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Review

The Glasgow Coma Scale – a brief review
Past, present, future

Georgios Matis and Theodossios Birbilis
Neurosurgery Department, Democritus University of Thrace, University General Hospital of Alexandroupolis, Greece

Abstract

The Glasgow Coma Scale (GCS) was introduced in 1974 aiming at standardizing assessment of level of consciousness in head injured patients. It has been used mainly in evaluating prognosis, comparing different groups of patients and monitoring the neurological status. However, its use expanded beyond the original intention of the scale and certain limitations were identified. The skewness toward the motor subscore, the experience of the raters, the process of intubation, the time and setting of rating among others are to be taken into account. In this review a thorough presentation of this scale's history, principles of scoring and associated common pitfalls, major applications and drawbacks is attempted. Moreover, future trends and implications are considered. The key concept in all articles reviewed is that even though GCS is not a perfect tool and other coma scales have been proposed, it seems destined to be incorporated in clinical decisions regarding coma for many years to come. Nonetheless, deep knowledge of its proper applications on one hand and limitation of its misuse on the other is essential to benefit both health care professionals and their patients.

Key words : Glasgow coma scale ; head trauma ; history ; principles of scoring ; applications ; limitations ; trends ; review.

Introduction

The Glasgow Coma Scale (GCS) was introduced in 1974 as a method for determining objectively the severity of brain dysfunction and coma six hours after the occurrence of head trauma (HT) (Teasdale, Jennett, 1974). Nowadays, it is by far the most widely used score to assess the severity of HT in clinical research and to compare series of patients (Alvarez *et al.*, 1998). The main advantage of this scale is that it can be utilized by physicians, nurses, and other care providers due to its simplicity (Fischer, Mathieson, 2001). In the present review the history of GCS, the principles of scoring, the applications, the shortcomings and future trends concerning its application are discussed.

History

The GCS was the result of two parallel international studies on coma funded by the National Institutes of Health, Public Health Service, US Department of Health and Human Services (Fischer, Mathieson, 2001). It was first published in 1974 (Teasdale, Jennett, 1974) and revised in 1976 with the addition of a sixth point in the motor response subscale for "withdrawal from painful stimulus" (Sternbach, 2000 ; Teasdale, Jennett, 1976). The need to code the observations of the three portions of the scale for analysis of data for research purposes was apparent (Teasdale, Murray, 2000 ; Teasdale, Jennett, 1976). This coma scale utilized the theoretical model of level of consciousness proposed by Plum and Posner in 1972 (McNett, 2007 ; Posner, 1975). The authors from Institute of Neurological Sciences of Glasgow stated their scope for constructing this scale (a repeated bedside assessment of "the depth and duration of impaired consciousness and coma"), provided specific instructions on how it should be used and assigned numerical values for each component. Impaired consciousness was considered "an expression of dysfunction in the brain as a whole" (Teasdale, Jennett, 1974).

A 5-point scale to assess consciousness had already been described in 1966 by Ommoya (Sternbach, 2000). Until then the literature contained only "unstructured observations" and general descriptions, resulting in confusion and loss of information. Characteristically, Teasdale and Jennett (1974) mentioned that "almost every report of patients in coma" offered "another classification". Terms like "comatose", "drowsy", "obtunded", "stuporose" and "semistuporose" were frequently encountered (Pickard *et al.*, 2006 ; Servadei, 2006). This caused tremendous difficulty in communication between physicians and made the comparison of patients treated by different regimens cumbersome (Deshpande and Patel, 1999). Teasdale and Jennett (1974) chose to examine three aspects of behavioural response, namely eye

Table I

Standard Glasgow Coma Scale

Eye opening	Best verbal response	Best motor response
4 : spontaneous 3 : to speech 2 : to pain 1 : none	5 : oriented 4 : confused 3 : inappropriate words 2 : incomprehensible sounds 1 : none	6 : obeys commands 5 : localizes 4 : withdraws 3 : abnormal flexion 2 : extension 1 : none
TOTAL GCS SCORE : 3-15		

opening, verbal and motor response (Table I, Fig. 1).

Up to 2005 more than 4,500 publications made reference to the GCS (Laureys *et al.*, 2005). This instrument was eventually incorporated into various trauma scoring systems : the Revised Trauma Score (RTS) (Davis *et al.*, 2006), the Acute Physiology Age and Chronic Health Evaluation (APACHE II) (Walther *et al.*, 2003), the Simplified Acute Physiology Score (SAPS) (Teoh *et al.*, 2000), the Circulation, Respiration, Abdomen, Motor, Speech scale (CRAMS) (Laureys *et al.*, 2002), the Traumatic Injury Scoring System (TRISS) and A Severity Characterization Of Trauma (ASCOT) scale (Moore *et al.*, 2006). Actually, it was reported that removing the neurological weighting (GCS) from APACHE II weakened its predictive ability, showing that it's the neurological status that best predicted overall functional outcome (Hartley *et al.*, 1995). Besides, GCS has the potential to contribute 17% of the theoretical maximum Acute Physiology Score (APS) in the APACHE II and 19% in the APACHE III systems (Livingston *et al.*, 2000). The GCS is also the basis of the World Federation of Neurological Surgeons (WFNS) grading scale for subarachnoid hemorrhage (SAH) (Ogungbo, 2003).

An extended version of GCS, the Glasgow Coma Scale-Extended (GCS-E), was introduced later for helping the acute assessment (prognostic information regarding symptom severity and recovery, holding patients in the treatment loop until symptoms remit) of mild HT. This scale was coded by an additional digit which followed the classic GCS in order to better address the posttraumatic amnesia (PTA) issue. A numeric value between 0-7 was assigned based on the duration of the PTA (Nell *et al.*, 2000).

The GCS is often used in conjunction with Glasgow Outcome Score (GOS) which was published in 1975, in order to investigate the relationship between severity of HT and long term functional recovery (Gabbe *et al.*, 2003 ; Jennett, Bond, 1975). It defines levels of quality of outcome, ranging from good recovery to persistent vegetative state or death (Teasdale *et al.*, 1998 ; Bion, 1997) without being specific concerning cognitive ability or paralysis (Rush, 1997) (Table II). The extended version of GOS (GOS-E) is also available (van Baalen *et al.*, 2002).

Since 1974 many scales have been proposed as alternatives to GCS : (a) the Reaction Level Scale (RLS) which was developed in Sweden in 1985 (Starmark *et al.*, 1991), has 8 values (Walther *et al.*, 2003 ; Laureys *et al.*, 2002) and resembles an enhanced GCS motor subscore (Healey *et al.*, 2003) ; (b) the Innsbruck Coma Scale (ICS), a 23-point scale (Laureys *et al.*, 2002 ; Marosi *et al.*, 1991) ; (c) the Edinburgh-2 Coma Scale (E2CS) which is not applicable to patients unable to provide an oral response (Laureys *et al.*, 2002) ; (d) the Advanced Trauma Life Support AVPU (Alert, response to Verbal and Painful stimuli, Unresponsive) scale (Gill *et al.*, 2007) and (e) the ACDU (Alert, Confused, Drowsy, Unresponsive) scale (McNarry, Goldhill, 2004).

The need to incorporate the brainstem reflexes when evaluating patients in coma led to the development of other scales such as the Bouzarth Coma Scale and the Maryland Coma Scale (Laureys *et al.*, 2005). Wiejdicks *et al.* (2005) have recently proposed a new coma scale : the Full Outline of Unresponsiveness (FOUR) which includes four components (eye, motor, brainstem and respiratory functions) each rated with a maximum score of four (Pickard *et al.*, 2006 ; Servadei, 2006).

The GCS gained global acceptance mainly thanks to nurses, since in the beginning no consensus regarding its accuracy had been reached by physicians. Paradoxically, one of the last places to start applying this tool was Edinburgh, a city 60 minutes east of Glasgow (Rush, 1997).

Despite the worldwide adoption, it seems necessary one to keep in mind the following principles of scoring, applications and shortcomings of the scale under review, in order to avoid phenomena such as the continuation of usage of the original 14-point GCS by many British hospitals instead of the revised 15-point GCS (Wiese, 2003).

Principles of scoring

The GCS is a collection of 120 mathematical combinations out of which only about 15 are clinically valid (Healey *et al.*, 2003 ; Bhatty, Kapoor,

				8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7
GLASGOW COMA SCALE	EYE OPENING	*Spontaneously*	4							TO OPERATING ROOM													x	x	x	x	
		To speech	3	x	x	x	x									x	x	x	x	x	x	x					x
		To pain	2					x	x					x	x												
		None	1											x													
	BEST VERBAL RESPONSE	*Oriented*	5																								
		Confused	4	x	x	x																					
		Inappropriate words	3																								
		Incomprehensible sounds	2				x	x	x																		
		None	1										T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	BEST MOTOR RESPONSE	*Obeys commands*	6	x	x	x	x									x	x	x	x	x	x	x	x	x	x	x	x
		Localizes	5					x	x				x	x	x												
		Withdraws	4																								
		Abnormal flexion	3																								
		Extension	2																								
		None	1																								

FIG. 1. — Chart for monitoring neurological status using GCS scores' plotting

Table II

Glasgow Outcome Scale

CATEGORY	RESPONSE	COMMENTS
Good recovery	Normal life, minor neurological and psychological deficits.	Family relationships, leisure activities.
Moderate disability	Disabled (hemiparesis, ataxia, dysphasia, personality change, memory and intellectual deficits) but independent.	Able to use public transportation and work in a sheltered environment.
Severe disability	Conscious, disabled, and dependent for support for some activities of daily living.	Physical or mental disability or both.
Vegetative state	Awake, marked with cycles of sleeping and wakefulness.	Although cerebral cortex may be intact, absence of function.
Dead		Need to differentiate between death due to primary head injury and death due to complications.

1993). For example, eighteen possible permutations exist for total GCS score of 9, seventeen for scores 8 and 10, fourteen for scores 7 and 11, and ten for scores 6 and 12 (Teoh *et al.*, 2000). Minimum score is 3 (deep coma or death) and maximum score is 15 (no neurological deficit). Higher scores indicate a better prognosis (Fani-Salek *et al.*, 1999). Singounas (1995) proposed the addition of the score 2 to GCS as symbolic expression of brain death and the designation of a score of -1 in absence of brainstem reflexes.

The initial score should be assigned six hours after HT had been sustained in order to avoid overestimation of brain damage produced by transient factors, such as hypoxia, hypotension or alcohol intoxication (Marion, Carlier, 1994 ; Jennett, Teasdale, 1977). In addition, using the GCS score recorded before sedation is preferable to the assumption of normality as was demonstrated by a prospective cohort study of 13,291 patients undertaken in 22 general adult intensive care units (ICUs) in Scotland. The discrimination of both APACHE II and III systems increased when the presedation score was used (Livingston *et al.*, 2000). The three spheres of GCS are described in the following section.

EYE OPENING

– Spontaneous (4) : is 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).
– 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.

Scores of 3 and 4 imply that cerebral cortex is processing information, even though this is also seen in the vegetative state, while a score of 2 that lower levels of brain are functioning (Fischer, Mathieson, 2001 ; Harrahill, 1996 ; Teasdale, Jennett, 1974).

BEST VERBAL RESPONSE

– Oriented (5) : awareness of the self and the environment (who / where / when).
– 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.

Presence of speech indicates a high degree of integration in the nervous system even though lack of speech could be attributed to other factors (dysphasia, tracheostomy) (Alverzo, 2006 ; Heim *et al.*, 2004 ; Fischer, Mathieson, 2001 ; Teasdale, Jennett, 1974).

BEST MOTOR RESPONSE

– Obeying commands (6) : the rater must rule out grasp reflex or postural adjustment.
– Localizing (5) : movement of limb as to attempt to remove the stimulus, the arm crosses midline.
– Normal flexor response (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.

A score of 3 implies that the lesion is located in the internal capsule or cerebral hemispheres (Harrahill, 1996 ; Jones, 1979) and is attributed to disinhibition by removal of corticospinal pathways above the midbrain (Greenberg, 2001). On the other hand, a score of 2 describes a midbrain to upper pontine damage (Iacono, Lyons, 2005 ; Heim *et al.*, 2004) and is attributed to disinhibition of vestibulospinal tract and pontine reticular formation by removing inhibition of medullary reticular formation transection at intercollicular level between vestibular and red nuclei (Greenberg, 2001). Yet, according to other authors, the term “decerebrate rigidity” should be avoided because it implies a specific physioanatomical correlation. Moreover, abnormal flexion and extension motor responses often co-exist (Bricolo *et al.*, 1977).

The motor response is considered a good indicator of the ability of central nervous system (CNS) to function properly due to the variety of possible motion patterns. The rater records the best response from any limb when assessing altered consciousness and the worst one when focal brain damage is in question (Fischer, Mathieson, 2001 ; Sternbach, 2000 ; Teasdale, Jennett, 1976 ; Teasdale, Jennett, 1974). According to others, it is the best response that should be also scored in focal brain damage.

All the above responses are tested after the application of a painful stimulus (pressure to the fingernail bed with a pencil). Stimulation follows in head, neck, and trunk. Arms are more useful to test since they present a wider range of responses, while a spinal reflex may cause flexion of legs if pain is applied locally (Teasdale, Jennett, 1974). Yet, one should keep in mind that peripheral stimuli may elicit a spinal reflex response, while pressure on the sternum or the supraorbital ridge may cause injury to the patient (Fischer, Mathieson, 2001). These techniques do not accurately test the motor response. Instead, it is advisable to pinch the pectoralis major or the trapezius muscles (Iankova, 2006 ; Iacono, Lyons, 2005 ; Lowry, 1998).

To end with, some comments regarding children are to be made. Scores in children are more subjective and prone to misinterpretation. The GCS is inapplicable to infants and children below the age of 5 years. The responses of children change with development therefore the GCS requires modification for paediatric use (Knight, Slater, 2003 ; Matthews, 2003 ; Reilly *et al.*, 1988) (Table III). Using the standard GCS for adults, the normal aggregate scores are 9 (at six months), 11 (at twelve months), and 13-14 (at sixty months) (Matthews, 2003). Researchers reported a devised paediatric coma scale which took into account the fact that the expected normal verbal and motor responses must be related to the patient’s age (Palazzo, 2003 ; Martens, 1993 ; Reilly *et al.*, 1988). Several scales have been presented as GCS substitutes in children, including one from the Children’s Memorial Hospital in Chicago, the Children’s Coma Scale (Hahn *et al.*, 1988), the Children’s Coma Scale by Raimondi and Hirschauer (1984), and the Adelaide paediatric modification of the GCS (Simpson *et al.*, 1991). Champion *et al.* (1989) modified the verbal component for children as follows : 5 points for an appropriate response, 4 points for consolable cries, 3 points for persistent irritation, 2 points for restlessness and agitation and 1 point for no response. Nevertheless, whichever scale is chosen, it should be used in a repetitive and consistent way by all care providers (Ward, 1996). As for adults, emphasis should be placed on the accurate measurement of the motor score before intubation by physicians or paramedics (Jones, Daly, 1998).

Applications

An overview

The use of standardized scales aids in evaluating different studies and trials (Ko, 2002). The GCS describes and assesses coma, monitors changes in coma, is an indicator of severity of illness, facilitates information transfer, and is used as a triage tool in patients with HT (Heim *et al.*, 2004 ; Bion, 1997). And what’s more, it facilitates monitoring in the early stages after injury, allowing rapid detection of complications even among patients with a GCS score of 13 to 15, discriminating between those more or less likely to be at risk of complications (Jennett, 2002). Moreover, it aids in clinical decisions, such as intubation (for total GCS score ≥ 8 or motor score ≥ 4), monitoring of intracranial pressure (ICP) (for total GCS score ≥ 13 or total GCS scores 14 or 15 with evidence of HT) and admission to ICU (King *et al.*, 2000).

Table III

Glasgow Coma Scale modified for infants

Eye opening	Best verbal response	Best motor response
4 : spontaneous 3 : to speech 2 : to pain 1 : none	5 : coos, babbles 4 : irritable cries 3 : cries to pain 2 : moans to pain 1 : none	6 : obeys commands 5 : withdraws to touch 4 : withdraws to pain 3 : flexion to pain 2 : extension to pain 1 : none
TOTAL GCS SCORE : 3-15		

Classification of severity of HT

A score of 13-15, 9-12, 5-8 and 3-4 indicates minor, moderate, severe and very severe injury (Ko, 2002). Other studies report three GCS score intervals : 13-15 (mild HT), 9-12 (moderate HT) and ≥ 8 (severe HT) (Sternbach, 2000). Stein (1996) proposed five intervals : (a) minimal (15, with no LOC or amnesia) ; (b) mild (14-15 plus amnesia or LOC for ≥ 5 minutes or impaired alertness or memory) ; (c) moderate (9-13 or LOC ≥ 5 minutes or focal neurological deficit) ; (d) severe (5-8) ; (e) critical (3-4). Many authors suggest that patients with a GCS score of 13 should be included in the moderate HT group, since they present the same risk of complications as patients with a GCS of 9 to 12 (van Baalen *et al.*, 2002). It was also stated that alteration in eye and verbal responses scores for more than 1 point and higher total scores are useful in discriminating between patients with less severe impairment of consciousness (Servadei, 2006 ; Teasdale *et al.*, 1983).

Skull radiography, Computed Tomography (CT) scans, and Magnetic Resonance Imaging (MRI)

Patients with GCS scores of 13-14 had a significantly higher incidence of initial loss of consciousness, skull fracture, abnormal CT findings, need for hospital admission, delayed neurological deterioration and need for operation than patients with a GCS score of 15 (Gómez *et al.*, 1996). Kotwica and Jakubowski (1995) reported that patients with GCS score of 3 on admission without major CT abnormalities "had a chance of survival". It was also shown that patients with a GCS score of 13 should probably not be characterized as "mild" due to apparent brain damage on CT scans ; patients with score 14 should undergo MRI since CT scans do not demonstrate clearly the parenchymal lesions ; even in subjects with a score of 15 with amnesia or of advanced age CT scans should be performed promptly and MRI when available (Uchino *et al.*, 2001). Follow-up CT scans should be decided only in patients with clinical deterioration that can not be explained by ICP changes alone because of the detrimental effects of mobilizing critically ill patients (increased ICP, hemodynamic and respiratory instability) (Lee *et al.*, 1997). The same authors reported that 73.1% of 113 patients with moderate and severe HT had improved or had the same CT appearance when their GCS score was unchanged or improved. On the other hand, when patients had a worse GCS, the CT was worse in 77.9% of cases.

Prediction of hospital mortality

The GCS predicts hospital mortality in ICU patients without trauma (Grmec, Gašparovic, 2001 ; Bastos *et al.*, 1993) or with HT (Alvarez *et al.*, 1998 ; Rimel *et al.*, 1979 ; Jennett, Teasdale, 1976). Grmec and Gašparovic (2001) studying 286 non traumatic coma patients found GCS to have the most correct prediction of outcome, Youden index and area under Receiver Operating Characteristic curve as compared to Mainz Emergency Evaluation System (MEES) and APACHE II score. The authors concluded that the GCS score proved to be the best indicator for assessment of mortality thanks to its simplicity, less time-consumption and effectiveness in an emergency department. Cho and Wang (1997) reported a Youden index of 0.6 and a correct classification rate of 82.4% in 200 patients admitted in an ICU for HT. Mortality prediction was also documented in 315 patients with severe HT (Fearnside *et al.*, 1993). Rocca *et al.* (1989) found that GCS was superior to Acute Physiology Score (APS), Simplified Acute Physiology Score (SAPS) and Therapeutic Intervention Scoring System (TRISS) in predicting outcome in 70 patients with HT hospitalized in a neurosurgical ICU. Application of the GCS in 100 neurosurgical patients in Newcastle gave a predictive value of 95% (for minimum GCS score) and 93% (for initial GCS score). The corresponding value for APACHE II system was 97% (Hartley *et al.*, 1995). It was demonstrated that GCS scores were most accurate at outcome prediction when they were combined with age, pupillary response and broad outcome categories (McNett, 2007 ; Prasad, 1996). On the other hand, Demetriades *et al.* (2004) found no correlation between GCS scores and outcome in 7,764 Trauma Centers' patients with HT.

Evaluation of children

The GCS predicts outcome in children with HT. Chung *et al.* (2006) reported that a critical point of GCS set at 5 was most strongly correlated with outcome of paediatric HT. White *et al.* (2001) undertook a retrospective cohort study of 136 severely head injured children (0-17 years). The results of this study confirmed that all subjects with scores > 8 at 6 hours survived, while all non survivors had a score ≥ 8 at 6 hours. In addition, the GCS predicts outcome of intracranial hemorrhage in children with cancer. Kyrnetskiy *et al.* (2005) suggested that a decrease in GCS of more than 3 points at the time of intracranial hemorrhage was an indicator of increased mortality. As long as the accurate evaluation of preverbal blunt head injured children (two years and younger) is concerned, the paediatric version of GCS compares favorably with the standard GCS in respect to the need for acute intervention (Holmes *et al.*, 2005).

Evaluation of hemorrhage

The GCS is utilized in the comparative study of traumatic and spontaneous intracerebral hemorrhage.

In a sample of 530 patients it was reported that younger age and higher GCS scores at presentation were strongly related to favorable outcome for both types of hemorrhage (Siddique *et al.*, 2002). Moreover, initial GCS score predicts outcome in infratentorial traumatic brain hemorrhage. A retrospective analysis of 18 patients concluded that initial GCS score was predictive of long term outcome. The trend between GOS and initial GCS when evaluated with the Spearman rank correlation coefficient was strong ($r_S = 0.804$, $p < 0.001$) and even stronger at 24 hours ($r_S = 0.840$, $p < 0.001$) (Harris *et al.*, 2000).

Evaluation of surgical or intensive care demand

The GCS helps in exploring how different age groups may acquire different benefits from intensive treatment and surgical intervention. A study from a greek ICU concluded that it was valid to treat patients aged 65-74 as a separate group from patients 75 and older. In contrast to the older patients the younger subset of elderly patients may benefit from ICU treatment or surgical intervention (Bouras *et al.*, 2007).

Evaluation of acute stroke and aneurysmal SAH

A study of 275 patients with acute stroke found that the eye and motor subscales had 87% accuracy compared to 88% for the total GCS, making the short form as good a predictor for early (< 14 days) as the full form in those patients (Prasad, Menon, 1998). In addition, a retrospective study of 304 patients who underwent surgery for ruptured cerebral aneurysms found that in those with a GCS score of 14 a "confused" verbal response indicated poorer prognosis. A different outcome was also noticed for total scores of 7 and 8 (Hirai *et al.*, 1997). Yet, Lagares *et al.* (2005) did not find significant differences between most of GCS grades in predicting outcome in 442 patients with spontaneous SAH.

Assessment of meningitis and CNS infections

This scale is used as a prognostic indicator in patients with meningitis. Schutte and van der Meyden (1998) examined 100 patients with meningitis. They found that 88% of them with GCS score > 12 had a good neurological outcome, while 88% of them with GCS score ≥ 8 had a poor outcome ($p < 0.0001$). A significant relationship between the first ICU day GCS score and the subsequent ICU mortality in patients with CNS infections ($r = 0.3152$, $p = 0.0015$) was also reported. This was not confirmed for other infections ($r = 0.0919$, $p = 0.1106$) (Barši *et al.*, 1996).

Evaluation of carotid artery injuries

The GCS is useful in the clinical stratification of patients with carotid arterial injuries associated with focal neurological deficit or altered state of consciousness. Teehan *et al.* (1997) reported that these injuries should only be repaired in patients with GCS score > 9, since comatose patients with GCS score < 8 do poorly regardless of management.

GCS in motor vehicle accidents

It is utilized to predict patient hospitalization after motor vehicle collisions. An analysis of 2,880 patients evaluated in the Emergency Department of a Level II trauma center found that a prehospital GCS score ≥ 14 accurately predicted patient hospitalization (Norwood *et al.*, 2002). In addition, values of field GCS were found to be highly predictive of arrival GCS scores and both were associated with outcome of HT (Davis *et al.*, 2006).

GCS-E in head injuries. The utility of GCS-E in symptom prediction following HT was demonstrated. Drake *et al.* (2006) showed that in 361 patients with mild HT the longer the PTA duration, the more severe the symptoms experienced during the first weeks after injury (dizziness, depression, cognitive impairments).

Evaluation of risk of aspiration pneumonia

In a study of 224 drug-poisoned patients 14.7% of those having a GCS score > 8 and < 15 had radiographic evidence of aspiration pneumonia. The authors concluded that the risk of aspiration pneumonia should be taken into account even in the presence of high GCS values (Adnet, Baud, 1996).

Measuring the quality of care

The GCS assesses efficiency of care (structures, processes and outcome) (Babhulkar, 1997 ; Bion, 1997) and establishes benchmarks for paramedic airway management success. The initial GCS score was found to have a clear relationship with endotracheal intubation success (Davis *et al.*, 2005).

Limitations

Lack of brainstem reflexes and pupillary response evaluation

The GCS is criticized for failure to incorporate brainstem reflexes which are considered good indicators of brainstem arousal systems' activity. This issue was addressed with the introduction of various scales such as the Glasgow-Pittsburgh coma score (Bozza-Marrubini, 1984), the Comprehensive Level

Table IV

Conditions that affect the calculation of three components of 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		+	
Edema of tongue		+	
Facial trauma		+	
Mutism		+	
Hearing impairments		+	
Injuries (spinal cord, peripheral nerves, extremities)			+
E : Eye, V : Verbal, M : Motor			

of Consciousness Scale, the Maryland Coma Scale (Sternbach, 2000) and the Glasgow Liège Scale which was developed in 1982 (Laureys *et al.*, 2002). The latter combined the GCS with five brainstem reflexes (pupillary, fronto-orbicular, oculocardiac, horizontal and vertical oculocephalic) (Laureys *et al.*, 2002). In addition, the GCS does not incorporate the size and reactivity to light of patients' pupils. This would be certainly helpful, since a dilated pupil or unequal pupils not reacting to light suggest temporal lobe herniation (Iankova, 2006 ; Lowry, 1998).

Pain stimulation

The stimulation techniques are of outmost importance. Various modifications of the anatomical location of pain application have been tested : earlobe, sternum, supraorbital ridge, finger nailbed, retromandibular and trapezius regions. The literature suggests that pressure of the finger nailbed with a pencil as was first proposed by Teasdale and Jenett (1974, 1976) falsely lowers the level of responsiveness (Prasad, 1996 ; Starmark, Health, 1988).

Clinical obstacles

There are several clinical conditions that have great impact on GCS rating with sedation and intubation being of great importance (Heim *et al.*, 2004 ; Rush, 1997 ; Harrahill, 1996 ; Jennett, Teasdale, 1977 ; Teasdale, Jennett, 1974) (Table IV). Some authors designate a "P" for administration of paralyzing agents, a "S" for administration of sedatives, and a "U" for untestable components (Fischer, Mathieson, 2001). Besides, high blood alcohol concentrations (> 240 mg / 100 ml) were associated with a 2-3 point reduction in GCS. So, neurological assessment should take into account the variable and depressive effects of alcohol (Brickley, Shepherd, 1995). Nevertheless, Stuke *et al.* (2007) did not find a clinically significant impact of blood alcohol on GCS in HT patients. Mechanism of injury (penetrating versus blunt) and age (> 55 versus ≥ 55 years) were found to have a major effect in the predictive value of GCS too (Demetriades *et al.*, 2004).

The problem of intubation

Scoring in intubated patients has been enigmatic (Bruechler *et al.*, 1998). These authors contacted 73 Level I trauma centers and questioned them about GCS scoring in case of intubation. They found that 26% of the trauma centers gave 1 point for verbal component, 23% 3 points for total GCS, 10% 15 points for total GCS and 16% assigned a "T" for verbal component. Other studies mention the pseudoscoring technique, i.e. replacing missing values with an average value of the testable score (Meredith *et al.*, 1998) or assigning a score of 5 if patients seem able to talk, of 3 if there is questionable ability to talk and of 1 if patients are generally unresponsive (Rutledge *et al.*, 1996). With such approaches the contribution of verbal portion to the predictive value of GCS is reduced (Jagger *et al.*, 1983). The non universal application of the verbal scoring techniques may account for the disparity in mortality rates published by different trauma centers (Meredith *et al.*, 1998). Prophetically, Teasdale and Jennett (1974) had stated that the GCS "should not depend on only one type of response because this may ... be untestable".

Statistical implications

The GCS is an ordinal scale (Pickard *et al.*, 2006). The difference between unit values is not consistent and compares only better with worse (Fani-Salek, 1999). Yet, minimal differences of GCS scores are important in terms of prognosis (Bruder, 1997). It is true that the scale incorporates a numerical skew towards motor response, because there are only 4 points for eye response, versus 5 for verbal and 6 for motor responses (Heim, 2004 ; Bhatty, Kapoor, 1993). Summing the three subscales assumes an equal weighting for each one, thus leading to loss of information since the same score can be made up in various ways (Teasdale *et al.*, 1983). Teoh *et al.* (2000) reported that it was possible for patients to have the same total score, but significantly different mortality risks due to differences in the GCS profile making up that score. More specifically, different permutations for total scores of 7, 9, 11 and 14 were correlated with significantly different incidence of mortality. Bastos *et al.* (1993) found that in the intermediate levels of consciousness (GCS scores 7 to 11) the discriminative power of GCS was reduced. But even a low GCS does not always predict the outcome of severe HT. A retrospective study of 79 head injured children admitted to an ICU in Michigan showed that in the absence of ischemic-hypoxic injury, subjects with GCS scores of 3 to 5 could recover independent function (Lieh-Lai *et al.*, 1992). This led Bozza-Marrubini (1984) to consider the total score as "meaningless, like saying that two pounds, three dollars, and three Lire give a monetary value of eight". Yet, Moore *et al.* (2006) studied 20,494 patients of three Level I urban trauma centers and showed that the separate use of the three portions did not improve the predictive ability. It seems that the predictive purpose of the scale is best served by using the three scales separately, while the discriminative one for a series of patients is served better by the total score (Prasad, 1996 ; Teasdale, Jennett, 1974). Prasad (1996) and Worrall (2004) presented strong evidence against summing in the monitoring and evaluation of infants too.

Prediction of mortality

The GCS was worse than APACHE II and III systems in the prediction of late (> 15 days) mortality in 200 neurosurgical patients. The correct prediction was 60% and the Youden index 0.49 (Cho, Wang, 1997). Alvarez *et al.* (1998) reported a better performance of the Mortality Probability Models (MPM II) system in comparison to the GCS in 401 HT patients. Data derived from the German Rescue System showed that GCS scores of 3 to 6 during the first two post-traumatic days did not correspond to the outcome after one year. Moreover, a score of 4, as the best score during the day after the injury, had a poorer long-term prognosis than a score of 3 (Moskopp *et al.*, 1995). In the case of aneurysmal SAH it was proposed to grade patients by the eye-verbal-motor profile which is more informative than the total GCS score (Hirai *et al.*, 1997).

Collectors' experience and the inter-rater variability issue

Teasdale and Jennett (1974) reported a high degree of consistency in eliciting responses by different raters. High degree of inter-rater reliability was shown between registered nurses with experience in use of the scale (Fielding, Rowley, 1990). Another study in a tertiary hospital emergency department found excellent rating agreement between physicians and nurses (weighted kappa > 0.75) for verbal and total GCS scores and intermediate (weighted kappa 0.4 – 0.75) for eye and motor scores. Total GCS differed by more than 2 points only in 9.3% of eligible patients (Holdgate *et al.*, 2006). Rimel *et al.* (1979) found the GCS easy to measure by all members of an emergency medical team, giving reproducible results. Rowley and Fielding (1991) concluded that the GCS was accurately used by experienced users, while inexperienced ones made consistent errors (in some cases more than 1 point on the 4 or 5-point scales) mainly at the intermediate levels of consciousness. While the inter-observer variability between resident and nurse data collectors had minimal effect on APACHE II calculation, Holt *et al.* (1992) found that significant variability may occur in individual patients with an error in GCS calculation reaching 20% ; residents proved to be more accurate data collectors than nurses. Nonetheless, 100 trainees in a French Anaesthesiology Department were shown to be prone to many errors in calculation due to lack of compliance with the principles of scoring (Lenfant *et al.*, 1997). It was also noted that presence of sedation, motor asymmetry, hypotension or hypoxemia did not affect the GCS evaluation. Riechers *et al.* (2005) investigated whether military physicians were familiar with GCS or not. They found that military physicians could state what "GCS" stands for, but were unable to provide the titles of the three subscales and the specific rating of each category. Those in surgical specialties and those with Advanced Trauma Life Support (ATLS) certification outperformed those in medical specialties and those with no training in ATLS. The inter-rater agreement in a prospective observational study at a university Level I trauma center was moderate. When 116 patients were examined by two emergency physicians, only 55% to 74% of paired measurements were identical and 6% to 17% of them were 2 or more points apart. The clinical significance of this observation is that a 1 or 2-point change in GCS may not reflect true changes in neurological status (Gill *et al.*, 2004). Another observational study of 120 subjects evaluated by emergency physicians provided an agreement percentage of 42%. The percentage was higher for eye and motor (71% each) components and lower (60%) for the verbal one (Gill *et al.*, 2007). Interestingly, only 51% of 82 patients referred to a Department of Surgical Neurology had a correct score. Surprisingly, 2.4% of them were referred with a GCS score of less than 3 (Crossman *et al.*, 1998). In a study conducted by Morris (1993) 100 telephone referrals of head injured patients to a Neurosurgery Department were assessed to determine if altered consciousness was adequately described by the referring physician. Only 30% of physicians could use GCS properly and 18% of them were unable to describe accurately altered consciousness. This was more prominent in motor response evaluation mainly due to an inappropriate stimulus selection. Finally, patients with extreme levels of GCS scores (3, 15) have been identified as easy to assess and derive high inter-observer reliability scores (McNett, 2007 ; Worrall, 2004 ; Prasad, 1996).

Poisoning

The GCS use in the assessment of the acutely poisoned patient should not be recommended. For example, after an ingestion of gamma hydroxybutyrate many patients will not require intubation even with a GCS score of 3 if adequate ventilation and oxygenation are maintained (Fulton *et al.*, 2005).

Future trends concerning the GCS application

General considerations

Undoubtedly, a reliable coma scale could reach empirically based estimates of prognosis only if two criteria are fulfilled : (a) the level of consciousness is defined by all and only the most powerful prognostic indicators ; (b) the time factor is considered, setting the onset of the observation period after the correction of all causes of transient initial deterioration, since coma is a dynamic and not static condition (Bozza-Marrubini, 1984). One should keep in mind that differences between hospital units and diagnostic groups underline the possible effect of case mix in the predictive ability of prognostic scoring systems (Livingston *et al.*, 2000).

Research goals

Research will have to overcome all the aforementioned drawbacks. Further prospective data collection is in need in order to face the issues of missing data and non representative samples (Gabbe *et al.*, 2003). In the published outcome prediction studies the majority of patients have extremely high scores, a smaller group has a GCS of 3 and only a minority has scores in the midrange, where prediction is the most difficult (Sternbach, 2000). It is these midrange values that are thought to present different reliability than those at the extremes (3, 15), thus affecting the accurate outcome prediction (Rutledge *et al.*, 1996). Obviously, GCS values are ordinal scale data (Pickard *et al.*, 2006). Parametric statistical analysis should be performed only after testing for normality, since in the majority of cases these data are not normally distributed (Gaddis, Gaddis, 1994). However, Lucke (1996) proved that violation of normality of GCS scores' distribution had little effect on the Type I error rate, especially if equal sample sizes were used. Further validation of the GCS is also necessary by comparing ratings from different observers and expert ones, mainly in patients belonging in the intermediate levels of consciousness (Rowley, Fielding, 1991). Walther *et al.*, (2003) found that the APACHE II probability of death estimation was associated with minimal bias when GCS was replaced by RLS. So, rating cerebral responsiveness with RLS is thought to deserve more extensive evaluation as well.

Summing or not ?

It seems that assessment of individual patients will be performed in terms of findings on the three separate subscores, not in terms of their sum (Teasdale, Murray, 2000). Bhatty and Kapoor (1993) suggested the weighting of individual scores for the three responses, so that each one will have a maximum contribution of 5 points and a minimum of 1. While the three subscales carry unique clinical information, it appears that the motor component is the best predictor of short term outcome, thus reducing the variability which is inherent in summing three separate components (Jagger *et al.*, 1983). Healey *et al.* (2003) studied 204,181 trauma patients and found the motor component linearly related to survival, preserving almost the entire predictive power of total GCS and easily measured in intubated patients. Moreover, a modified GCS motor response was introduced in 2005, assigning 2 points for following commands, 1 point for movement but not following commands and 0 points for no movement. This modification could be of considerable practical value (Eftekhar *et al.*, 2005).

The role of regression models

Regression models will continue to be derived. Meredith *et al.* (1998) published a first order multiple linear regression equation to predict the verbal score from the ocular and motor ones and then calculate an accurate total GCS score. They reported a mean actual GCS score of 13.6 ± 3.5 versus a mean estimated GCS score of 13.7 ± 3.4 (Pearson's $r = 0.97$, $p = 0.0001$). Another study using a second order multiple regression equation reported a mean actual verbal score of 4.2554 ± 1.3939 versus a mean estimated verbal score of $4,2514 \pm 1.2629$ (Pearson's $r = 0.9179$, $p = 0.001$). In the same study a third order equation was also presented. Since all these equations are clinically difficult to apply, constructions of tables to facilitate the calculation of a predicted verbal score given the eye and motor scores is advised (Rutledge *et al.*, 1996). Yet, authors state that the post hoc integration of a system that tries to estimate data points that were not available during initial derivation of severity of disease systems (for example the APACHE system) is under question (Chesnut, 1997).

Prehospital evaluation of HT

Standard methods should be developed for the assessment of initial GCS scores (Marion, Carlier, 1994). Batchelor and McGuiness (2002) demonstrated that patients with a GCS score of 15 can be further stratified into four risk categories based upon their symptoms (vomiting, nausea, headache, blurred vision, dizziness). This comment is of value since total GCS score is insensitive in defining this heterogeneous subgroup. A retrospective analysis of 3,235 injured adults transported to a Level I trauma center concluded that the motor component was equivalent to GCS for prehospital triage and due to its simplicity it could replace GCS in triage schemes (Ross *et al.*, 1998). However, Bruder (1997) mentions that GCS scoring before patient reaches hospital should not be taken into consideration. Further incorporation of the 8-point GOS-E scale in studies analyzing outcome in patients with HT would be useful (Teasdale *et al.*, 1998).

Recommendations

As means of improving referral and enhancing audit in patients with HT, researchers propose the use of a pictorial guide to motor responses, under- or postgraduate training of physicians in evaluating altered consciousness, and training video tapes from Neurosurgical Departments demonstrating standard examination methods and typical responses (Morris, 1993).

Conclusions

The GCS carries valuable information about the neurological status of patients and constitutes an element of surveillance of their evolution. Yet, by no means should it replace a thorough neurological examination. The same is true for a number of other tools to assess level of consciousness that have been brought forward the previous years. Nonetheless, none of these seems able to replace the GCS. Moreover, even though it was designed for the evaluation of severe HT, the GCS is currently used in assessment of coma due to any etiology. However, full knowledge of this scale's strengths and limitations is essential in order to assure its proper use. Above all, uniform scoring is imperative and should be pursued. That would benefit both physicians and their patients.

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Georgios K. MATIS,
1st Emmanouil Roidi Rd,
54248 Thessaloniki (Greece).
E-mail : gkmatis@yahoo.gr