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LITERATURE REVIEW

Practical use of the Glasgow Coma Scale; a comprehensive narrative review of GCS methodology

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KEYWORDS
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Measurement;
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Summary
Objective: Narrative review of Glasgow Coma Scale (GCS) methodology.
Design: Narrative review of published papers describing methodological aspects of the GCS, from Premedline, Medline, EMBASE, CINAHL and Ovid Nursing databases from 1950 to May 2012.
Results: Examination of 18,851 references limited to descriptions of GCS development, pathophysiological correlations, examination techniques, complications or clinician agreement gave a final set of 33, which were summarised in this review.
Conclusion: The GCS was designed for the objective measurement of level of consciousness, assessment of trend, and to facilitate accurate and valid communication between clinicians. Concerns have been raised about the potential for misleading levels of precision engendered by the use of the GCS, and the use of simpler scales suggested. This review discusses the GCS and conditions affecting calculation of domain and summary scores, and recommends a method of implementation and interpretation.

Introduction

Impairment of consciousness is one of the most consistent features of head injury. The Glasgow Coma Scale (GCS) was described by Teasdale and Jennett in 1974,[1] based on a theoretical model of level of consciousness. It was introduced as a simple tool, initially in the research setting, as a method of describing states of impairment within the consciousness continuum.[1]

The GCS is utilised in many clinical specialities and settings not limited to the original patient group, raising issues of validity, diagnostic discrimination and prognostic power. Importantly, this widespread use has not been accompanied by instruction for clinicians in the appropriate methodologies needed to consistently and reproducibly use this tool. Many studies document variability and lack of agreement between the GCS measured by different clinicians and in

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What is known?

- The GCS was designed for assessment of consciousness in head injured patients in the 1970s, and has become ubiquitous since, now being put to many uses for which it was not originally designed.
- There have been concerns expressed regarding complexity, spurious precision, lack of agreement between individuals and groups of clinicians, and therefore validity of the scale.
- It has been suggested that subsets of GCS or alternative simpler scores may be useful.

What this paper adds?

- This paper comprehensively reviews published work relating to the derivation and use of the GCS, together with the identified advantages, disadvantages and flaws of the tool.
- It proposes that if subscores or adaptations of the GCS replace it for consciousness assessment, there is still a need for a standardised methodology with which to perform the assessment, the lack of which potentially lies at the heart of the flaws in GCS scoring agreement between clinicians.
- This paper discusses the intent of the original authors and their proposed methodology for use, then identifies and describes a standardised approach which should be utilised by all clinicians in the use of the GCS.

different clinical settings, making accurate and useful measurements of trend over time unlikely.[2–4] Assessment of consciousness has therefore developed in a variable way, leading to inconsistency in the application of stimuli, evaluation of responses, and summarising of component scores.

The purpose of this review is to provide an overview of the Glasgow Coma Scale in both its adult and paediatric forms, discuss conditions affecting the calculation of both domain and summary scores, explore innovation and alternative scores to GCS in the measurement of consciousness, and to recommend a standardised method of examination.

Materials and methods

A literature search was undertaken in Medline, Premedline, EMBASE, Ovid Nursing Database and CINAHL databases from 1950 to May 2012. Medical Subject Headings (MeSH) terms were Neurologic$ Examination, Coma, Glasgow Coma Scale, Brain Injuries, Consciousness, Unconsciousness, Consciousness Disorders, together with text words — level of consciousness, Glasgow coma score, assessment, measurement and methodology, and author names Teasdale G and Jennett B. These were limited by the terms methods, methodology, practice guidelines, clinical practice, development, technique, neurologic examination, physical examination, examination, examination technique, complications, clinician agreement, agreement, and pathophysiologic$ correlation, human and English language. A complementary search was made in all databases, using the above search terms, but adding children OR child OR paediatric OR pediatric terms. Hand searching of references was performed.

Results

18,851 references were found; an online review of abstracts and a hand-search gave 66 relevant references, limited to a final set of 33 describing GCS development, pathophysiological correlations, examination techniques, complications, and clinician agreement, as well as comparisons with simplified or component scores derived from the GCS, and references discussing the implementation and outcomes of specific paediatric derived versions of the GCS.

Early studies, including the original work by Teasdale and Jennett, were descriptions of case series of various sizes[1,6–12] from which much of the methodology of the GCS was drawn, including a descriptive study on paediatric head injury outcomes.[6] Early references also included letters from the original authors, elucidating aspects of the scale.[1,2,14] One early clinical trial was performed by Teasdale to examine Interobserver variability.[13]

A number of analyses of trauma registry data, and secondary analyses of data collected for other trials comprised a substantial proportion of relevant studies,[15–22] with clinical trials, including comparisons of Interobserver variability in cohort studies and later investigations of novel or abbreviated scores compared to GCS, being seen since 2005.[13,23–27]

A number of narrative reviews were utilised, mainly originating from nursing literature and concerned with methodology and implementation of the GCS.[5,28–31] Although sometimes unsupported by well-designed trial data they provided valuable insight into accepted practice among frequent users of the scale. Three systematic reviews were found, two summarising research into the GCS overall and one summarising research into associations with outcome in mild head injury patients alone.[3,4,32] One guideline was utilised,[33] describing alterations to the verbal domain in paediatric patients, due to its ubiquity and authority in the training of clinicians for the assessment of acute childhood illness.

Fig. 1 illustrates the processes of literature searching and study assessment, and Tables 1 and 2 detail included references and relevant study design.

Discussion

The National Institutes of Health, Public Health Service and the US Department of Health and Human Services funded two international studies in parallel,[27] one studying the prognosis of medical coma and the other studying coma in patients with severe head injury. As a result of this innovation, the Coma Index, and then the Glasgow Coma Scale, were developed in an attempt to standardise and quantify measurement of levels of consciousness.[27]

The original authors stated ''In the acute stage, changes in conscious level provide the best indication of the development of complications such as intracranial haematoma, whilst the depth of coma and its duration indicate the degree

Table 1 References 1977—2004.

Lead author	Year	Title	Clinical trial	Case series	Systematic review	Narrative review	Data analysis	Letter/guideline
Jennett B	1977	Aspects of coma after severe head injury		√				
Teasdale G	1978	Observer variability in assessing impaired consciousness and coma	√					
Rimel RW	1979	An injury severity scale for comprehensive management of central nervous system trauma		√				
Teasdale G	1983	Glasgow Coma Scale — To Sum Or Not To Sum						√
Hahn YS	1988	Head injuries in children under 36 months of age. Demography and outcome		√				
Simpson DA	1991	Head injuries in infants and young children — the value of the Paediatric Coma Scale		√				
Bhatty GB	1993	The Glasgow Coma Scale: a mathematical critique					√	
Hartley C	1995	The Apache II scoring system in neurosurgical patients: a comparison with simple Glasgow Coma Scoring					√	
Meredith W	1998	The Conundrum of the Glasgow Coma Scale in Intubated Patients — A Linear Regression Prediction of the Glasgow Verbal Score from the Glasgow Eye and Motor Scores					√	
Livingston BM	2000	Should the pre-sedation Glasgow Coma Scale value be used when calculating Acute Physiology and Chronic Health Evaluation scores for sedated patients?		√				
Fischer J	2001	The history of the Glasgow Coma Scale — Implications for practice				√		

Table 1 (*Continued*)

Lead author	Year	Title	Clinical trial	Case series	Systematic review	Narrative review	Data analysis	Letter/guideline
Batchelor J	2002	A meta-analysis of GCS 15 head injured patients with loss of consciousness or post-traumatic amnesia			√			
Ogungbo B	2003	The World Federation of Neurological Surgeons Scale for subarachnoid haemorrhage						√
Healey C	2003	Improving the Glasgow Coma Scale Score — Motor Score Alone Is a Better Predictor					√	
Gabbe BJ	2003	The status of the Glasgow Coma Scale			√			
Kelly CA	2004	Comparison of consciousness level assessment in the poisoned patient using the alert verbal painful unresponsive scale and the Glasgow Coma Scale		√				

Table 2 References 2005—2011.

Lead author	Year	Title	Clinical trial	Case series	Systematic review	Narrative review	Data analysis	Letter/guideline
Iacono LA	2005	Making GCS as easy as 1, 2, 3, 4, 5, 6.				√		
Gill M	2005	A comparison of the Glasgow Coma Scale score to simplified alternative scores for the prediction of traumatic brain injury outcomes					√	
Holmes JF	2005	Performance of the Pediatric Glasgow Coma Scale in Children with Blunt Head Trauma	√					
Holdgate A	2006	Variability in agreement between physicians and nurses when measuring the Glasgow Coma Scale in the emergency department limits its clinical usefulness	√					
Iankova A	2006	The Glasgow Coma Scale. Clinical application in emergency departments				√		
Davis DP	2006	The predictive value of field versus arrival Glasgow Coma Scale score and TRISS calculations in moderate-to-severe traumatic brain injury					√	
Moore L	2006	Statistical Validation of the Glasgow Coma Score					√	
Gill M	2007	Interrater Reliability of 3 Simplified Neurologic Scales Applied to Adults Presenting to the Emergency Department With Altered Levels of Consciousness	√					
Haukoos JS	2007	Validation of the Simplified Motor Score for the prediction of brain injury outcomes after trauma.					√	

Table 2 (*Continued*)

Lead author	Year	Title	Clinical trial	Case series	Systematic review	Narrative review	Data analysis	Letter/guideline
Kerby JD	2007	Agreement Between Prehospital and Emergency Department Glasgow Coma Scores		√				
Matis G	2008	The Glasgow Coma Scale — a brief review				√		
Gorelick MH	2008	Interobserver agreement in assessment of clinical variables in children with blunt head trauma	√					
Zuercher M	2009	The use of Glasgow Coma Scale in injury assessment — A critical review			√			
Fortune P-M	2010	The motor response to stimulation predicts outcome as well as the full Glasgow Coma Scale in children with severe head injury		√				
Green SM	2011	Cheerio Laddie! Bidding Farewell to the Glasgow Coma Scale				√		
Takahashi C	2011	A simple and useful coma scale for patients with neurologic emergencies — the Emergency Coma Scale	√					
Mackway-Jones K	2005	Advanced Paediatric Life Support (APLS) The Practical Approach — 4th Edition						√

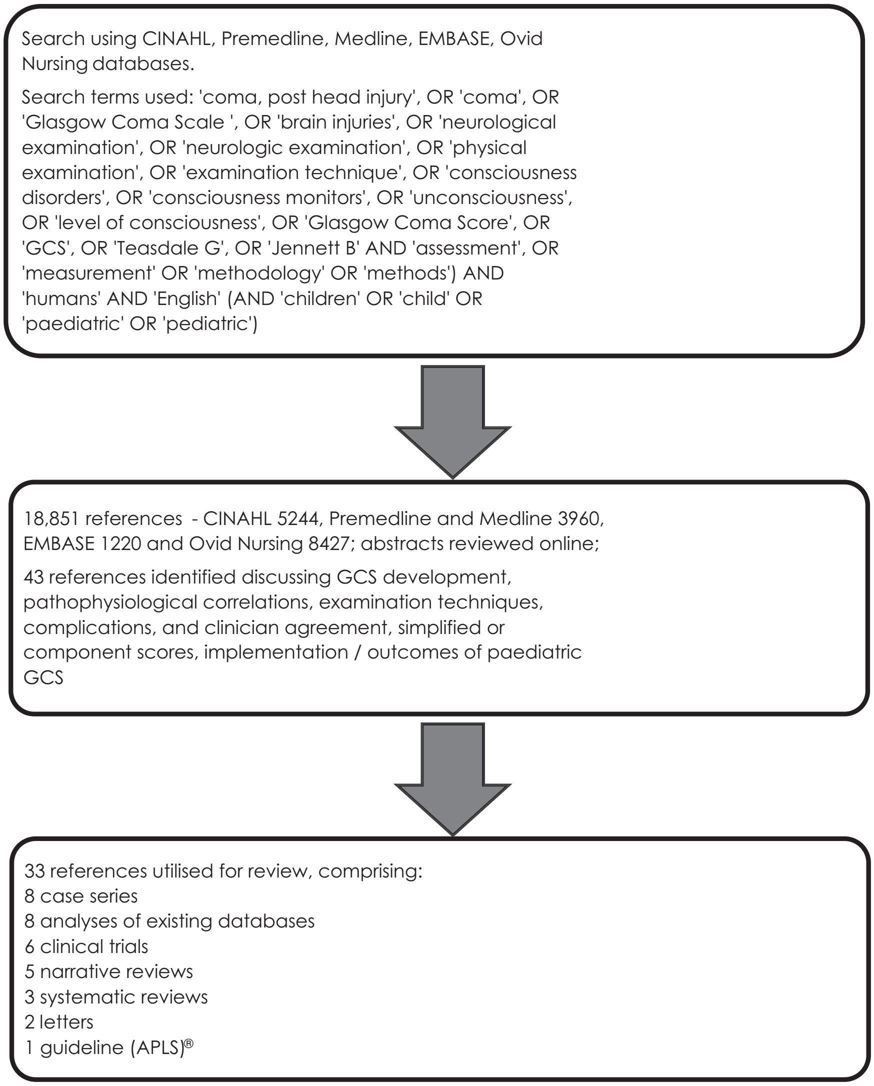


Figure 1 Study flow diagram.

of ultimate recovery which can be expected''.[1] Prior to this most descriptions of altered levels of consciousness revolved around very subjective portrayals such as ''comatose'', ''drowsy'', ''obtunded'', and ''stuporose''.[31]

The GCS was originally described as a repeated bedside assessment of the ''...depth and duration of impaired consciousness and coma'',[1] and was used to objectively determine severity of coma and underlying brain dysfunction at 6 h following head trauma. This time frame was chosen to avoid overestimation of brain damage produced by temporary factors such as alcohol, hypoxia or hypotension,[6,30] and prior to any sedation.[1]

The GCS has since become ubiquitous, being used not only for the measurement of consciousness after traumatic brain injury but also in various medical conditions including overdose,[9] infection, spontaneous intracranial bleeding, seizures and hepatic encephalopathy.[24] It is also used in situations, including the prehospital setting, very different from its original derivation cohort, where patients were in coma for at least 6 h.[1] Agreement between prehospital and emergency department GCS measurement has been investigated,[11,20] and the change over time between these scores used for prognostication.[19] Within these disparate uses, the GCS has been found to be a good discriminator between survivors and non-survivors of trauma patients,[4,5] predictive of severe injury as measured by the Anatomic Injury Scale, and predictive of functional outcome in patients with intracerebral and subarachnoid haemorrhage, although discrimination was poor. Experimental design disparities in study size, follow up and outcome measures have handicapped many studies in this area, precluding generalisation to other populations.[4,5]

The GCS was compared to the AVPU (Alert, responds to Verbal stimuli, responds to Painful stimuli, Unresponsive) score[10] and median GCS scores of 15, 13, 8 and 3 corresponded to AVP and U respectively. A meta-analysis of studies investigating the incidence of radiological abnormalities in fully conscious patients found that this heterogeneous group could be categorised into levels of risk by the addition of clinical features such as headache, persistent nausea and vomiting to the GCS.[32]

Table 3 The Glasgow Coma Scale.

Domain	Level of response	Score
Eye opening	Spontaneous	4
	To speech	3
	To pain	2
	None	1
Best verbal response	Oriented	5
	Confused	4
	Inappropriate words	3
	Incomprehensible sounds	2
	None	1
Best motor response	Obeying commands	6
	Localising	5
	Normal flexor response/withdrawal	4
	Abnormal flexor response	3
	Extensor posturing	2
	None	1

The GCS has also been incorporated into aggregate scores such as the Acute Physiology and Chronic Health Evaluation score (APACHE) and the Trauma Score — Injury Severity Score (TRISS),[16,31] and taking out this neurological component has been shown to worsen predictive ability, leading to the presumption that neurological status is the best predictor of overall functional outcome.[15] The GCS makes up 17% of the theoretical maximum Acute Physiology Score (APS) in APACHE II, 19% of the APS in APACHE III[31] and is the basis of the World Federation of neurosurgeons (WFNS) subarachnoid haemorrhage (SAH) grading scale (Table 3).[2]

The GCS has therefore evolved to fulfil multiple functions, and can be said to

- Aid in clinical decision-making for interventions such as airway management or intensive care admission.
- Describe, quantitate and add structure to the assessment of coma.[6]
- Facilitate and standardise communication between clinicians.
- Enable monitoring of trends in both component and overall scores, allowing rapid detection of complications and discriminating between high or low risk of complications.
- Indicate the severity of injury.[6]
- Allow triage of injured patients.
- Provide a prognostic tool.
- Allow standardisation and comparison of patients and groups for research.

The important primary uses for the GCS are therefore:

- To indicate the level of injury and illness, allowing triage and immediate intervention, and enabling monitoring of trends in consciousness.[6]
- To facilitate understanding, clear description and communication between clinicians.

The original authors believed that measurement of consciousness should not depend on a single measure, so the GCS was designed to utilise the three domains of eye opening, verbal response and motor response.[31] These were chosen as they represent differing, independent aspects of central nervous system function, scored in rank order to indicate the degree of dysfunction. They are represented by three different behavioural responses, each assessable in the absence of the others, therefore being more effective than subjective ''levels'' of function. The total GCS was said to be time-efficient and easy to sum.[2]

Eye-opening represents information processing by the cerebral cortex[31] and the level of arousal or wakefulness.[1] The verbal response measures integration within the nervous system, presence of speech representing a high degree of integration of cerebral cortex and brainstem.[3,31] The motor response is a good indicator of overall nervous system function and integrity of cerebral cortex and spinal cord,[3] due to the variety of possible motion patterns,[1,31] and is considered to represent that part of the central nervous system least affected by trauma.[31] Total GCS <8 largely reflects changes in motor response, referring to patients with no eye opening or verbal response, whereas scores from 9 to 15 depend more on eye and verbal factors.[14] Changes in these factors, and thus higher overall scores, are useful in discriminating between patients with less severe impairment of consciousness. One research group found that increasing scores in the 9—15 range (reflecting improving eye and verbal performances) are associated with a doubling of the rate of good recovery in survivors of head injury.[2]

An exact understanding of terminology, pathophysiology, response, and of examination methodology is essential. Unfortunately, many clinicians are unaware what reaction to a stimulus actually means in practice, but there is also variable and inconsistent teaching and practice in the detail of precisely how to perform the examination. Studies have shown varying degrees of clinician agreement in assessment of the level of consciousness with the GCS; despite the high degree of consistency reported by the original authors,[13] one 2004 study[10] showed only moderate agreement between two emergency physicians (EPs) who assessed the GCS of a broad range of patients, and a further EP-based study comparing different types of score found similarly low values.[25] An Australian study comparing an EP with a registered nurse found excellent agreement in verbal and total GCS scores, but only intermediate agreement in motor and eye scores.[24] Given other work which suggests that the motor score is the most discriminating part of the GCS,[18] this is a cause for some concern, however, in one study of clinician agreement in the assessment of clinical variables in children, agreement in GCS achieved a kappa score of 0.89, being superior to all other variables except the incidence of vomiting.[26]

Given that there is little formal training in the application of the GCS, and also that definitions of the stimuli to apply and details of responses to observe are similarly scanty, the literature was reviewed in an attempt to produce a didactic guide and a standardised method of examination (Table 4).

Table 4 Details of eye opening component.

Level of response	Score	Details of response
Spontaneous	4	Indicative of activity of brainstem arousal mechanisms, but not necessarily of attentiveness (primitive ocular-following reflexes at subcortical level)
To speech	3	Tested by any verbal approach (spoken or shouted); not necessarily the command to open the eyes
To pain	2	Tested by a stimulus in the limbs (supraorbital pressure may cause grimacing and eye closure)
None	1	No response to speech or pain

Detailed breakdown of GCS components

Detailed aspects of assessment

Eyes

A GCS of 3 or 4 implies that information processing is occurring and that related arousal mechanisms at the brain stem are functioning, whereas a GCS of 2 indicates functioning of lower levels.[31] It is not true, however, that eye opening indicates awareness; patients in a persistent vegetative state may have spontaneous eye opening, which is a reflexive action not indicating awareness of self or surroundings.[2]

Verbal

Presence of speech implies a high level of integration in the nervous system, although a lack of speech may be attributed to factors such as tracheostomy, endotracheal tube or dysphasia. Local factors needs to be carefully considered, as including a spurious low verbal score, especially when only the sum is being used, may falsely decrease the total score. GCS is a measure of level of consciousness, and to use a tracheostomy in an otherwise fully conscious patient to give a decreased GCS seems clearly counter-intuitive and incorrect.

In verbal score gradations, *oriented* indicates that the patient is aware of themselves and the surrounding environment,[29] and is usually described in terms of questions about patient's name, the role of the person asking the questions, the month and year, and the name of the hospital or health care facility. *Confused* patients may converse but the content betrays disorientation and misunderstanding. *Inappropriate words* describes clear and comprehensible speech,[29] but using random words or swearing and cursing; repeating words or perseveration also falls into this category. *Incomprehensible sounds* refers to moaning and groaning without recognisable words,[29] even when

Figure 2 Localisation.

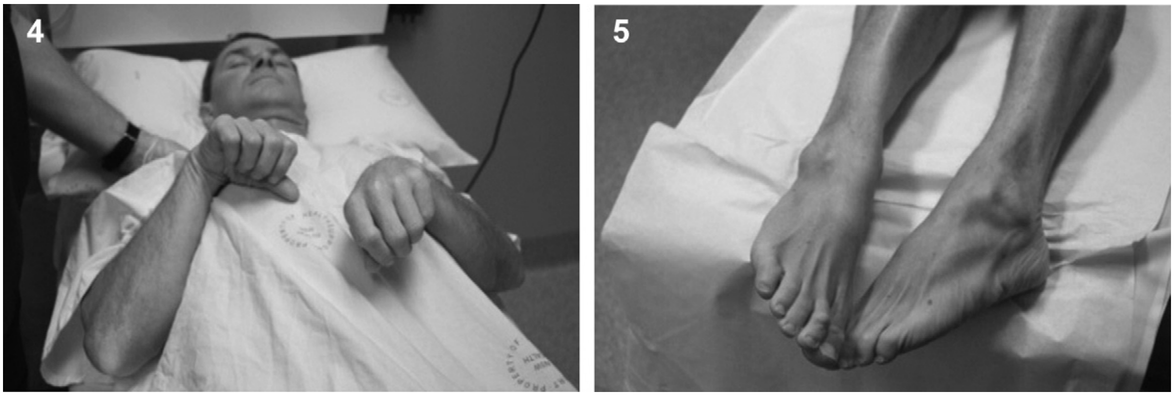
an attempt to articulate is being made. It is important to differentiate, for instance, between a patient with decreased consciousness and reduced cognition and an awake stroke patient, whose dysphasia may make the task impossible. *None* means that the patient is unable to verbalise at all,[29] and is subject to the factors described above.

Motor

Motor scores of 6, 5 and 4 imply the presence of cerebral function and the ability to react appropriately to a noxious stimulus. *Obeys commands* indicates an ability to process and obey verbal commands[29]; *localisation* (Fig. 2) means that the patient is able to identify the location of a painful stimulus and attempt to remove it, an action often accompanied by the upper extremity of a patient purposefully crossing the midline to remove the stimulus.[29,31] *Withdrawal* (Fig. 3), or a normal flexor response, means the patient attempts to move away from the noxious stimulus, by rapid withdrawal and/or abduction at the shoulder, and sometimes by adopting a foetal position.[29] This last position is particularly important when there are inexperienced observers, as differentiating a *localising response* from an *abnormal flexion response* may prove difficult.[29]

A score of 3, or an *abnormal flexor response*, implies a cerebral hemisphere or internal capsule lesion, whereas a score of 2 describes midbrain to upper pontine damage.[31] Abnormal flexor response is complex, but involves upper limb adduction, flexion of arms, wrists and fingers, extension

Figure 3 Withdrawal.



Figs. 4 and 5 Abnormal flexor response showing shoulder adduction, and flexion of elbows, wrists and fingers.

and internal rotation of lower limbs, and plantar flexion of feet (Figs. 4 and 5). This must be differentiated from the *normal flexor response* or *withdrawal*, and from extensor posturing which indicates a lesion lower in the CNS, and therefore reflects function at a lower level.[31] Extensor posturing includes lower limb appearances similar to abnormal flexion, but with upper limbs adopting a position of extension along the sides of the body, and with pronation of the forearms (Fig. 6). These response patterns are often known by the terms *decerebrate* and *decorticate*, implying the level of loss of CNS function. Studies have shown that patients showing *extensor posturing* are more likely to have a poor outcome than those with *abnormal flexion*.[29] If a patient demonstrates flexion on one side of the body, and extension on the other, the better of the two responses needs to be recorded.[31]

None means that the patient is flaccid, and makes no movement in response to a painful stimulus; it is essential to check that the patient is not pharmacologically or pathologically paralysed. Note that the GCS measures consciousness and cognition, and that abnormal motor responses due to the presence of anaesthetic paralysis or spinal cord injury invalidates the motor score as a means to measure consciousness. Another caveat is that the simple ''squeeze my fingers'' command is NOT sufficient or appropriate to demonstrate this function.[2] A grasp reflex can be elicited in many patients with decreased cognition, similar to that found in babies,

Fig. 6 Upper limb extension and pronation in extensor posturing.

and such attempts must include release of the fingers on command. More specific commands such as ''show me two fingers'' are more appropriate.

Local lesions of many types invalidate measurement of consciousness and cognition, and should therefore not be counted into an overall score at all, and should not be counted into a domain score without documented explanation. If one domain of the GCS is confounded by a local lesion, then both snapshots and trends should be limited to the use of the other domains.[1,31] Since the motor score contains most of the predictive power of the GCS, especially in the more severely head injured patients, it has been suggested that it would be reasonable to use this alone. When this occurs, it has been recommended that 1 is scored[6] for the non-included domain, however if this is done it has to be accompanied by a written explanation and cannot be used in an overall score.

Alcohol, drugs, language barriers and hearing impairment are all conditions that may confound the GCS, and once again consideration needs to be given to the reason for measuring cognition. For example, if the reason the GCS is being measured is to assess the level of consciousness associated with a head injury or pathological cause of decreased conscious level, conditions such as alcohol or sedative drugs are a confounder which invalidate the GCS; however, if the measurement is being used to assess the effect of drugs on the level of consciousness, this is then the relevant effect being measured. In these circumstances, however, many of the correlates of a decreased level of consciousness in head injury measured by GCS may not be accurate, such as an inability to protect the airway associated with a GCS $\leq$8, which is often not true in patients obtunded with certain drugs of abuse.

Various approaches to the problem of estimating the GCS in intubated patients have been attempted, with one trial of 24,000 patients[17] demonstrating that a verbal score derived by logistic regression, utilising the motor and eye opening scores as predictors, performed better than the actual GCS. An extended list of potential confounders is given in Table 5 below.[31]

It should also be remembered that the GCS is NOT a scale to measure an altered sensorium, so cannot be used to test sensation. It is also not a substitute for either a full neurological examination or an assessment of orientation.[29,31] It

Table 5 Details of verbal component.

Level of response	Score	Details of response
Oriented	5	Awareness of the self and the environment (who/where/when/why)
Confused	4	Responses to questions with presence of disorientation and confusion.
Inappropriate words	3	Speech in a random way, no conversational exchange
Incomprehensible sounds	2	Moaning, groaning
None	1	No response

Table 6 Details of motor component.

Level of response	Score	Details of response
Obeying commands	6	The rater must rule out grasp reflex or postural adjustment
Localising	5	Movement of limb as to attempt to remove the stimulus, the arm crosses midline, and moves to more than one site of noxious stimulus
Normal flexor response/withdrawal	4	Rapid withdrawal and abduction of shoulder
Abnormal flexor response	3	Adduction of upper extremities, flexion of arms, wrists and fingers, extension and internal rotation of lower extremities, plantar flexion of feet, and assumption of a hemiplegic or decorticate posture
Extensor posturing	2	Adduction and hyperpronation of upper extremities, extension of legs, plantar flexion of feet, progress to opisthotonus (decerebration)
None	1	The observer must rule out an inadequate stimulus or spinal transection

Table 7 Conditions that affect the calculation of the three components of the GCS.

Conditions	E	V	M
Ocular trauma	+		
Cranial nerve injuries	+		
Pain	+		+
Intoxication (alcohol, drugs)		+	+
Medications (anaesthetics, sedatives)		+	+
Dementia		+	+
Psychiatric diseases		+	+
Developmental impairments		+	+
No comprehension of spoken language		+	+
Intubation, tracheostomy, laryngectomy		+	
Oedema of tongue		+	
Facial trauma		+	
Mutism		+	
Hearing impairments		+	
Injuries (spinal cord, peripheral nerves, extremities)			+

also does not account for true lateralisation as it measures the best response rather than the worst.[31]

The sternal rub has been documented to cause injury, particularly pressure area damage[30] and cannot be recommended. Supraorbital nerve pressure has similarly caused damage and is less reliable and consistent than other methods of applying a central noxious stimulus.[28] The trapezius or pectoralis major pinch is recommended as it causes no local damage, simply comprising point pressure on a large muscular area, whilst providing a suitable painful stimulus.[30] Whether the upper limb localises to the painful stimulus by crossing the midline or not must be recorded; if it does not, careful assessment is important to discriminate between this and abnormal flexion (Tables 6 and 7).

To accurately elicit a response to a noxious or painful stimulus, both a peripheral stimulus such as nail bed pressure, being cautious not to damage the nail fold and underlying matrix, as well as a central stimulus using the trapezius or pectoralis pinch (Fig. 6) should be applied. Bilateral nail bed stimulus should be applied as this allows the ascertainment of the best side, which should be documented as the GCS response in this domain.

It is taught in some institutional settings to apply a central stimulus such as a trapezius or pectoralis pinch to elicit localising, and then to apply nail bed pressure to assess withdrawal/abnormal flexor/extensor posturing/no motor response. This appears to have the benefit of conferring added precision in the eliciting of responses to pain and is recommended as an approach to practice (Fig. 7).

Assessment of the GCS in children adds another layer of complexity,[12] as there is a need to relate normal responses to minimum normal developmental attainments.[8] A child under 6 months of age for instance may still demonstrate primitive reflex responses and simply 'withdraws' or 'flexes' after any form of painful stimulus.[7] It has been stated that the motor score domain of the GCS is ''In children less than one year old, the only useful part of the GCS...''[8] however it has also been shown that the 6-poin motor scale is inappropriate for use below the age of 6 months,[7] and in the Paediatric GCS (PGCS)[8] system derived in Adelaide a 5-point scale was used without attempting to differentiate between normal and abnormal flexion. This clearly leads to the use of a 14 point PGCS rather than a 15 point scale. In the PGCS it was stated, therefore, that the expected normal coma score was 9 in the period from birth to 6 months old, 11 between 6 and 12 months, 12 between 12 months and two years, 13 between 2 and 5 years and 1 after 5 years. Another study using Receiver Operating Characteristic (ROC) curves to compare the use of a paediatric and adult GCS concluded that ''...the motor component had the worst test performance, both in younger and older children''.[23]

The main difference between paediatric and adult GCS has been in verbal scoring. The PGCS[8] described above uses a verbal scale which includes Orientated, Words, Vocal Sounds, Cries and None, whereas the earlier Children's Coma Scale uses a verbal subscore based on both crying and interaction (Table 8). The Advanced Paediatric Life Support (APLS)® course uses a detailed verbal subscore utilising descriptive terms which can be applied across a spectrum of age, with a score of 5 for 'Alert' also being described as 'babbles, coos words to usual ability', and a score of 4 described as 'Less than usual words; spontaneous irritable cry'.[33] This may be seen in Table 8, however a salient and important point is that paediatric GCS scoring may be particularly challenging, and often requires consistent practice to become familiar with its use.[12]

A number of criticisms have been leveled against the GCS since its inception, one being its complexity, leading to a lack of agreement among clinicians attempting to quantitate consciousness for the purposes of diagnosis, intervention or prognosis, and another being the lack of contribution of the eye opening and verbal scales to the overall discrimination of the scale.

It has been said that to be accurately and consistently applied, a clinical scale must be easy to use and remember.[5] In a recent review Greene pointed out that in 2003 it was realised that 25% of British hospitals were using the 12-point GCS and 75% were using the 13-point GCS, a fact that had not been previously noticed, and which reflects eloquently on the complexity of the GCS. It has also been shown that

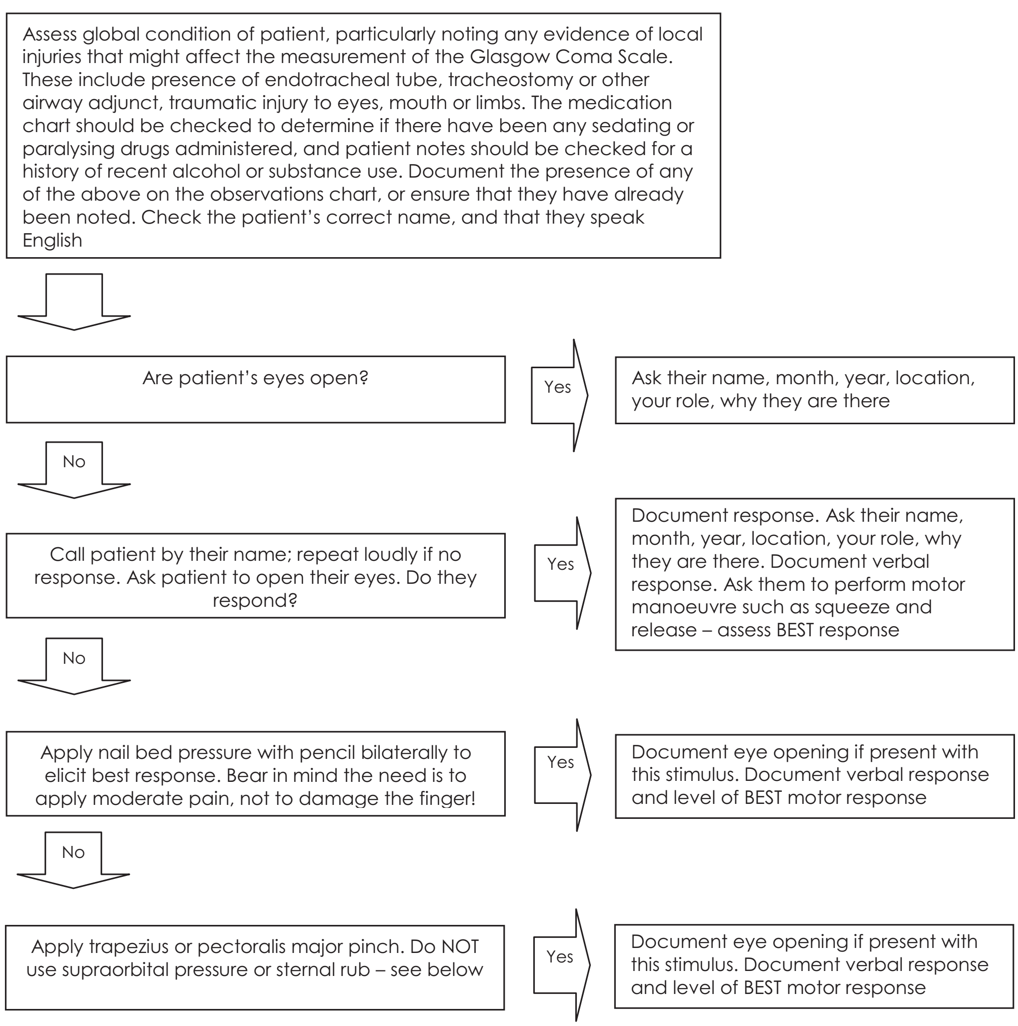


Fig. 7 Algorithm for implementing the GCS.

only 15% of military physicians could correctly calculate the scale, despite having attended an Advanced Trauma Life Support® course. The GCS is actually a collection of 120 different combinations of the three domain scores, which summed as a single score may be associated with very different mortalities,[18] with a non-linear relationship between GCS and survival.

The motor score component does however have a linear relationship with survival, and contains the majority of the predictive power of the GCS overall.[18] It has been suggested that the motor score alone may be used rather than the GCS due to its simplicity and power, but also as part of a greater, more comprehensive survival model which takes into account age, injury severity and comorbidities. One statistical study of GCS performance in the prediction of in-hospital mortality concluded that the eye component added no predictive power to the verbal and motor components, but the GCS overall performed badly when used as an ordinal categorical variable, arguing against the use of a summed score.[21] Furthermore, in children the motor score has been shown to have predictive power equivalent to the full GCS, has a linear relationship with mortality and was found to be easier to collect accurately.[12]

A derivation of the GCS motor score is the Simplified Motor Score (SMS)[19] which streamlines the GCS motor component into a simple ordinal scale comprising ''obeys commands'', ''localises pain'', or ''withdraws to pain or lesser response'', giving a score of 2, 1 and 0 respectively.[19] Physician recordings of the GCS, the SMS, the AVPU, and the ACDU (Alert, Confused, Drowsy, Unresponsive) scales demonstrated superior inter-rater reliability for the SMS in altered mental status in both traumatic and non-traumatic cases,[19] and the SMS has demonstrated similar test performance to the GCS against a range of clinical outcomes such as emergency intubation, neurosurgical intervention and mortality.[19,22] The Emergency Coma Scale, an alternative score to the GCS developed to be simpler in application, has been demonstrated to be superior to the GCS in outcome prediction and displayed greater inter-rater agreement.[27]

Finally, one of the most potent criticisms of the GCS is that it engenders spurious precision in the evaluation of consciousness.[5] The tendency to demand quantification and exact measurement of pathological and physiological processes, despite them being continuous, constantly changing and often subject to subjective interpretation, is endemic in the clinical and scientific community. The GCS takes one of those shifting and imprecise variables and superimposes a structured ordinal classification upon it. Not only does the GCS contain multiple subjective elements,[32] perform well only at its extremes and suffer from large margins of error and low inter-rater reliability, but it fundamentally errs in suggesting that a single, precise, ordinal measurement is valid or even possible.

Teasdale and Jennett essentially designed the Glasgow Coma Scale to be a measure of trend and change, arguably the most important markers of clinical state, and not to provide a static but inappropriately exact scale of level of consciousness. It has been suggested that simpler scales such as the GCS motor score, SMS, or the AVPU provide consistently adequate information to measure trend, whether that signifies recovery or deterioration.

Summary

The GCS is a ubiquitous ordinal score designed to evaluate changes in conscious level, depth and duration of coma, and to identify development of complications and the potential degree of ultimate recovery. The widespread use of GCS has not been accompanied by robust descriptions of examination or measurement technique needed for accurate and valid usage, and there is increasing evidence that simpler scales may serve the purpose of the GCS without the complexity of calculation or measurement.

If the GCS is to be used however, particularly the motor score or derivations of this score, it is vital that clinicians use identical and appropriate stimuli and evaluate responses in a repeatable and reliable way. This review has examined the published literature, including the original descriptions by the authors of the tool, and has suggested a methodology for its appropriate use.

Table 8 Comparison of verbal domains of paediatric GCS versions.

Level of response	Score	Paediatric GCS type			
		PGCS	CGCS		APLS
Oriented	5	Orientated	Smiles, oriented to sound, follows objects, interacts Crying	Alert; babbles, coos words to usual ability Interacts	
Confused	4	Words	Consolable	Inappropriate	Less than usual words; spontaneous irritable cry
Inappropriate words	3	Vocal sounds	Inconsistently consolable	Moaning	Cries only to pain
Incomprehensible sounds	2	Cries	Inconsolable	Irritable, restless	Moans to pain
None	1	None	No response	No response	No response to pain

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