TITLE PAGE

Review

The use of computerised clinical decision support systems in Emergency Care: a substantive review of the literature

Dr Paula Bennett Emergency Department, Stockport NHS Foundation Trust, Poplar Grove, Stockport, Cheshire SK2 7JE. UK. Paula.Bennett@stockport.nhs.uk
044 161 419 5826

Professor Nick Hardiker School of Nursing, Midwifery, Social Work & Social Sciences MS1.12 Mary Seacole Building, University of Salford, Salford M6 6PU. UK

Corresponding author Paula Bennett

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ABSTRACT

Objectives: This paper provides a substantive review of international literature evaluating the impact of computerised clinical decision support systems (CCDSS) on the care of emergency department (ED) patients.
Material and Methods*:* A literature search was conducted using Medline, CINAHL, EMBASE electronic resources and grey literature. Studies were selected if they compared the use of a CCDSS with usual care in a face-to-face clinical interaction in an ED.
Results: Of the 23 studies included approximately half demonstrated a statistically significant positive impact on aspects of clinical care with the use of CCDSSs. The remaining studies showed small improvements, mainly around documentation. However, the methodological quality of the studies was poor with few or no controls to mitigate against confounding variables. The risk of bias was high in all but six studies.
Discussion*:* The ED environment is complex and does not lend itself to robust quantitative designs such as Randomised Controlled Trials. The quality of the research in approximately 75% of the studies was poor and therefore conclusions cannot be drawn from these results. However the studies with a more robust design show evidence of the positive impact of CCDSSs on ED patient care.
Conclusion This is the first review to consider the role of CCDSSs in emergency care and expose the research in this area. The role of CCDSSs in Emergency Care may provide some solutions to the current challenges in EDs but further high quality research is needed to better understand what technological solutions can offer clinicians and patients.

OBJECTIVES

This paper provides a description of a substantive review of published international literature evaluating the impact of computerised clinical decision support systems (CCDSS) on the care of emergency department (ED) patients. The principal aims of this review are: to identify the body of CCDSS research undertaken in EDs, the research methods used, their quality and the impact of CCDSSs on clinical care in EDs. The discussion synthesises what is known and not known about the effectiveness of CCDSSs in Emergency Care and the quality of the current evidence base.

BACKGROUND AND SIGNFICANCE

There are huge challenges facing providers of emergency and urgent care within the UK National Health Service and internationally. Ever increasing use and on-going economic uncertainties have created a situation where the demand for emergency health care cannot consistently be matched by the resources available to deliver it. There is clear international evidence of the deleterious effects of long waits on the mortality and morbidity of ED patients.[1-4] The effect of waiting in the ED has been directly correlated with mortality even when co-morbidities are controlled

for,[5]. In counties where there are performance targets the pressure to deliver timely and efficient emergency care is compounded .[6, 7]

Within the National Health Service (NHS) in England there are additional challenges that complicate matters further. Changes to medical education have reduced the time doctors in training spend working in EDs.[8] There is evidence that as a result of this decision-making takes longer, more tests are ordered and more referrals are made to in-patient specialities.[9] In Emergency Care the use of locum (temporary replacement) doctors is proportionately high with reports that one fifth of medical staffing on weekends is by locums.[10] Locum doctors will not know the EDs policies or clinical guidelines and often require a level of support and supervision, adding to the pressure within the system.[11]

A parallel and equally important issue is that of the ageing population. The number of people over the age of 85 years in the UK has increased by 20% since 2006,[12] and is expected to continue to increase over the next 20 years by two-thirds,[13]. In 2009-2010 15% of UK ED patients were over 70 and this will increase.[14] An ageing population adds to the increase in demand for EDs and subsequent hospital admission. Compared to patients of less than 30 years, those over 70 years are five times more likely to be admitted.[15] The elderly have unique care needs that can be difficult to meet in a busy emergency care environment.[16] The elderly spend more time in the ED, their problems are more complex, they undergo more tests and often require critical care.[15]

The current climate within emergency care settings provides significant safety challenges. The workforce is less experienced and there are numerous vacancies at consultant level.[9, 17] The pressure within the emergency care system is further compounded by rising numbers of patients. The global economic crisis is preventing any increase in health care spending.[18, 19] The clinical work in EDs is often complex and the environment more challenging than other more traditional settings.[20] Distinctive features of decision-making in ED are the frequency and complexity of decisions with limited time and information.[21] This creates a clinical environment with additional risk of adverse events and clinical incidents.[22]

Novel approaches are required to ensure the workforce can deliver high quality care. Over the last 20 years there has been an explosion in the number of studies evaluating the role of CCDSSs. There is a growing consensus that CCDSSs have the potential to significantly improve healthcare.[23] Several systematic reviews have identified the benefits of CCDSS with regard to patient safety, improved clinical performance and improved patient outcomes.[24, 25]

A recent series of six comprehensive systematic reviews has drawn overall conclusions that CCDSSs across a range of health care settings can improve the process of care for some patients.[26-31] However the number of studies that have demonstrated a positive impact on patient outcomes is relatively low; and these are only of moderate quality.[27] Within this series of systematic reviews only randomised controlled studies (RCTs) were reviewed as this method is regarded as

the gold standard for CCDSS evaluation.[32] CCDSS research using an RCT method in an ED setting is fraught with methodological challenges. It is unsurprising that the acute care review only identified three studies undertaken in EDs.[26] To date there are no comprehensive reviews of all types of studies of the effectiveness of CCDSSs in emergency care settings. This paper sets out to redress that balance and expose the body of CCDSS research in EDs, the quality of the research and identify the contribution that CCDSS can make to enhancing care in this challenged setting.

MATERIALS AND METHODS

Search strategy

The search strategy involved searching three bibliographic databases and multiple electronic resources and grey literature websites for resources published between 1994-2015., see Table 1

For the search terms used in the database searches see the Medline example Table 2

Figure 1 depicts the searching and screening process that took place against the inclusion and exclusion criteria. .The preliminary results identified 1773 papers from the three databases and 49 papers/documents from other sources. These were screened by title an abstract for CCDSS research in ED. This reduced the papers to 399. The second review screened for primary research and reduced the papers to 180. The final review screened each abstract (if needed the entire paper was reviewed) against the inclusion and exclusion criteria to identify 23 studies.

Inclusion and exclusion criteria

The studies included in this review had to meet three principal inclusion criteria. Studies that embodied any of the exclusion criteria were rejected.

Inclusion

1. The study had to take place in an ED
2. The study had to report primary research on the use of a CCDSS for an acute problem in a face-to-face situation
3. The study had to compare care supported by CCDSSs with usual care

Exclusion

- Studies identifying only the beliefs, attitudes and opinions of system users
- ED tracking systems
- Technical development of CCDSS (bench testing/simulated settings)
- Bed management systems
- Paper-based decision support tools
- Radiology imaging systems
- Pathology ordering systems

- Pharmacy systems for drug prescribing (dosing/error reduction)
- Systems used by patients
- Health screening/surveillance

Justification of inclusion and exclusion criteria

For practical reasons only English language research papers were included. As CCDSSs are a relatively novel health care intervention with little research before the 1990s, studies were selected from the last 21 years (1994-2015). As the literature search progressed it become evident that there was only a small number of CCDSS studies that had taken place in EDs. All study designs where included to increase the understanding of how CCDSSs in EDs had been evaluated. Computerised Physician/Provider Order Entry (CPOE) systems have been the subject of extensive research in the United States. There is a small but growing number of studies that have evaluated the benefits of CPOE on ED patients, workflow, safety and some have incorporated decision support.[33] Only the studies involving the use of CPOE that had a specific clinical decision support tool embedded in the system were included. Once the set of included studies was finalised a review of their reference lists was undertaken to identify any additional relevant publications.

Methodological review of the studies.

Traditional critical appraisal tools to assess the quality of all of the study designs in this review are not available. A pragmatic approach was taken to assess study quality by analysing the risk of bias that each design presents. Assessing the risk of bias is critical in understanding the validity of results and the effect of the CCDDSS intervention.[34] The approach was based on the Cochrane Collaboration Effective Practice and Organisation of Care Group (EPOC),[35] criteria for assessing the risk of bias in RCTs and ITSs designs (see Table 3).

As before and after studies are not recognised by the Cochrane Collaboration as a reliable method to evaluate complex interventions no EPOC criteria exist for such studies.[35]. Table 4 describes the criteria used in this review to detect bias, developed from various sources.[36-38]

PB and NH constructed the search. PB screened all the papers for inclusion/exclusion. NH audited a sample of the selected papers to ensure rigour in the selection process. As the body of evidence was small (23 papers in total) and little is known about the evaluation of CCDSSs in EDs, all papers were included in the review, irrespective of the quality of research.

RESULTS

Overview of included studies

Twenty three studies met the inclusion criteria and were included in the review (see Table 5). Sixty percent of the studies were undertaken in the US (n=14); the

remainder were undertaken in Canada (n=3), Australia (n=3), UK (n=1), France (n=1) and the Netherlands (n=1). A majority evaluated CCDSSs in one ED (n=18). There were four multi-centre studies: 2 in the US which evaluated the same CCDSS in 4 EDs, a Canadian study involving 4 EDs and a study in France involving 20 EDs. The vast majority of studies were undertaken in academic EDs (n=21).

Rationale for undertaking CCDSS research

All of the studies, by way of rationale, referred to the challenges of guideline adherence in an era where there is rapid expansion of clinical guidelines, quality indicators, risk assessment tools and core measures for specific clinical conditions. Several papers cited the unique challenges of the ED environment: multiple interruptions, complex patients and overcrowding, indicating that these add considerably to the difficulties of guideline implementation and adherence.[39-43]

The consensus within many of the selected studies was that CCDSSs can provide an encouraging means of improving the quality of ED patients' care.[39-52] Some departments were so encouraged by the results that they developed additional CCDSSs, for example to cover a range of presenting conditions, and generated several additional studies.[45, 46, 53]

Clinical conditions investigated

There were a wide variety of clinical conditions studied. Conditions covered by more than one study included:

- community acquired pneumonia (n=3)
- pulmonary embolism (n=3)
- sepsis (n=2)
- fever in children (n=2)
- asthma in children (n=2).

One study covered both heart failure and community-acquired pneumonia. The remaining 11 studies covered a range of clinical conditions:

- acute coronary syndrome
- sexual assault
- soft tissue infection
- acute low back pain
- triage
- neck trauma
- pain in children
- febrile neutropenia
- syncope
- blood borne virus exposure
- heart failure.

Type of CCDSSs and their functionality

Various types of functionality were used within the CCDSSs. Four CCDSS were incorporated into CPOE using an embedded order set.[47, 48, 54, 55] The most common method of decision-support was via pop up alerts (n=12), which provided suggestions to clinicians regarding assessment and or treatment options. See Table 6 for a more comprehensive overview of functionality.

Impact of CCDSSs on clinical care in EDs

The following section analyses how each study design evaluated the impact of CCDSSs in EDs. Analysing the robustness methods used for evaluation is an intrinsic part of understanding the evidence base and how reliable it is. Ultimately this will enable firm conclusions to be drawn about the effectiveness of CCDSSs in EDs.

Five research designs were employed:

1. Randomised controlled trial (n=3)
2. Before and after study (n=13)
3. Interrupted times series (n=5)
4. Prospective observational design (n=1)
5. Comparative cohort design (n=1)

Randomised controlled trials that have assessed the use of CCDSSs in EDs

Three studies used a RCT design.[40, 44, 49] The studies by Roukema et al,[44] and Dexheimer et al,[40] were both conducted in Paediatric Academic EDs. The study by Roy et al,[49] was a cluster randomised controlled trial across 20 EDs in France, approximately half of which were academic departments.

In the study by Dexheimer et al,[40] there was no statistically significant difference between the control and intervention groups for time to referral, admission rate or length of stay in ED. The results of the study by Roukema et al,[44] demonstrated that here was no difference in length of stay between the two groups. Adherence to the guidance within the CCDSS was deemed successful. Eighty four percent had tests ordered in the intervention group compared to 44% in the control group. However the prediction rule in the CCDSSs was not specific enough to discriminate between children at high risk of serious bacterial infection, and was discontinued.

The cluster RCT by Roy et al,[49] randomised 20 EDs across France to either control or intervention departments. Appropriate diagnostic workups increased in all patients when compared to the pre-trial data. The greatest increase was in the CCDSSs group. After adjusting for confounding variables the appropriateness of the diagnostic workup increased by 19.3% ($p=0.023$). Pre-test probability scoring was greater in the CCDSS group ($p<0.001$)

Finally, the asthma detection and management CCDSS evaluated by Dexheimer et al,[40] did not appear to demonstrate any benefits. Roukema et al,[44] did demonstrate an increase in initial tests for children with fever. However the CCDSS was discontinued due to its inability to discriminate between children with low or high risk of serious infection. The cluster RCT by Roy et al,[49] is the only study using a randomised experimental design that demonstrated tangible improvements in the process of care. However it is unlikely that cluster RCTs are a feasible option for future studies due to the high cost and logistical challenges of implementation.

Before and after studies that have assessed the use of CCDSSs in EDs

Before and after studies were the most commonly-used design identified by this review (n=13). They are also the leading research method in general CCDSS research [56]. All the before and after studies in this review compared the process of care and/or patient outcomes before and after the introduction of the CCDSS.[39, 41, 42, 47, 48, 50, 51, 54, 55, 57-60] None included a control. Four of the studies assessed the effect of order sets and prompts embedded within the CPOE systems on the management of acute coronary syndrome (ACS),[54], sexual assault,[55] and pulmonary embolism.[47, 48] Both of the studies assessing the impact of ordering appropriate investigations for pulmonary embolism revealed statistically significant results with an increase in the number of positive results when the CCDSS guided the ordering of computerised tomography pulmonary angiography (CTPA).[47, 48] In the study by Britton et al,[55] post-test compliance with adherence to treatment guidelines in sexual assault was highly statistically significant ($p<0.001$). However in the study by Asaro et al,[54] there was no improvement in overall compliance with the recommendations for ACS management.

Three studies assessed the impact of CCDSSs on the management of infection in the ED; two of these concerned sepsis,[39, 42] and the other focused on soft tissue infections.[57] For the management of sepsis, the study by Britton et al,[55] suggested that patients in the CCDSS group were treated more aggressively. However, this contrasts with the study by Nelson et al,[42] who identified that the only difference in the process of care between the before and after groups was the speed in which blood cultures were taken. The study by Carman et al,[57] evaluated the use of embedded guidelines within the electronic patient record (EPR) for the management of soft tissue infection. The CCDSS had a statistically significant impact on wound cleansing only ($p<0.001$). Although antibiotic adherence improved this did not appear to correlate with use of the CCDSS.

Two before and after studies in paediatric EDs considered the effects of CCDSSs on pain assessment and management,[59] and adherence to asthma guidelines.[41] Both studies demonstrated an increase in appropriate documentation (pain score $p <0.001$, asthma severity $p <0.01$ and asthma discharge plan $p <0.01$). However, although pain scores were more frequently recorded, there was no corresponding increase in the number of children given analgesia.[59]

The management of community acquired pneumonia (CAP) was evaluated by Jones et al,[50] and Niemi et al.[51] The introduction of a real-time CCDSS to assess CAP severity and to make management recommendations demonstrated positive results when outcomes were compared across four EDs.[50] The appropriateness of hospitalisation was increased ($p=0.02$) and a reduction in inpatient mortality was demonstrated ($p <0.02$). Conversely in the study by Niemi et al,[51] which first assessed the ability to detect CAP and/or heart failure and then measured compliance against national indicators for CAP and heart failure combined, the results were less convincing. The only statistically significant result was the provision of discharge advice for patients with heart failure ($p <0.01$).

The final two before and after studies considered the impact of CCDSS adherence to national guidelines for syncope,[60] and imaging following neck trauma,[58] Both studies demonstrated positive results in adhering to admission guidelines in syncope,[60] and reducing the number of inappropriate neck images ordered following neck trauma.[58]

Although the results of the majority of these studies appear encouraging and justify the use and introduction of CCDSSS in EDs, they should be viewed with caution. There is a threat to internal validity and an intrinsic risk of bias in before and after studies. Indeed several authors discount the method as a means of contributing to the CCDSS evidence base as the risk of bias is unacceptably high.[56, 61]

Interrupted time series studies that have assessed the use of CCDSSs in EDs

Five studies used an interrupted time series (ITS) design.[43, 45, 46, 52, 53] ITS studies collect data at multiple time points before and after the implementation of the intervention.[62] Collection of data at multiple points before the intervention reveals the underlying secular trend, which will have a naturally occurring variation. The analysis, which compares the data points after implementation of the intervention takes account of this underlying trend to enable the truer effect of the CCDSS to be revealed.[61]

Buising et al,[52] and Gibbs et al,[43] both evaluated the impact of a CCDSS on CAP at multiple times points. Both studies were concerned with improving the correct antibiotic selection for CAP. Gibbs et al,[43] also evaluated the timeliness of antibiotics. Both studies demonstrated statistically significant improvements in appropriate antibiotic selection; Gibbs et al,[43] also demonstrated an improvement in the number of antibiotics given within 6 hours ($p <0.001$) when a CCDSS was introduced to aid clinicians in the assessment of patients with pneumonia.

The ITS studies by Schriger,[45]and Day et al,[63] were both conducted in the same academic ED. Both studies measured various elements of guideline adherence, documentation and the provision of aftercare instructions. All measures increased during the implementation phase and returned to or below the baseline when it was removed. There were also improvements in the documentation ($p <0.001$) and discharge advice ($p <0.001$) for patients with back pain on implementation.[64]

However there was no statistically significant difference between x-rays ordered, medication use and cost of care.

Overall the results from the studies using ITS designs appear encouraging. However unless such studies are rigorously conducted to take into account the effect of confounding variables and the underlying secular trend it is difficult to draw firm conclusions about the true impact of CCDSS in the ED. The study by Buising et al,[52] was the only ITS study to consider the underlying trend and does demonstrate that a properly conducted ITS design is an appropriate method for investigating the impact of a CCDSS.

Prospective observational studies that have assessed the use of CCDSS in EDs

One study used a prospective observational design to analyse the effectiveness of a CCDSS on the use of the Canadian Acuity and Triage Scale (CTAS).[65] A convenience sample of 693 patients were triaged by the usual "memory-based" triage method by the triage nurse that was on duty. Patients were then "re-triaged" by a blinded research nurse using the CTAS CCDSS. The results of both triage decisions were then compared using kappa statistics. Agreement was poor (Kappa = 0.202). An expert panel assessed 100 triage records and there was more agreement between the experts and the CCDSS than the triage nurses. The results suggest that a CTAS CCDSS might support better triage decisions, according to expert panel views, than the usual triage method.

However there are some weaknesses in the conduct of the study. This study did not consider any confounding factors e.g. triage nurse experience. Moreover, through its design it actually introduced confounding factors itself. For example, the research triage nurse using the CTAS CCDSS triaged the same patients some time after their initial triage and when they had already been directed to a clinical area in the ED for their subsequent care e.g. majors, resuscitation, minors. This process eliminated the time pressure that triage nurses face when having to make rapid decisions often in an environment fraught with interruptions. The presence of this detection bias does not enable any firm conclusions to be drawn regarding the results of this study.

Comparative cohort studies that have assessed the use of CCDSSs in EDs

Finally the last study in this review used a retrospective comparative cohort design to evaluate the impact of the use of an electronic clinical practice guideline (eCPG) on the management of patients with neutropenic sepsis.[66] Outcome data was retrospectively extracted from clinical records across four EDs in Canada over a 3-year period. Overall the use of the eCPG was low at 37.8% overall, although in the intervention ED it was 57%. When the eCPG was used there was a statistically significant improvement in ECG recording and in the collection of blood cultures. There were statistically significant reductions in triage-to-doctor assessment time and triage-to-first antibiotic. Again this study like many others in this review failed to address confounding factors. An important factor overlooked in this study was the experience of clinical staff in managing the care of patients with neutropenic sepsis.

DISCUSSION

This substantive review identified and critically appraised 23 studies that have evaluated the impact of CCDSSs on care in EDs. The results of 13 of the studies identified a statistically significant positive impact on aspects of clinical care with the use of a CCDSS.[39, 41, 43, 45, 47-50, 52, 55, 58, 59, 66] Two studies showed no benefit after the introduction of the CCDSS.[40, 54] The remaining 8 studies showed small tangential improvements, mainly concerned with documentation.[42, 44, 46, 51, 53, 57, 60, 65] While more than half of the included studies showed favourable results a brief analysis of the methodological quality revealed a high risk of bias in all but six studies.[41, 48-50, 52, 60] Only one RCT adequately addressed performance and detection bias.[49] Only one of the five ITS studies considered the underlying secular trend within the analysis.[52] And of the before and after studies, less than one third considered and statistically adjusted for confounding variables.[41, 48, 50, 60]

Systematic reviewers have been highly critical of the lack of robust evidence on the effectiveness of eHealth interventions.[67] A substantial review by the Agency for Healthcare Research and Quality drew similar conclusions.[68] They identified strong evidence for improvements in the process of care when CCDSSs were used, but little evidence of a positive effect on patient outcomes or costs.[68] When considering the quality and safety benefits of IT in ED, Handel et al. also determined that the evidence is mixed.[69] The critical appraisal of studies in this review supports this position. The evidence is weak regarding the impact of CCDSSs in EDs due to the inherent risk of bias in the design of most studies and/or the inability to control for or address confounding variables

This review of the current primary research concerned with the effectiveness of CCDSSs in EDs has identified the body of evidence and the research methods used. Firm conclusions cannot be drawn due to weak study designs. Of the studies with a higher quality designs, [41, 48-50, 52, 60] results are more promising in terms of improving the process of care. In the management of pulmonary embolism, both Roy et al,[49] and Raja et al,[48] demonstrated improved guideline adherence and more appropriate diagnostic test ordering. Melnick et al,[60] also demonstrated improved diagnostic test ordering in the management of syncope. Enhanced quality of care as judged by improved documentation was demonstrated by Kwok et al,[41] in the management of asthma. Finally, in two studies of CAP improved antibiotic prescribing was demonstrated [52], and most significantly patient outcome was improved in the study by Jones et al,[50] who demonstrated a reduction in inpatient mortality.

Limitations

The rigour of this review was limited as a single researcher (PB) constructed the search critieria, reviewed the studies for inclusion/exclusion and extracted the data. Any papers where decisions were not easily reached were discussed with NH who also advised on data extraction processes.

CONCLUSION

Clinicians face ongoing and ever-increasing challenges in the delivery of consistently high quality care in Emergency Care settings. Research in others settings would suggest that CCDSSs might help to address some of these challenges. This is the first review that has considered the effectiveness of CCDSSs specifically in EDs. The review has revealed an increasing body of literature, but continuing shortcomings in research design and a predominance of before and after studies. Although such studies are relatively easy to implement in a clinical environment, they are fraught with challenges; the threats to internal validity do not permit confident conclusions to be drawn about causal relationships. The results of the higher quality studies included in this review are encouarging but more high-quality evidence is required to enable the role of CCDSSs in enhancing quality and safety in EDs to be more fully understood.

COMPETING INTERESTS

There are no competing interests

FUNDING

There was no funding associated with this review

CONTRIBUTORSHIP STATEMENT

PB & NH designed the review. PB undertook the literature searching, analysed the paper, revised the review and approved the final version. NH critically reviewed the drafts and reviewed papers for inclusion. PB is accountable for all aspects of the work.

References

[1]. Trzeciak S, Rivers EP. Emergency department overcrowding in the United States: an emerging threat to patient safety and public health. Emergency Medicine Journal. 2003;20(5):402-5.

[2]. Cooke M, Fisher J, Dale J, McLeod E, Szczepura A, Walley P, et al. Reducing Attendances and Waits in Emergency Departments. A systematic review of present innovations. Report to the National Co-ordinating Centre for NHS Service Delivery and Organisation R & D (NCCSDO)2004 18 July 2013. Available from: http://wrap-test.warwick.ac.uk/134/1/WRAP_Szczepura_29-final-report.pdf.

[3]. Guttmann A, Schull MJ, Vermeulen M, Stukel T. Association between waiting times and short term mortality and hospital admission after departure from emergency department: population based cohort study from Ontario, Canada. British Medical Journal. 2011;342.

[4]. Higginson I. Emergency department crowding. Emergency Medicine Journal. 2012;29(6):437-43.

[5]. Singer A, Thode H, Viccellio P, Pines JM. The Association Between Length of Emergency Department Boarding and Mortality. Academic Emergency Medicine. 2011;18(12):1324-9.

[6]. DH. Reforming Emergency Care. London: Department of Health; 2001.

[7]. Stokes B. Four Hour rule Program Progress and Issues Review. In: Austrailia DoHGoW, editor. 2011.

[8]. DH. Modernising Medical Careers - the new curriculum for the foundation years in postgraduate education and training 2005 [cited 2013 6 November]. Available from: http://webarchive.nationalarchives.gov.uk/+/www.dh.gov.uk/en/Aboutus/MinistersandDepartmentLeaders/ChiefMedicalOfficer/Features/FeaturesArchive/DH_4107830.

[9]. Armstrong PA, White AL, Thakore S. Senior house officers and foundation year doctors in emergency medicine: do they perform equally? A prospective observational study. Emergency Medicine Journal. 2008;25(11):725-7.

[10]. O'Dowd A. Locums make up a fifth of doctors ain emergency units at weekends 2013 [updated 23 October 2013; cited 2014 3 March]. Available from: http://www.publications.parliament.uk/pa/cm201314/cmselect/cmhealth/171/17108.htm - n82.

[11]. General Medical Council. Medical Education Frontine. A review of training in seven emergency departments2013 23 October 2013. Available from: http://www.gmc-uk.org.

[12]. Appleby J, Humphreies R, Thompson J, Galea A. How is the health and social care system performing? Quarterly monitoring report 2013 [cited 2013 22 July]. Available from: http://www.kingsfund.org.uk/sites/files/kf/field/field_publication_file/quarterly-monitoring-report-kingsfund-jun13.pdf

[13]. Wanless D. Securing good care for older people: Taking a long term view. London: Kings Fund, 2006.

[14]. Health and Social Care Information Centre. Accident and Emergency Attendances in England 2009-2010 2011 [cited 2012 2 October]. Available from: http://www.hscic.gov.uk/hes

[15]. George G, Jell C, Todd BS. Effect of population ageing on emergency department speed and efficiency: a historical perspective from a district general hospital in the UK. Emergency Medicine Journal. 2006;23(5):379-83.

[16]. Dawood M, Dobson A, Banerjee A. the treatment of older patients in emergency departments. Emergency Nurse. 2011;19(7):18-9.

[17]. Hassan T, Walker B, Harrison M, Rae F. Stretched to the limit. A survery of Emergency Medicine consultants in the UK2013 12 Febuarary 2014. Available from: http://secure.collemergencymed.ac.uk.

[18]. NHS Institute for Innovation and Improvement. QIPP: Establishing the evidence n.d. [cited 2013 13 October]. Available from: http://www.institute.nhs.uk/establishing_evidence/establishing_evidence/background.html.

[19]. Kings Fund. Are accident and emergency attendnaces increasing? 2013 [cited 2013 22 October]. Available from: http://www.kingsfund.org.uk/blog/2013/04/are-accident-and-emergency-attendances-increasing.

[20]. Heartfield M. Research directions for specialist practice. Accident And Emergency Nursing. 2000;8(4):214-22.

[21]. International Federation for Emergency Medicine. Framework for Quality and Safety in the Emergency Department2012 December 2013. Available from: http://www.ifem.cc/Resources/PoliciesandGuidelines.aspx.

[22]. Wears RL, Woloshynowych M, Brown R, Vincent CA. Reflective analysis of safety research in the hospital accident & emergency departments. Appl Ergon. 2010;41(5):695-700.

[23]. Kaplan B. Evaluating informatics applications - clinical decision support systems literature review International Journal of Medical Informatics. 2001;64:15-37.

[24]. Bates D, Gawande A. Improving Safety with Information Technology. New England Journal of Medicine. 2003;348(25):2526-34.

[25]. Hunt D, Haynes B, Hanna S, Smith K. Effects of Computer-Based Clinical Decision Support systems on Physician Performance and Patient Outcomes. The Journal of the American Medical Association. 1998;280(15):1339-46.

[26]. Sahota N, Lloyd R, Ramakrishna A, Mackay J, Prorok JA, Weise-Kelly L, et al. Computerised clinical decision support systems for acute care management: A decision-maker-researcher partnership systematic review of effects on process of care and patient outcomes. Implementation Science. 2011;6(91).

[27]. Roshanov P, Misra S, Gertein H, Garg A, Sebaldt R, Mackay J, et al. Computerised clinical decision support systems for chronic disease management: A decision-maker-researcher partnership systematic review. Implementation Science. 2011;6(92):1-16.

[28]. Roshanov P, You J, Dhaliwal J, Koff D, Mackay J, Weise-Kelly L, et al. Can computerized clinical decision support systems improve practitioners' diagnostic test ordering behavior? A decision-maker-researcher partnership systematic review. Implementation Science. 2011;6(1):88.

[29]. Souza NM, Sebaldt RJ, Mackay JA, Prorok JC, Weise-Kelly L, Navarro T, et al. Computerized clinical decision support systems for primary preventive care: A decision-maker-researcher partnership systematic review of effects on process of care and patient outcomes. Implementation Science. 2011;6(1):87.

[30]. Nieuwlaat R, Connolly SJ, Mackay JA, Weise-Kelly L, Navarro T, Wilczynski NL, et al. Computerized clinical decision support systems for therapeutic drug monitoring and dosing: A decision-maker-researcher partnership systematic review. Implementation Science. 2011;6(1):90.

[31]. Hemens B, Holbrook A, Tonkin M, Mackay J, Weise-Kelly L, Navarro T, et al. Computerised clinical decision support systems for drug prescribing and management: A decision-maker-researcher partnership systematic review. Implementation Science. 2011;6(89):1-17.

[32]. Haynes RB, Wilczynski NL. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: methods of a decision-maker-researcher partnership systematic review. Implementation Science. 2010;5:12.

[33]. Georgiou A, Prgomet M, Paoloni R, Creswick N, Hordern A, Walter S, et al. The effect of computerized provider order entry systems on clinical care and work processes in emergency departments: a systematic review of the quantitative literature. Annals of Emergency Medicine. 2013;61(6):644-53.e16.

[34]. Brown C, Lilford R. Evaluating service delivery interventions to enhance patient safety. British Medical Journal. 2008;337(dec17 1):a2764-a.

[35]. EPOC. Cochrane Effective Practice and Organsiation of Care Group. Our Scope 2013 [cited 2014 11 January]. Available from: http://epoc.cochrane.org/our-scope.

[36]. Higgins J, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. British Medical Journal. 2011;343.

[37]. Higgins J, Green SM. Cochrane Handbook for Systematic Reviews of Interventions: Cochrane; 2011. Available from: http://handbook.cochrane.org.

[38]. Robson L, Shannon H, Goldenhar L, Hale A. Guide to Evaluating the Effectiveness of Strategies for Preventing Work Injuries:
How to Show Whether a Safety Intervention Really Works Cincinnati: DEPARTMENT OF HEALTH AND HUMAN SERVICES. Public Health Service. Centers for Disease Control and Prevention National Institute for Occupational Safety and Health; 2001 [cited 2013 17 April]. Available from: http://www.iwh.on.ca/evaluating-safety-programs.

[39]. Bond CM, Djogovic D, Villa-Roel C, Bullard MJ, Meurer DP, Rowe BH. Pilot Study Comparing Sepsis Management with and without Electronic Clinical Practice Guidelines in an Academic Emergency Department. The Journal Of Emergency Medicine. 2013;44(3):698-708.

[40]. Dexheimer JW, Abramo TJ, Arnold DH, Johnson KB, Shyr Y, Ye F, et al. An asthma management system in a pediatric emergency department. International Journal of Medical Informatics. 2013;82(4):230-8.

[41]. Kwok R, Dinh M, Dinh D, Chu M. Improving adherence to asthma clinical guidelines and discharge documentation from emergency departments: implementation of a dynamic and integrated electronic decision support system. Emergency Medicine Australasia. 2009;21(1):31-7.

[42]. Nelson J, Smith BL, Jared JD, Younger JG. Prospective Trial of Real-Time Electronic Surveillance to Expedite Early Care of Severe Sepsis. Annals of Emergency Medicine. 2011;57(5):500-4.

[43]. Gibbs MA, Baumann MR, Lyden J, Strout TD, Knowles D. Effect of the implementation of an electronic clinical decision support tool on adherence to joint commission pneumonia core measures in an academic emergency department. Academic Emergency Medicine. 2012;19:S198-S9.

[44]. Roukema J, Steyerberg EW, van der Lei J, Moll HA. Randomized trial of a clinical decision support system: impact on the management of children with fever without apparent source. Journal of the American Medical Informatics Association. 2008;15(1):107-13.

[45]. Schriger DL, Baraff LJ, Rogers WH, Cretin S. Implementation of clinical guidelines using a computer charting system. Effect on the initial care of health care

workers exposed to body fluids. The Journal of the American Medical Association. 1997;278(19):1585-90.

[46]. Schriger DL, Baraff LJ, Buller K, Shendrikar MA, Nagda S, Lin E, J., et al. Implementation of Clinical Guidelines via a Computer Charting System: Effect on the Care of Febrile Children Less than Three Years of Age. Journal of the American Medical Informatics Association. 2000;7(2):186-95.

[47]. Drescher FS, Chandrika S, Weir ID, Weintraub JT, Berman L, Lee R, et al. Effectiveness and acceptability of a computerized decision support system using modified Wells criteria for evaluation of suspected pulmonary embolism. Annals of Emergency Medicine. 2011;57(6):613-21.

[48]. Raja AS, Ip IK, Prevedello LM, Sodickson AD, Farkas C, Zane RD, et al. Effect of computerized clinical decision support on the use and yield of CT pulmonary angiography in the emergency department. Radiology. 2012;262(2):468-74.

[49]. Roy P-M, Durieux P, Gillaizeau F, Legall C, Armand-Perroux A, Martino L, et al. A computerized handheld decision-support system to improve pulmonary embolism diagnosis: a randomized trial. Annals of Internal Medicine. 2009;151(10):677-86.

[50]. Jones B, Jones J, Stoddard G, Vines CG, Jepson A, Ferraro JP, et al., editors. Impact of electronic decision support tool on outcomes for emergency department patients with pneumonia. European Respiratory Society Annual Congrress; 2013; Barcelona.

[51]. Niemi K, Geary S, Quinn B, Larrabee M, Brown K. Implementation and evaluation of electronic clinical decision support for compliance with pneumonia and heart failure quality indicators. American Journal of Health-System Pharmacy. 2009;66(4):389-97.

[52]. Buising KL, Thursky KA, Black JF, MacGregor L, Street AC, Kennedy MP, et al. Improving antibiotic prescribing for adults with community acquired pneumonia: Does a computerised decision support system achieve more than academic detailing alone? - A time series analysis. BMC Med Inform Decis Mak. 2008;8:35.

[53]. Day F, Hoang LP, Ouk S, Nagda S, Schriger DL. The impact of a guideline-driven computer charting system on the emergency care of patients with acute low back pain. Proceedings The Annual Symposium On Computer Applications In Medical Care. 1995:576-80.

[54]. Asaro PV, Sheldahl AL, Char DM. Embedded guideline information without patient specificity in a commercial emergency department computerized order-entry system. Academic Emergency Medicine: Official Journal Of The Society For Academic Emergency Medicine. 2006;13(4):452-8.

[55]. Britton DJ, Bloch RB, Strout TD, Baumann MR. Impact of a computerized order set on adherence to centers for disease control guidelines for the treatment of victims of sexual assault. Journal of Emergency Medicine. 2013;44(2):528-35.

[56]. Liu J, Wyatt J, C. The case for randomized controlled trials to assess the impact of clinical information systems. Journal of the American Medical Informatics Association. 2011;18(2):173-80.

[57]. Carman MJ, Phipps J, Raley J, Li S, Thornlow D. Use of a clinical decision support tool to improve guideline adherence for the treatment of methicillin-resistant staphylococcus aureus: Skin and soft tissue infections. Advanced Emergency Nursing Journal. 2011;33(3):252-66.

[58]. Goergen SK, Fong C, Dalziel K, Fennessy G. Can an evidence-based guideline reduce unnecessary imaging of road trauma patients with cervical spine injury in the emergency department? Australas Radiol. 2006;50(6):563-9.

[59]. Jadav MAR, Lloyd G, McLauchlan C, Hayes C. Routine pain scoring does not improve analgesia provision for children in the emergency department. Emergency Medicine Journal. 2009;26(10):695-7.

[60]. Melnick ER, Genes NG, Chawla NK, Akerman M, Baumlin KM, Jagoda A. Knowledge translation of the American College of Emergency Physicians' clinical policy on syncope using computerized clinical decision support. International Journal Of Emergency Medicine. 2010;3(2):97-104.

[61]. EPOC. What study designs should be included in an EPOC review and what should they be called?2013 1 Feburary 2014. Available from: http://epoc.cochrane.org/sites/epoc.cochrane.org/files/uploads/05 What study designs should be included in an EPOC review 2013 08 12.pdf.

[62]. Cochrane. Glossary n.d. [cited 2014 1 February]. Available from: http://www.cochrane.org/glossary/5 - lettera.

[63]. <datacollectionchecklist.pdf>.

[64]. Schriger DL, Baraff LJ, Hassanvand M, Nagda S. EDECS: the Emergency Department Expert Charting System. Medinfo MEDINFO. 1995;8 Pt 2.

[65]. Dong SL, Bullard MJ, Meurer DP, Colman I, Blitz S, Holroyd BR, et al. Emergency Triage: Comparing a Novel Computer Program with Standard Triage. Academic Emergency Medicine. 2005;12:502-7.

[66]. Lim C, Bawden J, Wing A, Villa-Roel C, Meurer DP, Bullard MJ, et al. Febrile neutropenia in EDs: the role of an electronic clinical practice guideline. The American Journal of Emergency Medicine. 2012;30(1):5-11.e5.

[67]. Black AD, Car J, Pagliari C, Anandan C, Cresswell K, Bokun T, et al. The Impact of eHealth on the Quality and Safety of Health Care: A Systematic Overview. PLoS Medicine. 2011;8(1):e1000387.

[68]. Lobach D, Sanders G, Bright T, Wong A, Dhurjati R, Bristow E, et al. Enabling Health Care Decisionmaking Through Clinical Decision Support and Knowledge

Management. Evidence Report No 203 Rockville: Agency for Healthcare Research and Quality; 2012 [cited 2014 17 March]. Available from: http://www.ahrq.gov/research/findings/evidence-based-reports/er203-abstract.html.

[69]. Handel DA, Wears RL, Nathanson LA, Pines JM. Using information technology to improve the quality and safety of emergency care. Academic Emergency Medicine. 2011;18(6):e45-e51.

[70]. Melnick ER, Nielson JA, Finnell JT, Bullard MJ, Cantrill SV, Cochrane DG, et al. Delphi Consensus on the Feasibility of Translating the ACEP Clinical Policies Into Computerized Clinical Decision Support. Annals of Emergency Medicine. 2010;56(4):317-20.