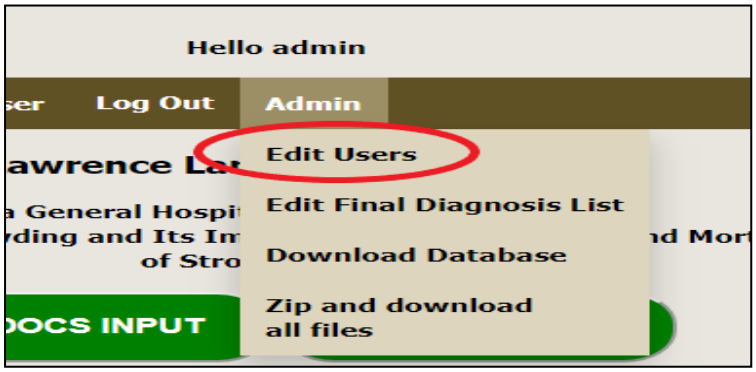
33. Data cleaning

For purposes of data cleaning and analysis, the data were downloadable in a 'csv' format for both the NEDOCS and the e-DET. The NEDOCS was set as a 'flat' file, in that each record could fit on one line of a dump with each item in a different field. With the stroke data, a relational data system was created because of the multiple recurrent blood pressure monitoring and measurement. A temporary table that merged all the elements but then gave a table with multiple identical records was added to the options available for download. This was compatible with Excel and SPSS and other data analysis tools. The use of automation of dates and time made it less cumbersome, and it also ensured consistency when it came to data entry. Various reports could easily be downloaded by the click of a button. Another important feature of the electronic data extraction tool was the various of administrative permission and clearance needed to assess the electronic tool.

34. Levels of administrative clearance and assess to the e-DET

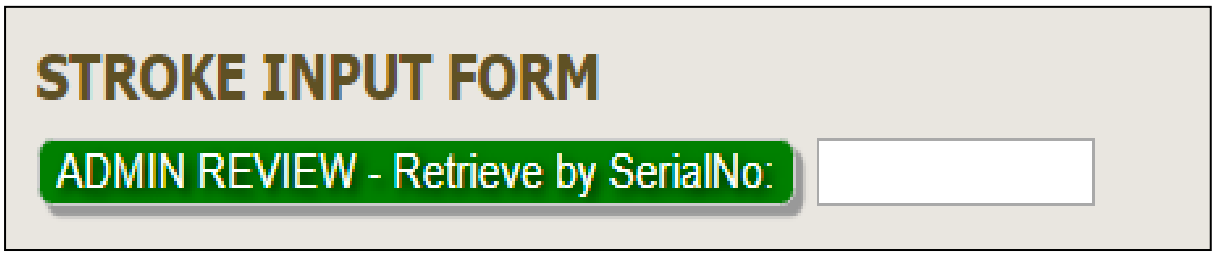
There were three view levels, namely 'Tech', 'Assistant', or 'Admin.' The research assistants were limited to 'Assistant' and 'Tech' categories. Each level had a different access to the reports; however, all the levels were able to enter data. In addition to login, the username was attached to each e-DET record with the most recent update for any submission (this was overwritten if there was a further update). The users could change their own passwords (this was mandatorily done every Monday) by using the password update button. I had overall access with the ability to monitor and manage the site. I had the ability to log out research assistants, reset passwords as and when necessary. This was done weekly to guarantee data security. I also had full access to edit the data and conduct data validation. From the main menu the appearance of the 'Edit Users' link when clicked is shown in the Figure below. Another important feature

of the tool was the completeness of data and the administrative steps to ensure that the data collected was complete.



35. Data completeness and administrative review

The e-DET report page was reworked after 2 months of data extraction. The updated version included completeness of the submitted form and it provided a link for record review and editing. The ‘complete’ indication meant that each section of the record had been assessed and ‘submitted’ with the ‘completed’ checkbox ticked, not that any new data had been entered. Using the ‘Review Link Pencil’ also led directly to the records for review and edits. I had ‘Admin' privileges and was able to easily recall records by using serial numbers for review and approval of data entered. This form item was not visible in the ‘techs’ view.



For administrative review, the selected serial number was inputted in the white box as shown in the Figure 3.11 above. The green (ADMIN REVIEW) button was then clicked. This brought up the requested record for review/edit. When the desired page hand been visited and ‘submitted’ having pages with changes, one could return to the main page to continue work on the e-DET. One was then able to enter a new serial number requested in the above box and the new record was brought up using the 'ADMIN REVIEW' button up. This was workable with multiple records on a copy of the real database on a computer. Once a serial number was assigned to a record, it could not be changed. There was a tendency to put a new serial number in the current patient box when really wanting to put it in the ‘Admin retrieval box’ (above). If

the serial number was changed and ‘UPDATED,’ it was supposed to block and not change to an existing record. But if a non-existent serial number was used, it was saved as a new number, which was undesired. This was corrected so that once a serial number had been entered and saved, the input box for the serial number (not the admin box) was disabled and did not allow changes. Data coding and data validation was conducted to ensure the accuracy of the data collected. This was a feature embedded in the e-DET.

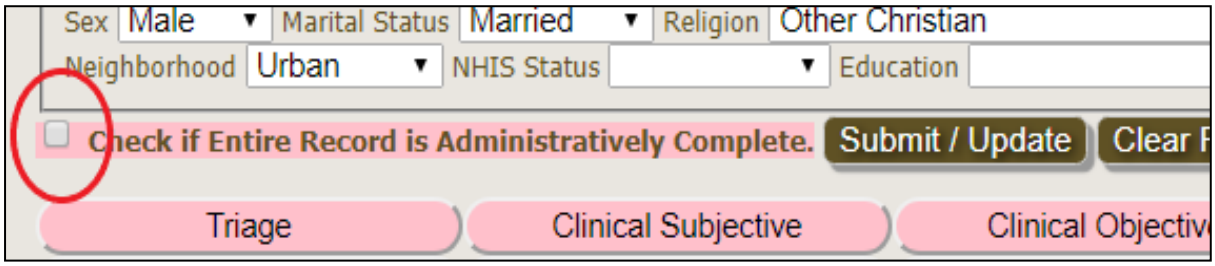
36. Data protection of patients

A security certificate was added to the Ghana subdomain on the site of the e-DET. This allowed for the use of the ‘https’ and that meant that all the information to and from the site was encrypted and secured at the backend. Various levels of access using unique ID names and passwords further enhanced the security of the data collected and ensured limited and protected access. The data collected were not shared to a third party either via email, fax, blue tooth, WhatsApp, telegram or using a pen drive. The computer at the ED used for the data collection was provided by me and it was passworded. Passwords of the research assistants were changed by meek every week. Only the research assistants had access to the computer that was used for the electronic data collection.

Appendix 3 – Data coding queries and data validation processes of the e-DET

Examples of queries that was copied and pasted into the SQL box and then run are discussed below. This was the default query that automatically showed up in the SQL page. SELECT * FROM "ptlist" WHERE '1' which meant select all fields (*) from table "ptlist". The WHERE was optional since the number 1 = true (or everything). This could be edited slightly and pasted in the query box which was down at the bottom of the page. SELECT * FROM "ptlist" WHERE "SerialNo" = 10. This allowed a show of all fields where the record had SerialNo = 10. This query SELECTED "SerialNo", "ModeOfArrival", "age", "sex", "education" FROM "ptlist" WHERE SerialNo = 11 only showed the SerialNo, ModeOfArrival, age, sex, and education fields where SerialNo = 11 or SELECT "SerialNo", "ModeOfArrival", "age", "sex", "education" FROM "ptlist" WHERE SerialNo < 11 showed the same fields for all SerialNo records less than 11. It is noted they are not in serial number order. To fix that the query was changed to SELECT "SerialNo", "ModeOfArrival", "age", "sex", "education" FROM "ptlist" WHERE SerialNo < 11 order by SerialNo the other direction SELECT "SerialNo", "ModeOfArrival", "age", "sex", "education" FROM "ptlist" WHERE SerialNo < 11 order by SerialNo DESC.

The main e-DET screen had an administrative completion box next to the bottom submit button as shown below. This used once all the necessary data validation has been successfully completed.



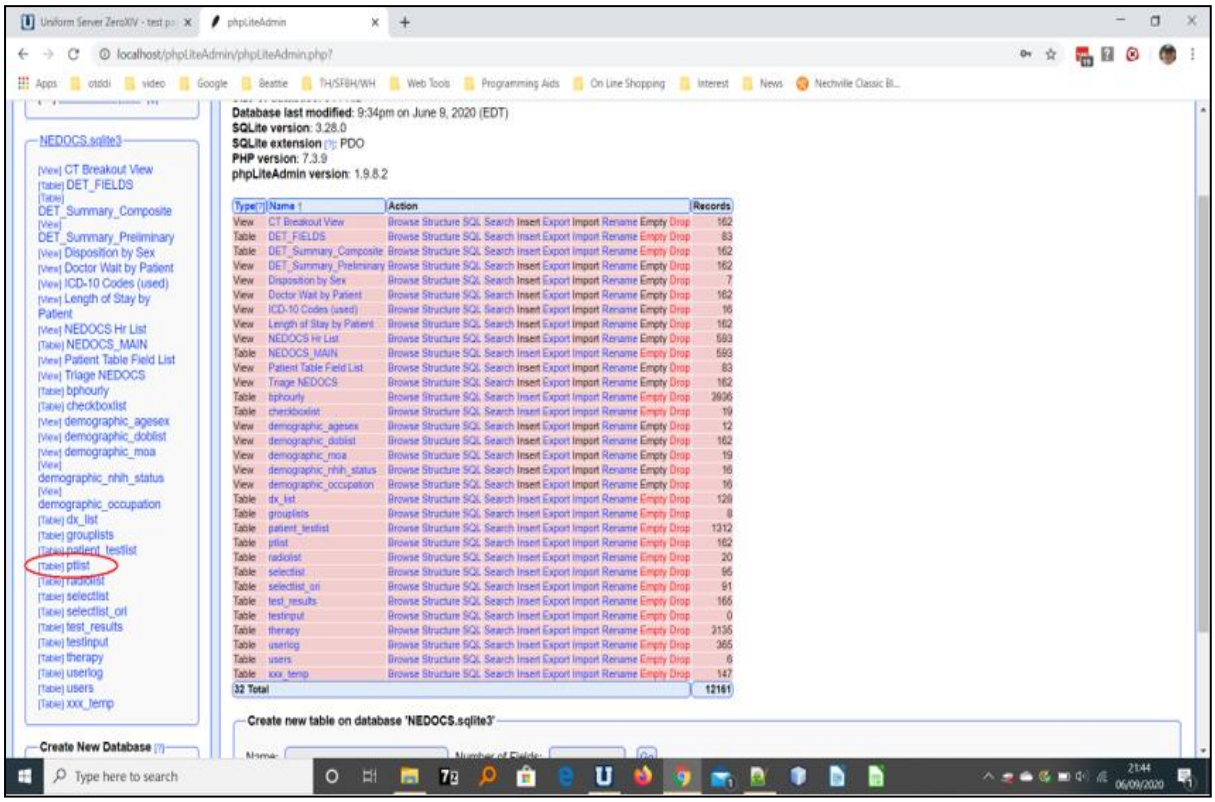
When it was unchecked, the associated text was 'pink.' When checked (and submitted) the text turned 'green.' This checkbox was not visible to logins with less than 'Admin' (principal investigator) classification. So only the principal investigator could see and complete this checkbox. It was intended for the principal investigator to use as a final check off of each record. A report that showed which records were incomplete was added, this gave the opportunity to review and complete records. Instruction to allow for data validation while entering data were as follows:

1. Any new entry MUST have a first and family name, Serial Number and Code # to enable the Submit button. If the Submit button was RED, it WON'T work.
2. One could create a 'code' entry from the serial entry by clicking the associated button. This only worked if the code entry box was blank. If one had an erroneous entry and wanted to create a new one, any text in the code box first was deleted.
3. One could search for prior entries. Using the search boxes at the top of the form. Using the last name or first few characters. If you searched by the serial number, you must have the entire correct number. If searching by last name, one was presented a list from which to select.
4. Once the record was created by clicking on Submit the remaining form linked buttons appeared. They were initially red. Once each form's data was entered and submitted, the button changed to green. Each form had the prior and next form buttons at the bottom.
5. Birthday/DOB. If the patient knew their birthday, you could enter it using the dropdown. Note you could adjust the year and month by clicking on those areas in the dropdown. one then clicked on the day to select the entire date. One could then click the 'Calc Age' button and the age was calculated to the arrival date or could simply type in the age. If one did both, there was a possibility that the two would not concur.

Appendix 4 - Data navigation and exploration of the e-DET

To explore the data base without worrying of corrupting it, the entire SQLite database file could be compressed into a zipfile and downloaded. This could be unpacked into a new 'Folder' in a Uniserver www section on the computer and it was named 'phpLiteAdmin.' 'phpLiteAdmin' is a powerful tool to explore SQLite database, alter and delete data, hence it was used on a database. There was a table called 'ptlist' (circled) that served as the main data table for the patients. SQLite queries were explored as well. At the top just below where it read, "Showing Rows…." The SQL query is seen, and this could be run to show the data in the table ('by selecting * from "ptlist").

Once the Uniserver local main page was opened it was seen in addition to the Ghana stroke study page that had been created in the file section. There was a unique username and password attached before access could be granted. Only the principal investigator had access to this function. The appearance of this zip file when downloaded is shown below.



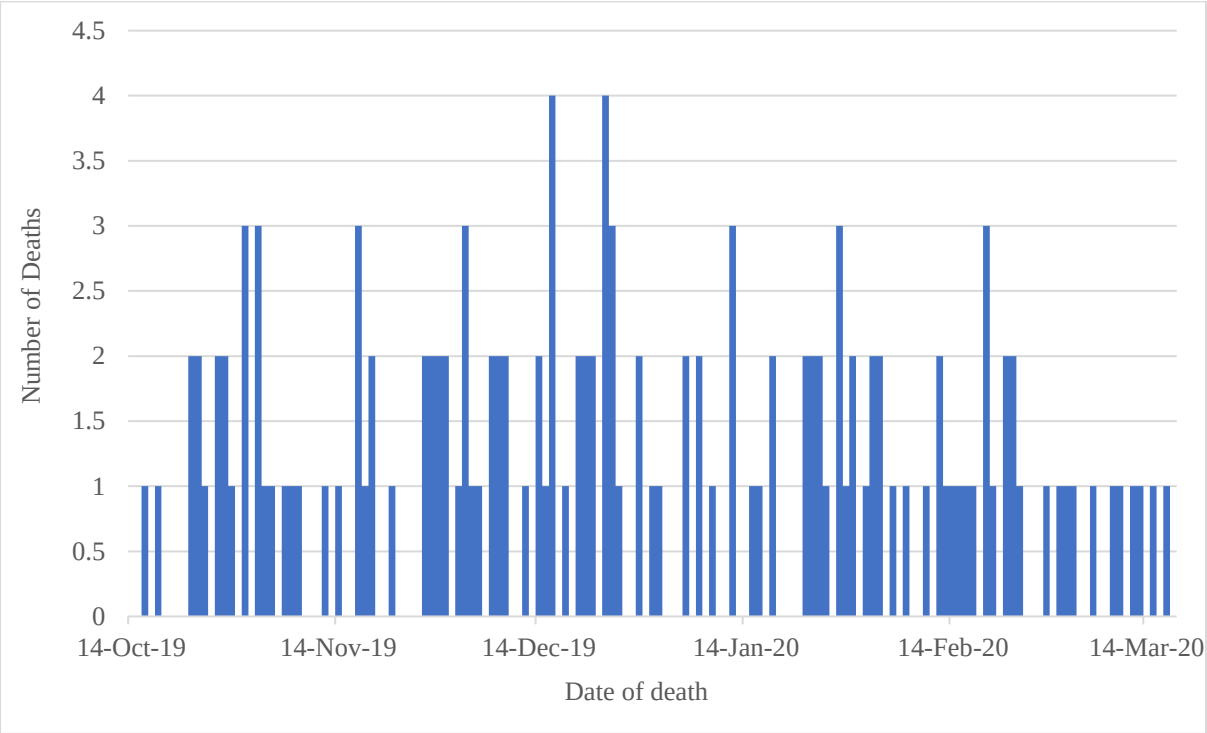
Appendix 5 – Age and systolic blood pressure of the stroke patients at presentation

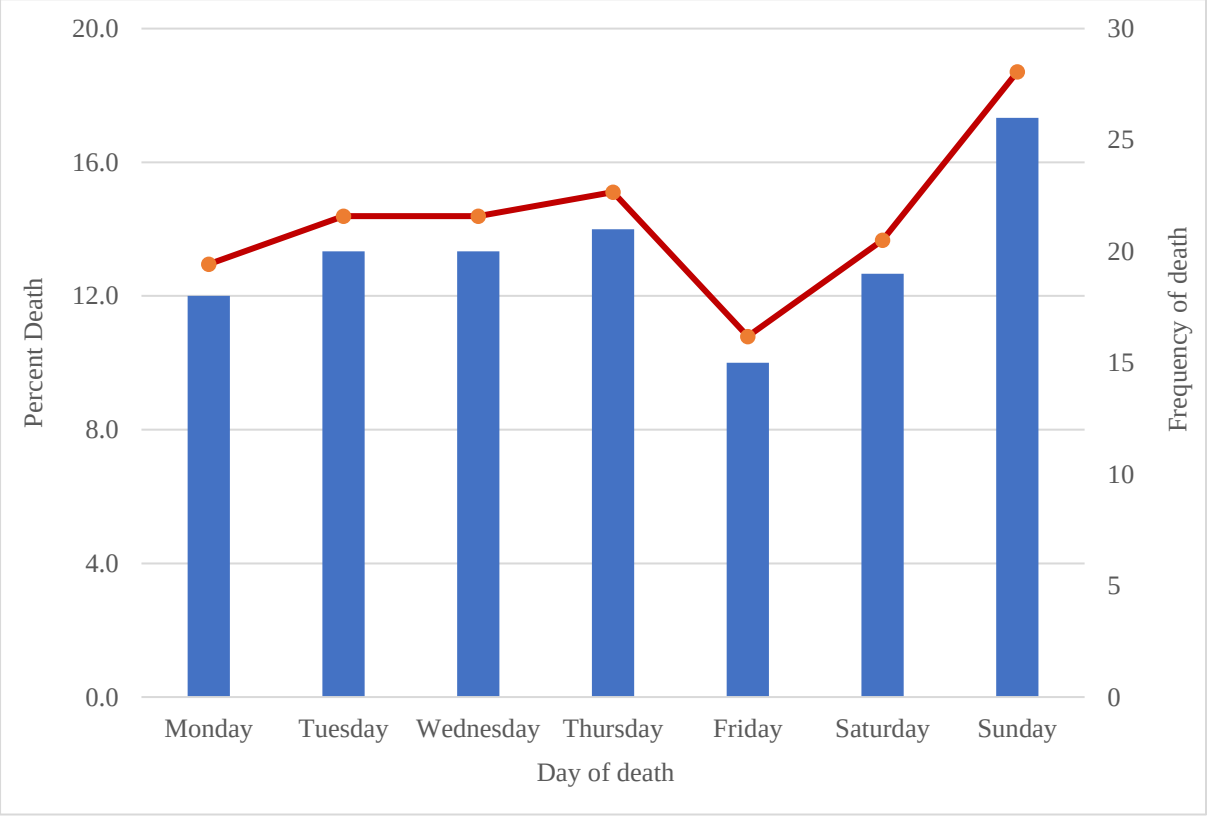
Age	Normal BP (<120 mmHg)	Elevated BP (120-129 mmHg)	Hypertension stage I (130-139 mmHg)	Hypertension stage II (140-179 mmHg)	Hypertensive crisis (≥ 180 mmHg)	Total
15-19	1	0	0	1	0	2
30-34	0	0	0	0	1	1
35-39	0	0	0	1	2	3
40-44	0	1	1	2	9	13
45-49	3	0	0	7	10	20
50-54	1	0	0	11	11	23
55-59	6	0	1	9	15	31
60-64	2	3	3	10	8	26
65-69	4	0	1	3	8	16
70-74	3	0	1	6	2	12
75-79	7	1	0	4	2	14
80-84	4	0	1	1	0	6
85-89	2	0	0	1	1	4
90-94	1	0	0	1	0	2
95-99	0	0	0	0	1	1
105-110	0	0	0	1	0	1
Total	34	5	8	58	70	175

Appendix 6 – Neurological presentation of the stroke patients according to gender

	Male (n = 89)		Female (n = 86)	
Clinical presentation	Yes (%)	No (%)	Yes (%)	No (%)
Facial palsy	41 (46.1)	48 (53.6)	30 (35.3)	56 (65.1)
Altered speech	47 (52.8)	42 (47.2)	56 (65.9)	30 (34.9)
Swallowing difficulties	24 (27.0)	64 (71.9)	20 (23.5)	66 (76.7)
Seizures	10 (11.2)	79 (88.8)	4 (4.7)	82 (95.3)
Raised intracranial pressure	27 (30.3)	62 (69.7)	14 (16.5)	72 (83.7)
Aspiration	50 (56.2)	39 (43.8)	34 (40.0)	52 (60.5)
Urine incontinence	65 (73.0)	24 (27.0)	67 (78.8)	19 (22.1)
Stool incontinence	64 (71.9)	25 (28.1)	63 (74.1)	23 (26.7)

Appendix 7 – Date and day of death of the stroke patients





Appendix 8 – Age distribution of death according to the type of stroke

Age group	IS	IS deaths	HS	HS deaths	Total deaths	Percent total death (%)	Total no. of stroke patients
15-19	1	1	1	0	1	50	2
30-34	0	0	1	1	1	100	1
35-39	1	1	2	2	3	100	3
40-44	6	5	7	5	10	76.9	13
45-49	10	7	10	9	16	80	20
50-54	9	4	14	14	18	78.3	23
55-59	14	13	17	15	28	90.3	31
60-64	19	14	7	4	18	69.2	26
65-69	11	9	5	5	14	87.5	16
70-74	10	9	2	2	11	91.7	12
75-79	11	6	3	3	9	64.3	14
80-84	6	5	0	0	5	83.3	6
85-89	3	2	1	0	2	50	4
90-94	2	1	0	0	1	50	2
95-99	0	0	1	1	1	100	1
105-110	1	1	0	0	1	100	1
Total	**104**	**78**	**71**	**61**	**139**	**79.4**	**175**

Appendix 9 – Ethics approval from the University of Salford

University of Salford MANCHESTER

Research, Enterprise and Engagement
Ethical Approval Panel

Doctoral & Research Support
Research and Knowledge Exchange,
Room 827, Maxwell Building,
University of Salford,
Manchester
M5 4WT

T +44(0)161 295 2280

www.salford.ac.uk

31 July 2019

Dear Lawrence,

RE: ETHICS APPLICATION–HSR1819-097 –'EMERGENCY DEPARTMENT CROWDING AND ITS IMPACT ON BED SIDE BLOOD PRESSURE MONITORING AND CT SCAN USE IN STROKE PATIENTS AND MORTALITY OUTCOMES.'

Based on the information that you have provided, I am pleased to inform you that ethics application HSR1819-097 has been approved.

If there are any changes to the project and/or its methodology, then please inform the Panel as soon as possible by contacting Health-ResearchEthics@salford.ac.uk

Yours sincerely,

Professor Sue McAndrew
Chair of the Research Ethics Panel

Appendix 10 – Ethics approval from the Ghana Health Service

GHANA HEALTH SERVICE ETHICS REVIEW COMMITTEE

In case of reply the number and date of this Letter should be quoted

Research & Development Division
Ghana Health Service
P. O. Box MB 190
Accra
GPS Address: GA-050-3303
Tel: +233-302-681109
Fax + 233-302-685424
Email: ghserc@gmail.com

MyRef. GHS/RDD/ERC/Admin/App
Your Ref. No. 19/573

19th September, 2019

Dr. Lawrence Lartey
P. O. Box STC 220
STC Kaneshie
Accra

The Ghana Health Service Ethics Review Committee has reviewed and given approval for the implementation of your Study Protocol.

GHS-ERC Number	**GHS-ERC 012/08/19**
Project Title	Emergency department crowding and its impact on the clinical care and mortality outcomes of Stroke Patients
Approval Date	19th September, 2019
Expiry Date	18th September, 2020
GHS-ERC Decision	**Approved**

This approval requires the following from the Principal Investigator

- Submission of yearly progress report of the study to the Ethics Review Committee (ERC)
- Renewal of ethical approval if the study lasts for more than 12 months,
- Reporting of all serious adverse events related to this study to the ERC within three days verbally and seven days in writing.
- Submission of a final report after completion of the study
- Informing ERC if study cannot be implemented or is discontinued and reasons why
- Informing the ERC and your sponsor (where applicable) before any publication of the research findings,
- Please note that any modification of the study without ERC approval of the amendment is invalid.

The ERC may observe or cause to be observed procedures and records of the study during and after implementation.

Kindly quote the protocol identification number in all future correspondence in relation to this approved protocol

SIGNED.....
Dr. Cynthia Bannerman
(GHS-ERC Chairperson)

Cc: The Director, Research & Development Division, Ghana Health Service, Accra