Abstract

Aims and Objectives

This critical review considers the evidence since the Glasgow Coma Scale (GCS) was first launched, reflecting on how that evidence has shaped practice. It illustrates the lack of clarity and consensus about the use of the tool in practice and draws upon existing evidence in order to determine the route to clarity for an evidence-informed approach to practice.

Background

The GCS has permeated and influenced practice for over 40 years, being well-established worldwide as the key tool for assessing level of consciousness. During this time, the tool has been scrutinised, evaluated, challenged and relaunched in a plethora of publications. This has led to an insight into the challenges, and to some extent the opportunities, in using the GCS in practice but has also resulted in a lack of clarity.

Design

This is a discursive paper that invites readers to explore and arrive at a more comprehensive understanding of the GCS in practice and is based on searches of Scopus, Web of Knowledge, PubMed, Science Direct and CINAHL databases.

Results

While the GCS has been rivalled by other tools in an attempt to improve upon it, a shift in practice to those tools has not occurred. The tool has withstood the test of time in this respect, indicating the need for further research into its use and a clear education strategy to standardise implementation in practice.

Conclusion

Further exploration is needed into the application of painful stimuli in using the GCS to assess level of consciousness. Additionally, a robust educational strategy is necessary to maximise consistency in its use in practice.

Relevance to Practice

The evidence illustrates inconsistency and confusion in the use of the GCS in practice; this has the potential to compromise care and clarity around the issues is therefore necessary.

Summary Box

What does this paper contribute to the wider global clinical community? This paper critically reflects on the published evidence on the Glasgow Coma Scale and how this translates to evidence informed practice. In doing so, an evidence-practice deficit is evident. This paper clarifies the existing evidence while also identifying where further research is necessary for practice to be informed and appropriate

Keywords

- Glasgow Coma Scale (GCS)
- Painful stimuli
- Eye opening response
- Motor response
- Neurological assessment

Introduction

Many articles over the last 40 years have been written about the Glasgow Coma Scale (GCS) but few have debated how each of the three components of the scale are elicited and their inherent problems. This paper aims to explore some of the issues, the intention of which is to raise awareness and explain how clarity and perspective may be achieved in order to consolidate the issues and move forward. The GCS (Teasdale and Jennett 1974; 1976) is a long established and universally accepted scale to assess and communicate a person's level of consciousness. The popularity of the tool is such that it has remained the most widely accessed tool for such assessment; others have been developed and challenge the GCS on a variety of issues. Despite its popularity, there remains confusion and a number of misunderstandings. These largely relate to issues of inter-rater reliability, the completeness of the tool and the controversy around the most appropriate methods to elicit eye opening and best motor response. This paper revisits the GCS to explore the evidence behind its use with a particular focus on debating the arguably most controversial and confusing aspect of the scale: the application of painful stimuli. It is not the authors' intention to outline the best approach but rather to offer points for reflection and challenge practitioners to re-evaluate their practices in this regard.

Background

The GCS was developed in 1974 by Teasdale and Jennett as a 14-point scale and revised three years later to its current 15-point scale as a tool to assess '*the depth and duration of impaired consciousness and coma*' (Jennett and Teasdale, 1974 p.81). Since the 1970's it has received acclaim from clinicians and although originally developed for use following head trauma, it has been extensively used in a variety of clinical settings for the evaluation of level of consciousness. The GCS is a popular, reliable (intraclass correlation coefficient, 0.8 to 1 for trained users (Prasad 1996)), physiological scoring system tool to assess changes in states and duration of consciousness in adults; it is therefore a critical measure of neurological function. Specifically, it is concerned with assessing arousability and awareness as components of consciousness; reflecting the person's conscious state. However, it is not designed to capture distinct details of the neurological examination or to determine the cause of reduced consciousness. Consciousness is evaluated by independently scoring responses to external stimuli in three areas: eye opening (E), verbal performance (V) and motor responsiveness (M) and is categorised as a specific scoring system. When using the GCS all three components or ordinal subscales (E-V-M) are scored separately, with a numerical value for each and an overall aggregation (combining the score of individual components) into a total score. Attributing a total (sum) score from all three components, ranging from 3 (deep coma) to 15 (fully alert and orientated), interestingly was initially only intended for use in audit and research purposes; yet today this is widely practiced and recorded in clinical practice. A number of authors have debated whether 'to sum or not to sum' (Teasdale et al.1983; Bastos et al. 1993; Teoh et al. 2000) arguing that failure to provide the components score results in a significant loss of valuable information not least due to the fact that varying number of combinations constitute each score, for example a score of 9 can be made up of 18 different combinations. Although Teasdale et al. (1983) acknowledged the convenience of the sum score, they caution against its use in everyday clinical practice. Crucially, it is the serial recordings of these responses and scores in the management of people with impaired consciousness that demonstrates the evolving clinical situation. The GCS has therefore become an important instrument for communicating an accurate assessment of a person's condition between different healthcare professionals (Holdgate, Ching and Angonese 2006). It also facilitates monitoring and thus maximises the management of care in the acute phase e.g. in the acute stage of triage and the acutely unwell person along with allowing rapid detection of neurological complications.

The GCS has a well-established profile for use with people who have sustained a traumatic brain injury, designating them into three severity categories; mild (GCS 13-15), moderate (9-12) and severe (3-8) categories (NICE 2014). These categories are a valuable indicator of injury severity; in the initial stages of assessment the depth of impairment of consciousness along with more long-term evaluations of duration of loss of consciousness can provide a useful measure of the brain injury. Although the GCS score as a single predictor of outcome is mixed in its ability to predict outcomes in trauma cases, the motor sub score contains most of the predictive power (Healey et al. 2003;

Lesko et al. 2013), with Healey et al. (2003) asserting that the addition of the verbal and eye components add little to the predictive power of the GCS.

A significant correlation exists between a low GCS and higher mortality and poor prognosis rates, particularly when pupils are bilaterally fixed and dilated (Tien et al. 2006). The scale, however, was never intended to be used as guide to outcome (Teasdale et al. 2014). In addition, the score has been incorporated into many trauma and critical illness classifications such as the trauma score (Champion et al. 1989) and the revised Acute Physiology and Chronic Health Evaluation (APACHE) II score; a physiologically based system including 12 physiological parameters and the GCS (Knaus et al. 1985). Although the APACHE II score is widely used in critical care, this is not the case in neuroscience settings. On the other hand, early warning scoring tools have been modified to incorporate the GCS in a variety of clinical settings (Lam et al. 2006; Cretikos et al. 2007), and it also forms the basis of the World Federation of Neurosurgeons (WFNS) subarachnoid haemorrhage (SAH) grading system (Ogungbo 2003), compressing all 15 points of the GCS into five grades (Oshiro et al. 1997).

Methods

In developing this discursive paper, the authors reviewed published literature since the development of the GCS over 40 years ago and focused on papers that were published in English. Literature was retrieved from Scopus, Medline (Web of Science), PubMed, Science Direct and CINAHL database which made use of key words and MeSH terms on the Glasgow Coma Scale and 'painful stimuli' 'noxious stimuli', 'motor score' and 'eye opening'. Although the term Glasgow Coma Scale alone yielded 399 hits in Scopus, over 7600 in Web of Knowledge and 164 in CINAHL, however, when searching Glasgow Coma scale with terms such as painful stimuli the yield was very small. In reviewing other publications to situate the discussion in the context of nursing and the clinical setting, we ascertained which elements of those publications were evidence-informed so as to eliminate potential cultural assumptions related to practice. Several key themes emerge from the literature and are subsequently discussed below.

Interrater Reliability

Whilst the GCS has strengths, it is not without limitations and weaknesses. In a broad review, Sternbach (2000) outlines both the strengths and observed weaknesses of the scale as well as evaluating the different scales that have been developed to overcome the weaknesses in the GCS. He concluded the various competing scales have found some acceptance in certain places, but that

> "…*the GCS remains the most universally utilized level of consciousness scale worldwide…, the GCS, by virtue of its simplicity, seems destined to be used in emergency medicine for some time*." (p.59)

Despite the GCS being the most universally used and validated consciousness scale worldwide it has been criticised for its poor inter-observer or inter-rater reliability (Anderson et al. 1993; Gill et al. 2004; Hodgate et al. 2006). Although earlier researchers purported a high level of inter-observer or inter-rater reliability (Teasdale and Jennett 1974; Jennett and Bond 1975; Teasdale et al. 1978; Fielding and Rowley 1990; Rowley and Fielding 1991; Juarez and Lyons 1995) these earlier researchers reported the consistency was reliant upon experienced and well-educated users. In an early literature review, Lowry (1998) found no evidence to support the validity of the scale. Additionally, Reith et al.'s (2016) systematic review of the reliability of the GCS found higher reliability for the GCS components than for the sum score itself. They assert that factors that may influence reliability include education and training, the level of consciousness and type of stimuli used. Reith et al. (2016) also reported that the majority of the studies used to evaluate the GCS were of poor quality with inconsistency existing in reported reliability estimates found. Gill et al. (2006) collapsed the GCS to form a Simplified Motor Scale. In a later study comparing the interrater reliability of the Simplified Motor Scale, with the GCS and its components, and 2 other scales, Gill and colleagues (2007) concluded this simplified scale had the better interrater reliability for the assessment of people with altered level of consciousness of traumatic and non-traumatic in the emergency department. Others have since validated the scale in the emergency department and non-hospital setting (Haukoos et al. 2009; Thompson et al. 2011).

Several researchers have raised the issue of accuracy of recording the GCS with many studies focused on the interrater reliability between various levels of staff. Menegazzi et al. (1993) researched interrater reliability between emergency doctors and paramedics and found high levels of agreement between these groups. Braakman et al. (1978) also found similar results when they examined interrater reliability between medical and nursing staff. However, when exploring the relationship between the level of experience and inter-rater reliability, both Rowley and Fielding (1991) and Ellis and Cavanagh (1992) showed that experienced nurses were more accurate in their use of the GCS than inexperienced nurses; user inexperience was associated with a high rate of errors. While these studies raise an important issue, that of experience underpinning inter-rater reliability, both studies had relatively small sample sizes, limiting generalisations from their results. Moreover, these studies were performed using hospital inpatient wards, not in settings such as the emergency departments where the clinician is often faced with more difficult assessment situations.

This issue is complicated further when the GCS is used outside of neuroscience settings. Crossman et al. (1998) revealed that the GCS was used inaccurately by non-neurological and neurosurgical doctors who incorrectly opted for the lowest possible scores. This inappropriate application is mirrored further in a study by Riechers et al. (2005) who reported that only 15% of military physicians could correctly calculate the GCS, despite all of them being familiar with the scale and most having completed the advanced trauma life support course. These physicians were experienced and indicated that the correct use of the GCS is not isolated to the degree of experience, but also the degree of knowledge, and possibly relates to how they were educated in the use of the GCS. The perception of the tools complexity may also contribute here. In a more recent Japanese study Namiki et al. (2011) similarly reported inaccurate GCS recordings by junior medical staff and contended that more specific instruction are required in order to improve reliability of GCS scores. The GCS is often mistakenly considered by many to be a simple tool when the evidence to date shows that its use is complex and multifaceted. Indeed, Shoqirat (2006) found that 38% of students felt the tool was complex and low levels of confidence in its use reported by Matter et al. (2015) confirm its complexity. In an attempt to determine how accurately emergency department healthcare professionals can determine the GCS in simulated patient encounters (Bledsoe et al. 2015) prospective observational American study of the accuracy of GCS scoring found out of a total of 2,084 GCS observations the overall accuracy was 33.1%. Specifically, the verbal, eye-opening and motor scores were only accurate and correct in 69%, 61.2% and 59.8% of assessments respectively. Failure to assess the level of consciousness accurately and take appropriate action in a timely manner may lead to irreversible and serious clinical implications with devastating consequences, especially when acutely/critically ill people are involved.

A number of studies have explored the use of the GCS by nurses. Shoqirat (2006), in exploring third year student nurses understanding of the GCS, revealed a lack of confidence in 62% of the student nurses who were interviewed; this is despite the use of the GCS being a core component in most pre-registration nursing curricula. In a more recent study Mattar et al. (2015) concurs with Shoqirat, finding a significant positive correlation between nurses' attitudes and nurses' self-confidence in using the GCS; length of time spent in nursing, working in a neuroscience setting and a more positive attitude towards the GCS affected nurses' self-confidence in using the GCS. The evidence cited suggests that should nurses not be experienced or undergo education that is of sufficient depth, then the consistency and accuracy of scoring is questionable. However, this can be said of many scales and so this could be considered more-so an argument for standardised education that a tool-specific fault. Indeed, this led Teasdale et al. (2014) to revise the scale as a result of variations in technique 40 years after its original development. However, this relaunch does not fundamentally change the scale, rather it uses more explicit wording and was accompanied by a training video to address the education element, which has yet to be adopted nationally and internationally. Moreover, the training video gives rise to controversy over approaches to assessment, and as a result, the issue around inconsistency of approach remains. It is not clear from the current available evidence whether a standardised approach to education, which may or may not lead to a cultural change to using the GCS as it was designed, would yield improved inter-rater reliability statistics. In Baker's (2008) review of the interrater reliability of the GCS these authors concluded that reliability is affected by training and by consistency in assessment technique. After 40 years, Teasdale and colleagues (2014I) in summary stated that due to its complexity that the use of the GCS is open to both misinterpretation and misapplication.

While it has long been established that a standardised approach is required to improve accuracy of assessment when using the GCS (Ellis and Cavanagh 1992; McLernon 2014), this has yet to be realised. There is a need for a standardised methodology with which to perform the assessment, in particular the motor response, a lack of which potentially lies at the centre of the errors in performing and recording an accurate GCS. The relaunch of the GCS in 2014 has attempted to address such issues but has equally raised further questions about approach to assessment leaving this matter unresolved. These issues primarily centre on the clinical application of painful stimuli to assess motor function and the evidence surrounding such practice.

Limitations of the GCS as an assessment tool

While interrater reliability may be attributed, in part, to education and consistency of use in practice, the GCS is also considered to have limitations in its structure as a tool in terms of how well it considers the complexities presented by a variety of factors. The inability to assess eye opening in people with periorbital oedema (due to trauma or following cranial surgery) and maxillofacial injuries is one often cited as a limitation of the tool (Starmark et al. 1988). Periorbital oedema does not represent, in itself, a reduction in consciousness and yet can result in a GCS score that is lower than the person's actual state. Starmark et al. (1988) could not determine eye opening response in 7% of people in their study. Jennett and Teasdale (1974) advocate in these enforced closures of the person's eye that 'C' (= eyes closed) is recorded on the GCS chart along with the reasons. This does not, however, result in a GCS sum score that is representative of their true neurological state. In such circumstances, the breakdown of the composite score is essential in enabling accurate monitoring of levels of consciousness.

Limitations exist, particularly in the critical care setting, where the GCS is performed on those who are sedated. This is often the subject of debate as sedation affects both arousability and awareness. However, the GCS is not intended to identify the cause but merely represent the current state of consciousness. Indeed, several studies indicate that the neurological status is frequently assessed through objective characteristics such as 'patient response to stimuli' in critical care environments (Brunker 2006; Aitken et al. 2009; Varndell et al. 2015). Brunker's (2006) UK based audit assessment and monitoring of sedated people with a traumatic brain injury (TBI) in intensive care units found considerable variation in practice with all units questioned performing regular GCS assessment on 'lightly sedated patients'. In a more recent Australian qualitative study, nurses working in the emergency department frequently cited using the GCS scale when quantifying depth of sedation and typically reported those who were sedated with a GCS sum score of 3 out of 15 (Varndell et al. 2015). It is clear that sedation and analgesia can mask and underestimate the true level of consciousness; changes in severity of the person's condition therefore may go unchecked. However, this can be argued of any tool assessing level of consciousness and not just the GCS. Some studies report the use of pseudo-scoring (assigning 0 or 1 for any untestable component), which may significantly overestimate the severity of the injury, rather than more appropriately reporting being unable to assess and recording this. Indeed, Livingstone et al. (2000) argue that recording the pre-sedation score rather than assuming the normality or recording the person as being unresponsive is preferable. Specifically, Stocchetti et al. (2004) contend that this is considered an inappropriate recording of unresponsiveness and may create erroneous morbidity and mortality data. While validated sedation scales can demonstrate a number of improved clinical outcomes with their use, they are not a substitute for the assessment of consciousness. In this respect, any comparison between the GCS and such scales is akin to comparing apples with pears.

Similar arguments are presented in terms of the use of the GCS in people who are intoxicated with alcohol and other drugs; ethanol produces dose related changes in the brain (causing cognitive impairment, and linguistic and intellectual abilities) and can significantly lower the GCS score, although there is much individual variation in this effect (Gunstad 2010). Equally, the GCS may be misleading in people who are hypoxic, haemodynamically shocked, fitting or post-ictal; all of whom often may have a reduced level of consciousness. This should not influence how the clinician scores, they should score what presents, but emphasises the need to critically evaluate those scores over time once the underlying acute condition has been addressed. People who are pharmacologically paralysed or have traumatic paralysis (i.e., high spinal cord injuries) also fall into this category. However, in terms of assessing best motor response this is an obvious critical limitation in eliciting a motor response.

The loss of verbal response in intubated and tracheotomised people limits the ability to assess verbal response (Meredith et al. 1998). Indeed, Starmark et al. (1988) could not test the verbal response in 58% of people in their study. Verbal response contributes to evaluating a person's awareness and while these could be assessed through other formats (e.g. writing, letter/word boards), the tool does not provide for this. The scale offers the opportunity to assign a non-numerical response 'T' (= intubated) in such circumstances but prevents the calculation of the sum score. Similarly, pre-verbal infants cannot satisfy the criteria for verbal response although a Paediatric GCS has been developed to overcome this particular gap (James 1986). Equally, damage to the speech centres (Broca's and Werrnicke's areas in the inferior frontal lobe and posterior temporal lobe respectively and connected together via a bundle of nerve fibres called the arcuate fasciculus) rendering the person to have aphasia or dysphasia also needs to be considered at the time of the assessment; otherwise the person may seem worse than they actually are. In this instance authors advocate that this should be recorded as 'D' (= **d**ysphasia) (Shah 1999) or 'DYS' (Barlow 2012). It is important to note that aphasia and dysphasia do not represent an alteration in arousal or awareness but this is not accommodated within the GCS. Some evidence suggests that the use of mathematical models such as linear regression to predict the verbal score of the GCS from the motor and eye opening component is feasible (Meredith et al. 1998; Rutledge et al. 1996). However this has yet to be translated into clinical practice. Consideration also needs to be given to those who are unable to converse in the local language, who have developmental disabilities, or who may have a hearing impairment that impacts on their verbal fluency. The inability to measure a component score adds powerful support to the original belief that the three component score should be described and not just assigning / attributed a sum score. Additionally, clinicians need to be aware of what they are assessing and ensure that factors unrelated to arousability and awareness does not cloud their assessment.

The GCS does not incorporate brainstem reflexes and thus the scale is considered to lack reliability when assessing progressive recovery from coma and entering a vegetative (unresponsive wakefulness syndrome) or minimally conscious state (Sternbach 2000). Such reflexes can be indicative of low levels of arousal and or awareness. While the GCS was never intended to assess the complexity of disorders of consciousness (DOC) such as coma, vegetative or minimally conscious states, these require more than the qualitative appraisal of eye, sensory, and motor function and are still presentative of arousal and awareness (Wijdicks et al. 2005) – the core of the GCS. Brainstem reflexes can determine aspects of consciousness that evaluate the extent of brain injury in these states along with more quantitative eye measurements (Wijdicks et al. 2005). The FOUR (Full Outline of UnResponsiveness) score developed by Wijdicks et al. (2005) integrates brain stem reflexes and breathing patterns alongside eye and motor responses in the GCS to successfully address this issue but has not seen acceptance and use on a wide scale in clinical practice. Interestingly, Jennett et al. (1977) constructed a composite score for eye movements, but this has also not been widely used. Born et al. (1988) also developed a composite coma scale combining the 15-point GCS with a five-point reflex scale called the Glasgow-Liège (GLS) score, but likewise has seen little success in being implemented on a large scale in clinical practice.

Application of painful stimuli

There are two components of the GCS that may require the application of a painful stimuli; eye opening and motor response. Guin (1997) highlights how the assessment of eye opening and verbal response components of the GCS are most consistently applied in practice, assessing motor response was the most problematic. Others agree (Heron et al, 2001; Barlow, 2012); the most appropriate method to apply a noxious or painful stimuli is not only controversial but is often the cause of much confusion for clinicians in terms of interpreting the response. Indeed, Heron et al. (2001) evidenced in their study that only 35% of nurses (26 out of 75 respondents) correctly assessed motor response. This is complicated by the absence of studies that evidence the best approach and by a plethora of publications that give conflicting and incorrect information. Waterhouse (2008) clearly illustrates confusion amongst staff with regards to choice and rationale in applying painful stimuli. This is further compounded by moral and ethical implications; painful stimuli should only be applied appropriately and should not cause the person harm. Indeed, it is in this regard that practitioners need to consider whether their approach could be considered assault, highlighting the need for clarity in appropriate and ethical practice. Two primary areas of confusion exist:

1. Peripheral versus central painful stimulus: published literature is not explicit with regards to whether peripheral/central refers to the anatomical position of the stimuli application or whether the peripheral/central nervous system is the target for stimulation. Clarity in this matter is central to choosing the correct form of application of painful stimulus,
2. Where to apply the correct painful stimulus to assess the either eye opening (E) or motor (M) component of the GCS. Published literature is often conflicting about which form of stimulus, and why, is needed for the eye opening or motor response of the GCS.

Peripheral versus Central Stimuli

It should be clear that if the GCS is evaluating arousability and awareness, which are components of consciousness regulated in the brain and brainstem, then any stimulus used to evaluate consciousness must transmit to these brain areas. It is important to be clear about what is meant by a peripheral and central stimulus; from the perspective of assessment using the GCS, the stimulus must be relayed to the primary somatosensory cortex. Therefore, any literature referring to a peripheral stimulus that terminates peripherally is incorrect; a peripheral stimulus that only results in a spinal reflex will not stimulate a central response. Conversely, a peripheral stimulus that results in the primary somatosensory cortex being stimulated is a central stimulus. The stimulus must therefore ascend the spinothalamic tracts to brain areas such as the thalamus, periaqueductal grey, and amygdala, where pain signals are processed and relayed to higher cortical areas such as the primary somatosensory cortex, via lightly myelinated Aδ and unmyelinated C-fibre nociceptive fibres (see Figure 1.). A centrally applied stimulus is largely applied by stimulating the trigeminal nerve (e.g. supraorbital ridge pressure), where the first point of relay is centrally at the pons, then the thalamus and finally the primary somatosensory cortex. These two nociceptive pathways ultimately end in the primary somatosensory cortex.

More specifically the periaqueductal grey matter in the midbrain and the thalamus are thought to be involved in modulating reflex responses to noxious stimuli. This is followed by pain processing (modulation) by descending control (facilitating and inhibiting nociception processing) by the cingulate gyrus, insular lobe, and prefrontal cortex (Ossipov et al. 2010; Fields and Margolis 2015). Therefore, a peripheral stimulus is one that is applied to stimulate a spinal nerve, resulting in a spinal reflex; if it is relayed centrally to the primary somatosensory cortex, it is a peripherally applied central stimulus.

If a peripherally applied central stimulus causes the person's eyes to open, this indicates that the stimulus has ascended the spinothalamic tract and been relayed centrally. However, if the spinothalamic tract is not intact, e.g. in spinal injury, then this form of stimulus will not be effective and a painful stimulus that uses a more direct route to the brain/brainstem is required. A peripherally applied painful stimulus can also lead to ambiguity in assessing motor response; it can be unclear to the clinician whether the response is due to a spinal reflex or a purposeful response resulting from interpretation and awareness in the brain. However, the presentation of a reflex response is visibly distinguishable to a non-reflex motor response and therefore should not leave the clinician unclear. It is also not clear in the literature that such clarifications are explicit and understood, yet they are seminal to deciding how to apply a painful stimulus. Additionally, the application of the stimulus must be considered in relation to the component of the GCS being assessed. The sequence of assessing the three components is not always apparent in research papers, nor is it explicitly discussed which sequence is preferred although logically starting at the top is the preferred sequence (E-V-M). In any respect, the sequence may not be relevant to determine an accurate response.

Location

Various locations have been used to apply painful stimuli (see Table 1), adding to the question of the scales reliability. Starmark and Heath (1988) were one of the first to compare the efficacy of painful stimuli and of the six techniques (earlobe, sternal rub, supraorbital pressure, nailbed pressure, retromandibular stimulation and trapezial grip) sternal rubbing and retromandibular pressure were most effective, and the painful stimuli advocated by Teasdale and Jennett (1974) was inadequate (nail bed pressure). Marion and Carlier's (1994) US survey of trauma centre neurosurgeons, medical staff and senior nursing staff reported that the majority of staff indicated that they used the sternum rub to apply noxious stimuli. Guin (1997) assessed the merits of three painful stimuli (at five sites); nail bed pressure (right and left), sternal rub, and trapezial grip[1] (right and left), concluding that there were no significant differences in any of the indices among painful stimulus test conditions. However, when the three types of stimuli were compared, without controlling for the side of the stimulus, the response to sternal rub was significantly greater than that to trapezial grip; nail bed pressure was in between both. As the spinal accessory nerve has a small sensory component according to Bremner-Smith et al. (1999), this result may not be surprising. However, it indicates that sternal rub is the more potent painful stimulus, with trapezial grip being the least potent. With sternal rub more likely to cause injury (bruising) than trapezial grip, this does not translate well to practice and the risk of harm. Furthermore, it is not clear for which component of the GCS these stimuli were being used. In a more recent survey of UK junior neurosurgeons (n=100) Reith et al. (2014) found that 7 different techniques were in use when applying painful stimuli with approximately 70% using nailbed pressure and 56% using sternal rub. In an earlier study determining the effects of delivering nail bed compression and supraorbital pressure in unconscious people Aragan (1999), found no differences in motor responses on the GCS between the two techniques.

Length of time stimuli is applied
A further issue, infrequently discussed in the literature, is the length of time the noxious stimuli should be applied. Teasdale and Jennett (1974) state that this "...*should be maintained until a maximum response is obtained"* (p. 82). However, this raises further issues of reliability due to the need to a consistent and standard application, thus it is crucial that the method and location of painful stimulation used to elicit responses is maintained and recorded. Bartlett's unpublished work in 2000 revealed that nurses applied noxious stimuli over a wide variety of time periods but no one exceeded 30 seconds. Lower (1992) asserts that the duration of stimuli is important, advocating to increase duration up to a maximum of 30 seconds after which the painful stimuli should be stopped if no response has been observed. Similarly, Woodward (1997) recommends not exceeding 30 seconds. How this time period has been arrived at is unclear, with no published evidence to date that supports the duration time period for applying a noxious stimulus. Although upon applying a noxious stimulus, pain travelling along myelinated large Aδ fibres is usually perceived after 6-30m/s (Krebs et al. 2012). However, our current understanding of pain and neural processing of the pain stimuli is far from complete. Indeed, it would appear multifactorial, being dependent on the intensity of stimulus, the degree of injury, thickness of skin, temperature of the stimulus and presentation rate (Thornton and Sharpe 1998). Whilst the interplay between pain and levels of consciousness continues to be debated, the individual responses to pain are indicative of brainstem, subcortical or cortical activity. Failure to use appropriate and sufficient painful stimuli can result in failure to determine the level of consciousness, yet there remains an absence of evidence-informed guidelines in this regard. The duration of stimulus may not be related to processing of the stimulus – the threshold for stimulus is more a factor to ensure a noxious stimulus has been generated; if neurons are intact, it is not clear why an increased duration of stimulus is necessary. Similarly, if neurons are not intact, an increased duration would not logically change anything.

Assessment of Eye Opening and painful stimuli

Teasdale and Jennet (1974) stated that in the eye opening response "*Spontaneous eye opening … indicates that the arousal mechanisms in the brainstem are active*" (p 83). Thus, the upward progression of a person along the scale from a state of no eye opening to spontaneous eye opening indicates recovery from impaired consciousness. As the eye response component is limited to opening or closing in response to simple stimuli, it is not universally agreed to be a reliable indicator of consciousness; this is largely because arousal does not equate to consciousness (Segator and Way 1992; Majerus et al. 2005). While spontaneous eye opening may be considered by some as evidence of arousal, as a person can have their eyes opens but remain unaware (unresponsive wakefulness syndrome or a minimally conscious state) (Majerus et al. 2005). This is generally accepted to be due to reflex action generated by the reticular activating system (RAS) (Majerus et al. 2005). Measuring brainstem reflexes can avoid the ambiguity of eye-opening responses whilst also providing better prognostic information (Born et al. 1985; Wijdicks et al. 2005); this was evidenced in the development of the FOUR assessment tool (Wijdicks et al. 2005). Additionally, bilateral occulomotor nerve damage, in which the person is physically unable to open their eyes,

[1] Trapezial grip is also referred to as trapezial squeeze or pinch

may further complicate the assessment process; as this physical state may not represent impairment of arousal or awareness.

If a person is unable to eye open spontaneously or to verbal stimulus then eye opening needs to be elicited by a painful stimulus. In the originally article by Jennett and Teasdale (1974) they suggested using a peripheral stimulus first to see what response the person produces. Several authors refer to the application of a peripherally applied painful stimulus to determine eye opening response in these circumstances (Frawley 1990; Waterhouse 2009; Okamura 2014). In addition, it has been advocated that this approach is adopted first as the application of a central stimuli can result in the person closing their eyes in response and inducing a grimace (Jennett and Teasdale 1974; Frawley 1990). Rabiu (2011) also refers to the application of the trapezius grip resulting in eyes closing when they would be expected to open and cited this as being the main reason for a peripherally applied stimulus for assessing eye response. It would appear, therefore, that the application of a peripheral painful stimulus to assess eye opening, in the absence of a spontaneous or verbally induced response, is the justifiable approach to elicit a central stimulus. However the method of peripheral application of this stimulus remains subject to debate.

Lower (1992) and Waterhouse (2009) refer to peripheral stimulation being the application of pressure with a pen to the lateral outer aspect of the second or third interphalangeal joint with increasing intensity over a 10-15 second period. This is referred to as appropriate for determining eye opening response. Anecdotally, this would be accepted practice, however, Teasdale et al. (2014) advocate this pressure being applied to the fingertip and illustrate this in both their publication and website as being applied over the nail. While they refer to never having witnessed this resulting in damage to the nail bed e.g. subungual haematoma (black nails), and in the long-term loss of nails from repeated application, the nail bed can easily be damaged especially when hard instruments such as pens are applied, and nurses report this anecdotally (Price 2002; McLernon 2014). Given the potential for nail damage, it is appropriate to apply this pressure laterally and not on the nail itself, however, it should be noted that none of the sources provide evidence for lateral application. Mancini et al. (2014) determined, in one of the few studies that looks at spatial acuity as a factor in the perception of pain, that the fingertips and forehead are the most sensitive areas for pain. They do not, however, make any differentiation between which fingers are more sensitive. This evidence supports Teasdale et al.'s (2014) approach to use the fingertip, but not the application over the nail. Brennum et al. (1989), in a study with limited numbers (n=30) found no difference in pain sensitivity between fingers and toes, but found that a person's pain-pressure threshold was significantly higher on the dominant side, versus their non-dominant side. This supported a historical study by Weinstein (1962) who also determined this, as well as identifying that the distal phalanx was significantly more sensitive than the middle (intermediate) or distal phalanges, with the middle phalanx being the least sensitive. This evidence highlights, in the absence of other evidence, that the distal phalanx of the non-dominant hand is the site of choice. Moreover, Barlow (2012) asserts that the assessor needs to rest the arm on the body, with an elbow flexion of 30-40º when the stimulus is applied, in order to view the response and minimise any anomalies when assessing for abnormal flexion or extension.

Further consideration is needed in choosing this form of stimulus; if the spinothalamic tract is not intact, e.g. in spinal injury, then this form of stimulus will not be effective and a painful stimulus that uses a more direct route to the brain/brainstem is required. To not realise that an intact spinothalamic tract is necessary and to score based on an assessment where such damage exists, will result in an incorrect analysis. Indeed, the same considerations should be applied when the person may have any form of neuronal damage, including those with neuromuscular and movement disorders. Therefore, it should not be universally accepted that a peripheral stimulus is appropriate. A more central stimulus may be necessary.

It is also advocated that a central painful stimulus is used as peripheral pain may evoke a spinal reflex action which can be misinterpreted as a central response (Teasdale and Jennett 1974; Mattis and Birbilis 2008). This is somewhat of a challenge as while supraorbital ridge pressure may be a more direct central stimulus, travelling via the ophthalmic division of the trigeminal nerve (Pareja et al. 2003), it can also result in eye closure, as can retromandibular pressure (Simpson 2005). There is no evidence, other than anecdotal, to claim that either supra-orbital ridge pressure or retromandibular pressure is damaging. However, the possibility exists that they can result in displacement of a skull or jaw fracture respectively and the clinician of the former must be cautious not to cause eye injury by their nail when a person moves suddenly in response to the stimulus. Arguably, applying supra-orbital ridge pressure in the case of periorbital haematomas is ill advised and contraindicated in suspected/ confirmed facial fracture. Equally, in the presence of glaucoma it is contraindicated due the further increases in intraocular pressure. McDougal and Gamlin (2015) highlight that stimulus to the trigeminal nerve will alter aqueous humour formation and outflow, impacting on intraocular pressure. Similarly, caution is required when applying a pain stimulus to those who are para - or quadriplegic or have underlying neurological condition such as Neuromuscular Disorders (e.g. Multiple sclerosis) and movement disorders (e.g. Parkinson Disease). Furthermore, retromandibular pressure may also compromise jugular venous return and potentially raise intracranial pressure; occluding the retromandibular vein when applying retromandibular pressure can block venous return to the internal jugular vein of which it supplies (Matta and Lam 1997). Considering this evidence, it is somewhat difficult to confirm the appropriate approach to elicit an eye opening response through a painful stimulus when it is not appropriate to apply at the fingertip; the evidence would appear to suggest that the more central methods are unsuitable but yet necessary when spinothalamic tracts are not intact.

Assessment of Motor Response and painful stimuli

The final component in the GCS, best motor response (M), assesses and evaluates the integrity of the motor strip in the cerebral cortex (Hickey 2009). Motor response is a good indicator of the overall nervous system function and integrity of the cerebral cortex and spinal cord (Zuercher et al. 2009). According to Teasdale and Jennett (1974) this component was rationalised for the following reason "....*ease with which motor responses can be elicited in the limbs, together with the wide range of different patterns which can occur, makes motor activity a suitable guide to the functioning state of the central nervous system*" (p.82). The best motor response is indicative of the brain's ability to identify a sensory input and translate this into a motor response. The motor score component does have a linear relationship with survival, and contains the majority of the predictive power of the GCS overall, making it the best choice for a level-of-consciousness indicator (Healey et al. 2003). The amendment to the motor component score from five levels of responses to six, by including the distinction between normal and abnormal flexion, to aid in assessing the persons prognosis (Teasdale and Jennett 1976; Jennett et al. 1977), saw some researchers arguing that the motor score alone was more informative, at least in comatose people. Indeed, research indicates that this component is nearly as accurate as the entire GCS score in predicting survival (Ross et al. 1998; Healey et al. 2003; Gill et al. 2004). Given its importance, it is interesting to note that many report this component as the most difficult to assess (Guin 1997; Heron et al. 2001; Barlow 2012).

If a person is unable to respond to verbal commands assessment of the motor component requires the application of a painful stimulus. It could be argued that the application of a trapezial grip may be ineffective based upon the premise that stimulus is of the small sensory component of the accessory nerve (Bremner-Smith et al. 1999). Anatomical and physiological literature clearly states that accessory nerve (cranial nerve XI) provides motor innervating to the trapezius muscle, which consists of three distinct parts, whilst the cervical plexus provides sensory innervation including pain via the cervical nerves (C3, C4). Explicitly, Brown (2002) and Kierner (2001) state that the superior or upper (or descending) third of the muscle is purely innervation by the accessory nerve and Pu et al (2008) state that all three parts are innervated by the cervical plexus. Any response to a trapezial grip that results in the head movement or elevation of the shoulders is a spinal reflex whereas a movement of arms such as flexion is reliant upon central processing. Any spinal injuries above C5, resulting in a loss or blunting of sensation along with lesions causing dysfunction of the nerve such as craniocervical junction, foramen magnum lesions, thus would severely hinder this stimulus approach. Supraorbital pressure and retromandibular pressure may be suitable alternatives, but involve risks as identified earlier.

Conclusion and relevance to clinical practice

It is clear from the evidence that there is significant merit in using the GCS in practice; its familiarity and widespread adoption enables effective inter-professional communication about the level of consciousness. While many criticisms exist, other tools have either failed to be more robust or have not been successful in achieving wide-spread adoption. The reasons for this are unclear but may be related to the level of skill and understanding needed for many of these tools to be successfully deployed across a variety of professionals. Considering there is no standard for education that exists across these professions, new tools that are more complex and require such a substantial change in practice are less likely to succeed given the pattern of tools that have emerged since the GCS but have not dominated practice. Evidence explored suggests that the accuracy of the GCS is dependent on the user using and interpreting it correctly with the level of experience and user confidence being influential factors.

The GCS has some clear limitations, most notably the inability to asses a subscale due to a number of confounding variables: Understanding their relevance and reporting these variables is critical if a complete and accurate picture of the person's level of consciousness is to be achieved. Of the three components the motor sub-score is the most important yet it causes the most confusion and controversy remains regarding the best location and approach for applying a painful stimuli.

Consequently, there is a need and the potential to standardise the approach to assessment through explicit clarification about its use in assessment. This would require further research to widen the evidence base. In particular, this would enable clarity to be achieved around the application of painful stimuli in order to inform appropriate, safe and accurate practice. Being clear that the GCS is restricted to assessing certain parameters of consciousness should also stem some of the criticism; the need for more in-depth assessment can then be considered be practitioners in terms of its needs and use by those appropriately educated and skilled. The GCS is likely to stay, given its longevity and popularity, highlighting the need to address these issues rather that dismiss a tool that has an established history of effectiveness in practice.

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Figure 1. Pain Pathways into the Central Nervous System
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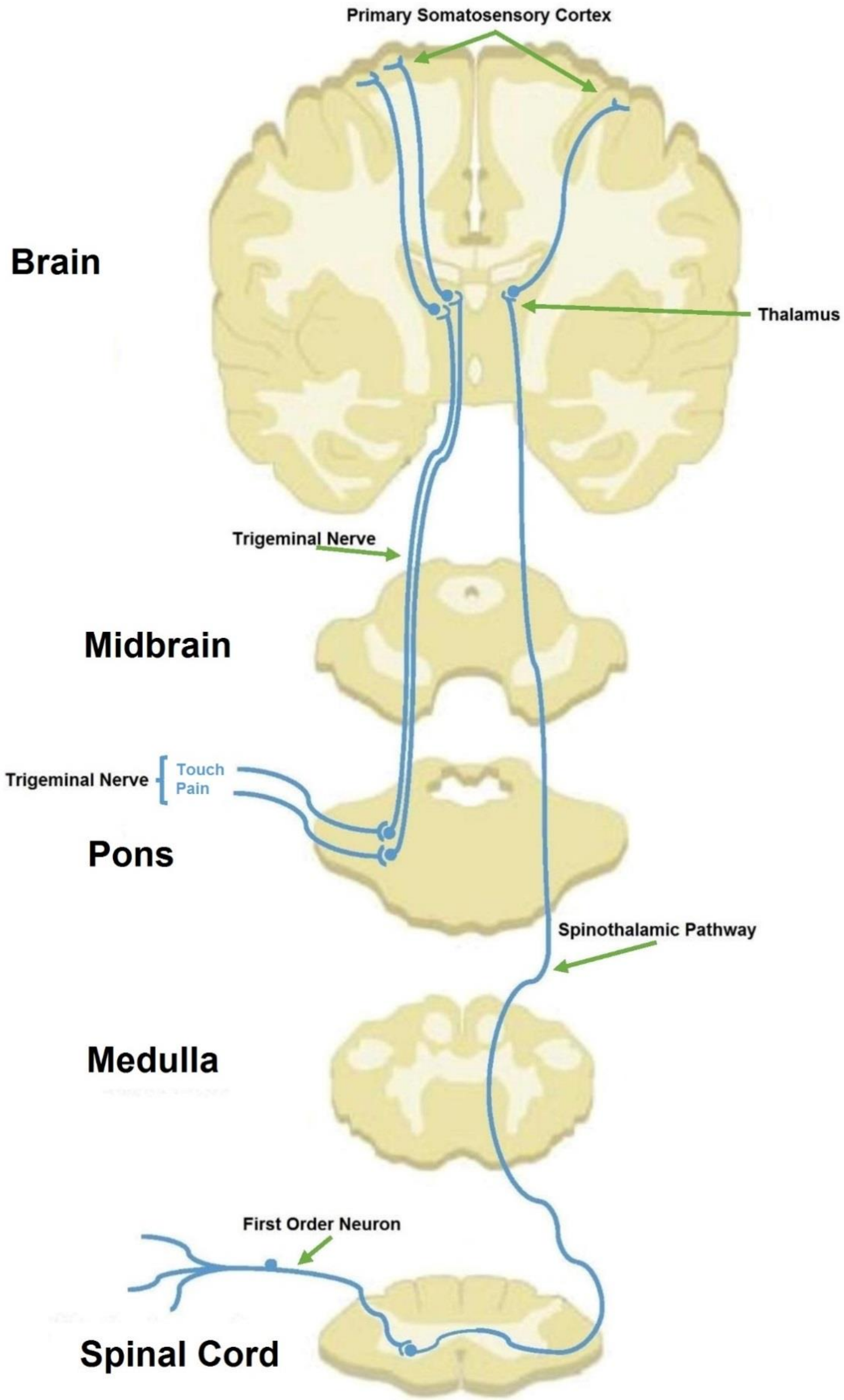

Table 1. Various locations used to apply painful stimuli

Noxious stimuli technique	Method of applying the noxious stimuli
Trapezius grip/pinch	Grasping approximately two inches of the trapezius muscle, located by palpating the area superior to the clavicle and medially to the shoulder, between the thumb and index finger and simultaneously twist and squeeze the muscle firmly
Pressure to the side of a finger	Using a pen or pencil apply pressure to the side of the nail bed
Pressure to the nail bed	Applying pressure to the lunula (the crescent-shaped whitish area of the bed of a fingernail or toenail) with a blunt instrument such as a pencil or pen
Fingertip pressure	Using a pen or pencil apply pressure across the tip of the finger nail
Sternal rub	Rubbing the knuckles of a closed fist firmly and vigorously on the person's sternum
Supraorbital pressure	Locate the notch on the supra-orbital margin and apply straight upward pressure with the tip of the thumb ensuring that no pressure is applied to the eyeball
Retromandibular or styloid process stimulation	Inserting a fingertip as high as possible into the depression between the back of the mandible and the mastoid process (just in front of the earlobe) an apply pressure
Ear lobe stimulation /pressure	Using thumb and index finger apply pressure to the earlobe