

# Behavioral evaluation of consciousness in severe brain damage

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**Abstract:** This paper reviews the current state of bedside behavioral assessment in brain-damaged patients with impaired consciousness (coma, vegetative state, minimally conscious state). As misdiagnosis in this field is unfortunately very frequent, we first discuss a number of fundamental principles of clinical evaluation that should guide the assessment of consciousness in brain-damaged patients in order to avoid confusion between vegetative state and minimally conscious state. The role of standardized behavioral assessment tools is particularly stressed. The second part of this paper reviews existing behavioral assessment techniques of consciousness, showing that there are actually a large number of these scales. After a discussion of the most widely used scale, the Glasgow Coma Scale, we present several new promising tools that show higher sensitivity and reliability for detecting subtle signs of recovery of consciousness in the post-acute setting.

## Introduction

The evaluation of consciousness in severely brain-damaged patients is of major importance for their daily management. Consciousness is a multifaceted concept that, in a simplified manner, can be divided into two major components: the *level* of consciousness (i.e., arousal, wakefulness or vigilance) and the *content* of consciousness (i.e., awareness of the environment and of the self) (Plum and Posner, 1983). Arousal is supported by numerous brainstem neuronal populations (previously called reticular activating system) that directly project to both thalamic and cortical neurons (see Fig. 1).

Therefore, depression of either brainstem or global hemispherical function may cause reduced wakefulness. Awareness is thought to be dependent upon the functional integrity of the cerebral cortex and its reciprocal subcortical connections; each of its many aspects resides to some extent in anatomically defined regions of the brain.

Unfortunately, for the time being, consciousness cannot be measured objectively by any machine. Its estimation requires the interpretation of several clinical signs. Many scoring systems have been developed for the quantification and standardization of the assessment of consciousness. The present paper will discuss the strengths and pitfalls of a behavioral assessment of consciousness in patients, with a special focus on patients in a vegetative state, and discuss new promising assessment tools. Neurophysiological assessment of consciousness as well as the prognostic value of assessment in patients with impaired consciousness will not be

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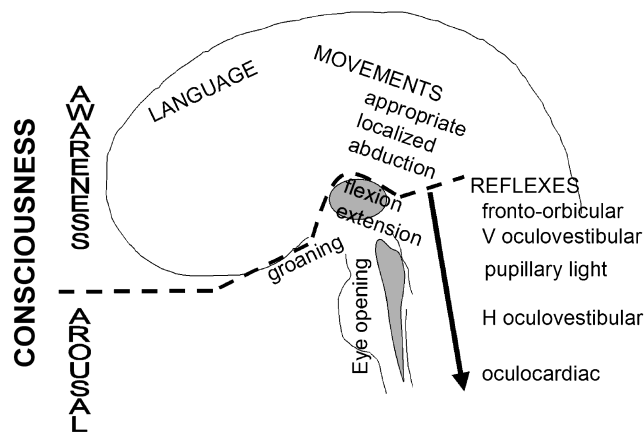


Fig. 1. A simplified scheme of consciousness and its two major components: arousal and awareness. *Note:* the gray area represents the reticular activating system encompassing the brainstem and thalamus; the arrow near the brainstem denotes the progressive disappearance of brainstem reflexes during rostral-caudal deterioration (i.e., evolution from coma to brain death). V = vertical; H = horizontal. (Reproduced with permission from Laureys et al., 2002.)

considered here as they are the issue of other papers in this volume (see Kotchoubey; Guerit; Jennett this volume).

### Clinical evaluation of consciousness

Arousal and awareness are not on-off phenomena but are part of a large continuum. At the bedside, arousal is assessed by the presence of spontaneous or stimulation-induced eye opening. It ranges from *coma* (no eye opening), *stupor* (eye opening following vigorous external stimuli), through *sleep* (eye opening following moderate external stimuli) and alert *waking* (spontaneous eye opening). Awareness refers to the collective thoughts and feelings of an individual. Clinically, we are limited to the appraisal of the patient's capacity to perceive the external world and to voluntarily interact with it (i.e., perceptual awareness). In practice, this is evaluated by careful and repeated examination of the capacity to formulate reproducible, voluntary, purposeful and sustained behavioral responses to auditory, tactile, visual or noxious stimuli (e.g., by asking the patient to follow command, to visually discriminate between Yes/No cards by pointing or eye movements). Much more difficult is the evaluation of patients' self-recognition in a mirror; this can be done by putting a mark (colored versus invisible) on the patient's face and by determining

whether the patient will touch this mark when being shown his face in a mirror (Gallup, 1997). Obviously, the patient needs to be well aroused in order to perform the cognitive processes required for awareness. Hence, patients in a coma are unaware because they cannot be aroused. However, as illustrated by patients in a *vegetative state*, arousal is only a necessary and not a sufficient condition for awareness. Indeed, patients in a vegetative state are aroused (as shown by preserved spontaneous eye opening and sleep-wake cycles) but show no sign of awareness (i.e., no sign of command following or any other voluntary behavior). When the first signs of voluntary behavior appear, the patient may be in a *minimally conscious state*: here the patient is partially conscious, as evidenced by the presence of limited but reproducible signs of awareness (inconsistent command following, inconsistent but intelligible verbalization, sustained visual fixation, localization of sound and noxious stimuli) (Giacino et al., 2002; Giacino and Whyte, 2005; Giacino, this volume).

### Diagnosing and misdiagnosing signs of consciousness

The diagnosis of the vegetative state depends on behavioral assessment of the responses obtained from the patient. It is not a pathological or even

neuro-physiological diagnosis. While there have been exciting developments in the use of functional MRI (Magnetic Resonance Imaging) scanning (see Schiff, this volume; Owen, this volume), brain mapping and other neuro-physiological approaches (see Kotchoubey, this volume; Guerit, this volume) these are primarily aids to diagnosis rather than a method of diagnosis. Consider, for instance, the patient whose neuro-physiological investigations suggest that there is some integrated “higher-level” cerebral function in response to stimulation — but where there is no behavioral evidence that the person is aware of his environment — who shows no evidence of communication or understanding of what others are communicating with him. Where does that leave the patient, the family and the caring team? While it might incite to reexamine the clinical responses and strive harder to demonstrate any awareness, if the patient continues with no meaningful responses and remains clinically vegetative, then we would argue that the patient is in the vegetative state.

This, however, does lead us on to questioning how sensitive our clinical-behavioral assessments are. Giacino and Zasler (1995) have pointed out the limitations of clinical assessment in the identification of “internal awareness” in a patient who otherwise lacks the motor function to demonstrate his awareness. The concept that we are only able to *infer* the presence or absence of conscious experience is a long-standing philosophical issue, which has been pointed out by Bernat (1992) and The Multi-Society Task Force (1994) in the specific context of the vegetative state. The International Working Party on the Vegetative State (Andrews, 1996) discussed this point in detail and criticized the use of the term “meaningful response” on the grounds that it requires a considerable amount of subjective interpretation on the part of the observer and that what was meaningful for the patient may not be considered meaningful by those treating the patient. Similarly the term “purposeful response” was criticized because of the subjective interpretation and that a withdrawal reflex could be considered as purposeful in that it removes the limb, for instance, from danger.

This is where there must be some concern. For instance there are several studies that have

described the misdiagnosis of the vegetative state. In a group of long-term patients in a nursing home in the USA, Tresch et al. (1991) found that 18% of those diagnosed as being in the persistent vegetative state were aware of themselves or their environment. Childs et al. (1993) report that 37% of patients admitted more than 1 month post-injury with a diagnosis of coma or persistent vegetative state had some level of awareness. In another study (Andrews et al., 1996), 43% of patients admitted to a profound brain injury unit at least 6 months following their brain damage (i.e. could be expected to be stable) were found to have been misdiagnosed. While these figures cause concern they at least emphasize that bedside diagnosis was possible — otherwise they would not have been identified as having been misdiagnosed.

So why are patients misdiagnosed? One striking finding was that 65% of the “misdiagnosed” patients were either blind or very severely visually impaired in the form of marked visual field defects and/or visual perceptual disorders (Andrews et al., 1996). This has obvious implications for assessment since one of the prime features for assessing whether a patient is non-vegetative is eye tracking. If the patient has visual impairment, then he will not follow objects and therefore eye tracking will be absent even in a mentally alert individual.

Since all patients followed verbal commands, it is assumed that none were deaf or had severe hearing impairment. This, however, is a possibility and should be considered. This also emphasizes the importance of assessing a wide range of stimuli (touch, taste and smell as well as visual or auditory), a range of frequent observations with standardized assessment tools and optimal patient management (e.g., with the patient in seating position) to ensure that disturbance of one modality is not the cause of missing evidence of awareness.

### *Making the diagnosis of vegetative state*

Previous studies have shown that misdiagnosed “vegetative” patients were at the “severe” level of the Glasgow Outcome Scale (Jennett and Teasdale, 1977), being totally physically dependent for all care needs (Andrews et al., 1996). The only

method that any of us can use to demonstrate our awareness to others is through some form of motor activity — speech, facial expression, eye-tracking, limb movement, shrugging shoulders, nodding-shaking the head, etc. For 88% of the patients, pressing a buzzer was the only functional movement, although one patient later developed an ability to point with a finger and another patient became able to write words; the other two patients communicated by eye pointing (Andrews et al., 1996).

The importance of physical function was dramatically demonstrated by one patient where responses were not identified until 25 weeks after admission, though it was obvious from subsequent conversations with him that he had not been vegetative for some time. This patient was admitted with very severe joint contractures, which required surgical release and a prolonged physical management program before he could be seated appropriately in a special seating system. Only when he was satisfactorily seated was sufficient muscle tone released for him to indicate with a slight shoulder shrug that he was aware — he was able to carry out simple mental mathematical calculations and was aware of his immediate physical and social environment (Andrews et al., 1996).

Another difficulty is the relevance of the blink response to awareness. The patient may blink to menace but appear not to be attentive. Note that at least one authority (Working Group of the Royal College of Physicians, 1996) has regarded a blink to threat as evidence of cortical connection and therefore indicating that the patient is not vegetative. This is a very questionable approach since the concept of the vegetative state is the demonstration of *awareness*, and not of whether there are some cortical connections. The Multi-Society Task Force (1994) urges *caution* in making the diagnosis of the vegetative state if there is blinking to threat but does not go as far as to claim that if present that it indicates that the patient is no longer vegetative. Actually one of the difficulties is taking too little notice of the blink response — or more relevantly the speed of the blink response. Often too little time is given to waiting for the response. There is often a delay between stimulation and response when there is awareness, as though the

brain was having to work out the response to give. Of course, this leads to the problem of how long to wait and the risk of spontaneous blinking being interpreted as a volitional response. This requires a considerable amount of experience to interpret. One clue is that the blink is often of a different quality to reflex blinking — either in the slowness of the blink or the length of time the eye is kept closed. As noted by Whyte and others, differentiation of spontaneous eye blinks from those that are purposeful can be done by systematically recording eye-blinks under different conditions (e.g., at rest, to inappropriate command, to appropriate command) and statistically determining whether the frequency of the response is significantly higher following administration of the appropriate command, relative to the other conditions (see, e.g., Whyte and DiPasquale, 1995).

There are, of course, other signs that may cause a misdiagnosis that the patient is aware when in fact the responses are reflex in nature. For instance, there may be roving eye movements and the patient's eyes may seem to briefly follow moving objects. The movement is usually inconsistent and never sustained. For instance, the patient's eyes may turn toward a sound or a sudden movement but does so only briefly and does not focus on the source of stimulation. This can catch out the unwary who interpret this as awareness. What is probably happening is that the subcortical centers that alert the brain to incoming stimuli, e.g., the superior colliculi for vision and the thalamus for tactile sensations, are still active but the alerting mechanism does not reach “higher level” cortical interpretation. This situation is seen, for instance, in cortical blindness where although the visual cortex is damaged the patient will still turn toward a visual stimulus even though he cannot “see” it.

Some staff and family interpret the withdrawal response as being an indication that the patient is aware of the noxious stimulus. It would be more relevant if the patient pushed away the stimulus. Another confusing feature for many carers is the non-volitional grasp reflex. This can cause considerable concern to relatives or carers who feel that the patient recognizes them when they hold his hand. This is particularly reinforced when the grip

tightens as there is an attempt to pull the hand or fingers away. This is supportive of the diagnosis of a grasp reflex rather than supportive of a meaningful response.

What can be even more confusing are the fragments of coordinated movement, such as scratching or even moving hands toward a noxious stimulus. These must always be taken seriously as indicating awareness but do occur in the vegetative patient usually affecting the same repetitive movement on each occasion. They are probably long-learned automatic response activities. However, scratching oneself on different locations depending on the irritant's source would be indicative of a minimally conscious state.

Chewing movements or grinding of teeth (to which can be added constant movement of the tongue) again cause concern to relatives and carers feeling that the patient is indicating that he is thirsty or hungry. Grunting and groaning provoked by noxious stimuli can also often be interpreted as indicating an attempt to communicate. This can cause disagreement between family and clinicians when some relatives claim to be able to "understand" the words spoken when others only hear sounds. These are, however, commonly found features in the vegetative state. The skill is to decide whether the responses are contingent on the quality of the external stimulus.

### ***Factors influencing the diagnosis***

The International Working Party (Andrews, 1996) pointed out that the assessments in general use are based on a series of behavioral patterns. The clinician is, therefore, dependent on overt responses that depend on a number of factors including:

- a. The physical ability of the patient to respond — this has been discussed above.
- b. The desire or willingness (if the patient is aware) of the patient to respond. It is not unusual for members of the family to obtain responses that the professional members of the team are not able to. This is probably not surprising since the members of the family are more likely to be "sensitive" to the responses seen. On the other hand, the family may be

desperate for a response and easily misinterpret the reflex responses. Patients may also be more willing to respond to family or to some members of the staff rather than to others. Let us face facts — some staff are better at relating than others.

- c. The ability to observe accurately. This is particularly relevant since profound brain damage is a rare condition and few professionals have seen sufficient patients to have gained that level of experience required to produce "expertise".
- d. The time available for observation and assessment. Time is one of the major factors in assessing the profoundly brain-damaged patients. They do not conveniently have their best levels of awareness at the time set aside for the formal assessment. This requires flexibility of the assessor to take advantage of the windows of opportunity and to take advantage of the observations of other members of the team and members of the family.
- e. The lack of available and reliable assessment tools. It is not so much that there is a shortage of tools — see discussion below — but that they are not used in more general acute, or even neurological or rehabilitation, units.
- f. The patient is not always seen by a skilled team to address all of these issues.
- g. The family and carers and those who know the patient best are not always involved as much as they should be.
- h. Patients are assessed by some assessors who are unfamiliar with the patient — leading to meaningful responses being missed.

There are several principles to the accurate assessment of the person thought to be in the vegetative state:

1. That the patient should be healthy. Even simple conditions such as constipation, chronic urinary tract infection (usually associated with long-term catheterization) or bronchial infections can prevent optimal responses from being obtained.
2. The patients should be in a good nutritional state. The earlier use of gastrostomy feeding has altered this pattern but still some patients

admitted from general units have a low Body Mass Index, emphasizing the difficulty in managing people with such complex medical and physical disabilities.

3. As many sedating drugs as possible should be withdrawn, or at least decreased to the lowest effective dose — these include antispasticity drugs and antiepileptic drugs. In the case of antiepileptic drugs, which are still required to control fitting, drugs with the least sedative effect should be used.
4. Complications and consequences of neurological imbalance should be prevented — this includes high muscle tone and contractures by the provision of special seating, good bed and sitting posture to control abnormal muscle tone. These complications in the long term increase the amount of nursing care required, which, since the patient may live for many years, increases the cost of care considerably.
5. Controlled posture is important. Most doctors have been trained to examine patients on the bed. Experience suggests that patients are more likely to be alert when sitting up (presumably due to greater stimulation of the ascending reticular activating system). A well-supporting seating system is essential to reduce sufficient muscle tone to allow movement of limbs that can be used for communication purposes, e.g. to press a touch-sensitive switch.
6. Providing a controlled environment of sensory *regulation* to avoid sensory overload of the severely damaged brain. Since it is likely that profoundly brain-damaged patients have problems with selective attention, sensory input should be simple and interspersed with periods of rest. It is, therefore, logical to assess for cognitive responses after a period of rest rather than after a period of activity, such as being washed and dressed or after physiotherapy. This requires staff and family to understand the importance of avoiding over-stimulation prior to the assessment.
7. Assessments should be short (to avoid tiring the patient), repeated (to identify windows

of opportunity) and over a prolonged period of time (to accommodate the learning process of both the patient and the assessor). One-off short assessment of the patient who is lying in bed is likely to result in a missed diagnosis even by the most experienced clinician.

8. The ability to generate a behavioral response fluctuates from day to day and hour to hour, and even minute to minute, depending on fatigue factors, general health of the patient and the underlying neurological condition.
9. Observation needs to take into account delayed responses. Assimilation of even basic information is often slow and therefore response time may be delayed. Because of this, information provided at any one time should be simple, consistent, repeated after a period of rest, and allow for a delayed response.
10. Communication requires skilled techniques and sensitivity for the method by which the patient wants to communicate.
11. Families and other carers have a very important role in identifying the best responses and the optimal conditions for assessment. While there are some relatives who interpret reflex responses as being meaningful, there is no doubt that members of the family are often more sensitive to early changes than even very experienced clinical staff.

### Consciousness scales

There are many scales designed to monitor the recovery of consciousness in brain-damaged patients. In this section, we will first address the Glasgow Coma Scale (GCS), which remains the most widely used scale in the acute and subacute setting. We will then review other existing tools, by focusing more specifically on three new and promising assessment instruments, the Coma Recovery Scale-Revised (CRS-R; Giacino et al., 2004), the Wessex Head Injury Matrix (WHIM; Shiel et al., 2000), and the Sensory Modality Assessment and

Rehabilitation Technique (SMART; Gill-Thwaites, 1997, 1999).

### *Glasgow coma scale*

Teasdale and Jennett (1974) developed the GCS as an aid in the clinical assessment of post-traumatic unconsciousness. It was devised as a formal scheme to overcome the ambiguities that arose when information about comatose patients was presented and groups of patients compared. The GCS has three components: eye (E), verbal (V) and motor (M) response to external stimuli (see Fig. 2). The scale consisted of 14 points, but was later adapted to 15, with the division of the motor category "flexion to pain" into two further categories. The best or highest responses are recorded. So far, more than 2390 publications have appeared to its use (MEDLINE search performed in February 2005, limited to title and abstract word). It is a component of the Acute Physiology and Chronic Health Evaluation (APACHE) II score, the (Revised) Trauma Score, the Trauma and Injury Severity Score (TRISS) and the Circulation, Respiration, Abdomen, Motor, Speech (CRAMS) Scale, demonstrating the widespread adoption of the scale.

The observation of spontaneous eye opening "indicates that the arousal mechanisms of the brainstem are active" (Teasdale and Jennett, 1974). As previously stated, recovered arousal does not imply the recovery of awareness. Patients in a vegetative state have awakened from their coma but remain unaware of their environment and self. Most comatose patients who survive will eventually open their eyes, regardless of the severity of their cerebral damage (Jennett, 1972). Indeed, less than 4% of head-damaged patients never open their eyes before they die (Bricolo et al., 1980). The eye opening in response to speech tests the reaction "to any verbal approach, whether spoken or shouted, not necessarily the command to open the eyes" (Teasdale and Jennett, 1974). Again, this response is observed in the vegetative state where "awakening" can be induced by non-specific auditory stimulation. In these patients, it is recommended to differentiate between a

reproducible response to command and to non-sense speech. Eye opening in response to pain should be tested by stimulation at the level of the limbs, because the grimacing associated with supraorbital or jaw-angle pressure may cause eye closure.

The presence of verbal responses indicates the restoration of a high degree of interaction with the environment (i.e., awareness). An oriented conversation implies awareness of the self (e.g., the patient can answer the question: "What is your name?") and environment (e.g., the patient correctly answers the questions: "Where are we?" and "What year/month is it?"). Confused speech is recorded when the patient is capable of producing language, for instance phrases and sentences, but is unable to answer the questions about orientation. When the patient presents intelligible articulation but exclaims only isolated words in a random way (often swear words, obtained by physical stimulation rather than by a verbal approach), this is scored as "inappropriate speech". Incomprehensible sounds refer to moaning and groaning without any recognizable words. This rudimentary vocalization does not necessitate awareness and is thought to depend upon subcortical functioning as it can be observed in anencephalic children and vegetative patients.

The motor response first assesses whether the patient obeys simple commands, given in verbal, gestural or written form. A non-specific sound stimulus may induce a reflex contraction of the patient's fingers or alternatively such a reflex response can result from the physical presence of the examiner's fingers against the palm of the patient (i.e., grasping reflex). Before accepting that the patient is truly obeying commands, it is advised to test that the patient will also release and squeeze again to repeated commands. If there is no response a painful stimulus is applied. First, pressure is applied to the fingernail bed with a pencil. If flexion is observed, stimulation is then applied to other sites (applying pressure to the supraorbital ridge, pinching the trapezium or rubbing the sternum) to differentiate between localization (i.e., a noxious stimulus applied at more than one site causes a limb to move so as to attempt to remove it by crossing the midline), withdrawal flexion (i.e., a

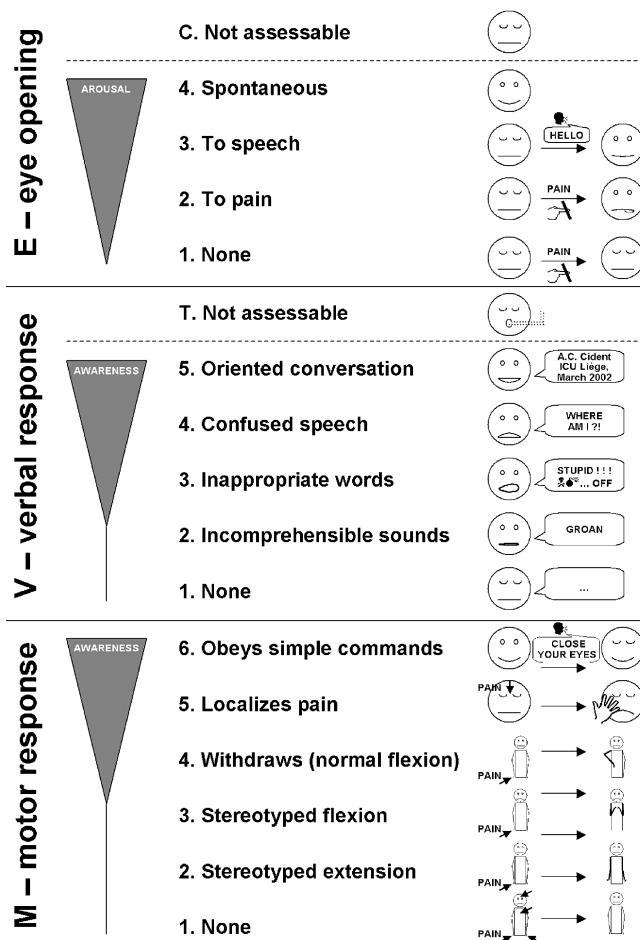


Fig. 2. Pictographic representation of the Glasgow Coma Scale (Teasdale and Jennett, 1974). (Reproduced with permission from Laureys et al., 2002.)

rapid flexion of the elbow associated with abduction of the shoulder) or “abnormal” flexion (i.e., a slower stereotyped flexion of the elbow with adduction of the shoulder that can be achieved when stimulated at other sites). Stereotyped flexion responses are the most common of the motor reactions observed in severely brain-injured patients; they are also the most enduring (Born, 1988). Extensor posturing is more easily distinguished and is usually associated with adduction, internal rotation of the shoulder and pronation of the forearm. Abnormal flexion and extension motor responses often co-exist (Bricolo et al., 1977). The scale of responses to pain is applicable to the movements

of the arms. The movements of the legs are not only more limited in range, but may take place on the basis of a spinal withdrawal reflex (e.g., in brain death, a spinal reflex may still cause the legs to flex briskly in response to pain applied locally (Ivan, 1973; Saposnik, 2000)).

Much too often the three components of the GCS (E–V–M) are summed into a total score, ranging from 3 to 15. However, given the increased use of intubation, ventilation, and sedation of patients with impaired consciousness (Marion and Carlier, 1994), patients might wrongly be scored as GCS 3/15 rather than being more appropriately reported as impossible to score. In a European



multi-centric study of head-injured patients, assessment of each of the three components of the GCS was possible only in 56% on arrival in the neurosurgical unit, and in 49% in the “post-resuscitation” phase (Murray et al., 1993). In Glasgow, patients are always described by the three separate responses and never by the total (Teasdale et al., 1983).

### *Glasgow Liège scale*

A frequently expressed reservation regarding the GCS is its failure to incorporate brainstem reflexes. A number of investigators have disagreed with Teasdale and Jennett that spontaneous eye opening is sufficiently indicative of brainstem arousal systems activity and have proposed coma scales that include brainstem responses (Segatore and Way, 1992). Many coma scales that include brainstem indicators have been proposed (e.g., the Comprehensive Level of Consciousness Scale (CLOCS, Stanczak et al., 1984), the Clinical Neurologic Assessment Tool (Crosby and Parsons, 1989), the Bouzarth Coma Scale (Bouzarth, 1968), the Maryland Coma Scale (Salcman et al., 1981)...) but none has become widely used. These scales generally have been more complex than the GCS.

A simpler system is the Glasgow Liège Scale (GLS) (see Fig. 3). It was developed in 1982 in Liège and combines the Glasgow Scale with a quantified analysis of five brainstem reflexes: fronto-orbicular, vertical oculo-cephalic, pupillary, horizontal oculo-cephalic and oculo-cardiac (Born et al., 1982). The fronto-orbicular reflex is considered present when percussion of the glabella produces contraction of the orbicularis oculi muscle. The oculo-cephalic reflexes (doll’s head) are scored as present when deviation of at least one eye can be induced by repeated flexion and extension (vertical) or horizontal neck movement (horizontal). If the reflexes are absent or cannot be tested (e.g., immobilized cervical spine), an attempt is made to elicit ocular motion by external auditory canal irrigation using iced water (i.e., oculo-vestibular reflex testing). With cold-water irrigation of the head at 30° elevation from the horizontal, the eyes deviate tonically toward the ear irrigated (horizontal). When cold water is injected simultaneously into both ear canals,

the eyes deviate tonically downward; the reverse occurs with bilateral irrigation of warm water (vertical). The oculocardiac reflex is scored as present when pressure on the eyeball causes the heart rate to slow down. As for the GCS, the best response determines the brainstem reflex score (R). The selected reflexes disappear in descending order during rostral-caudal deterioration. The disappearance of the last, the oculo-cardiac, coincides with brain death.

### *Pitfalls encountered when administering the GCS/GLS*

Inexperienced or untrained observers produce unreliable scoring of consciousness (Rowley and Fielding, 1991). In one study, one out of five health care workers were mistaken when asked to make judgments as to whether patients were “conscious” or “unconscious” (Teasdale and Jennett, 1976). Consciousness needs considerable skill to evaluate and the observer should be aware of the pitfalls. It is also well known that the preceding score of the patient frequently influences the examiner when rating the patient’s present state of consciousness. It is therefore recommended to score in a “blinded” manner. Problems arise when the eyes are swollen shut (e.g., following periorbital edema, direct ocular trauma or facial injury) or paralyzed (e.g., neuromuscular blockade). In these circumstances the enforced closure of the patient’s eyes should be recorded on his chart by marking “C” (= eyes closed) (Teasdale, 1975). In deep coma, flaccid eye muscles will show no response to stimulation yet the eyes remain open if the lids are drawn back. Speechlessness may be due to causes other than unawareness (e.g., intubation via the oropharynx or through tracheostomy, orofacial fractures, edematous tongue, foreign language, aphasia, confusion or delirium). The evaluation of verbal responses is also biased when patients received sedatives or neuromuscular blocking agents, alcohol or are drug intoxicated or too young to speak. When the verbal score cannot be assessed a non-numerical designation of “T” (= intubated) should be used (Marion and Carlier, 1994) and the total GCS score cannot be reported. Finally, motor responses cannot be reliably monitored in the presence of splint or immobilization devices or in cases of spinal cord, plexus or peripheral nerve injury. As

## R – brainstem reflexes

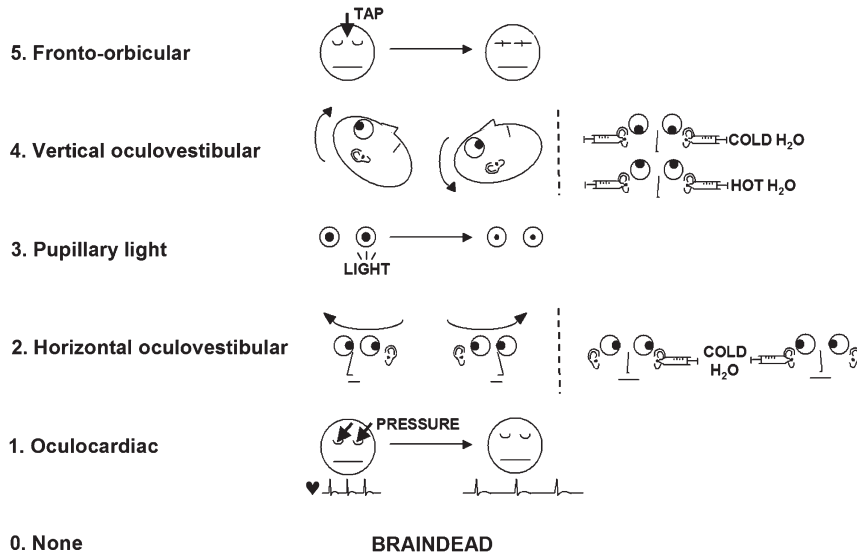


Fig. 3. Pictographic representation of the Glasgow-Liège Scale GLS; (Born et al., 1982). *Note:* when oculocephalic reflexes (doll's eyes) cannot be tested or are absent, the (vertical and horizontal) oculovestibular reflexes (ice water testing) should be evaluated. (Reproduced with permission from Laureys et al., 2002.)

is the case for all scoring systems, awareness is assessed as the level of obeying commands. This approach cannot be applied to cases where the patient is clinically or pharmacologically paralyzed yet alert (e.g., locked-in syndrome, severe polyneuropathy or use of neuromuscular blocking agents) or those with psychogenic unresponsiveness. It is important to stress that special effort should be made to identify and exclude these rare causes of pseudo-coma. In patients with brainstem lesions the diagnosis of "locked-in" syndrome should always be excluded. Locked-in patients suffer from quadriplegia and anarthria caused by a disruption of corticospinal and corticobulbar pathways, respectively. Their only means of expressing their thoughts and feelings is through vertical or lateral eye movement or blinking of the upper eyelid to signal (also see Laureys et al., this volume).

### *New promising tools: the CRS-R, SMART and the WHIM*

Following the acute stage, when patients are recovering from their coma, the GCS becomes less

reliable in monitoring consciousness (Segatore and Way, 1992). Here, a large number of alternative behavioral assessment tools of consciousness have been proposed (see also Horn et al., 1993; Majerus et al., 2000a; Canedo et al., 2002; Giacino and Whyte, 2005). For example, Majerus et al. (2000a) identified more than 20 different scales. However, only a few of them are really better alternatives than the GCS/GLS scales. Some alternative scales are mainly variants of the GCS scale (e.g., CLOCS, Stanczak et al., 1984; Benzer et al., 1991). Other tools are simple rating scales that classify the level of consciousness displayed by a patient in rather broad categories (see, e.g., Ommaya, 1966; Hagen et al., 1979; Stalhammar et al., 1988). These scales (although trying to explicitly answer the question whether the patient is aware or not by providing labels that are supposed to qualify the patient's level of consciousness) do not cover a broad range of behaviors nor do they provide explicit guidelines for the systematic observation of the patient's behavior. A far more limited number of scales have been designed to detect more subtle changes in awareness through a thorough, systematic, precisely defined

and reliable observation of the patient's behaviors. These scales are supposed to be more sensitive than previous scales as they include a much larger number of items (e.g., Davis, 1991; Giacino et al., 1991; Coma/Near Coma Scale; Rappaport et al., 1992; Visual Response Evaluation, Coma Exit Chart, Freeman, 1996; CRS, Giacino et al., 2004). However, it must be noted that studies specifically aimed at providing empirical evidence for this theoretically superior sensitivity are often lacking.

The CRS-R by Giacino et al. (2004) is a good example of those scales providing a more fine-grained assessment of the recovery of consciousness. The basic structure is similar to the GCS; it includes similar visual, motor and verbal subscales as the GCS, but there are in addition three other scales: an auditory function scale, a communication scale and an arousal scale (see Table 1). Furthermore, the visual, motor and verbal subscales are much more detailed than is the case in the GCS. For example, the visual subscale assesses visual startle responses, eye fixation, eye movement, visual object localization, and object recognition. These items are critical for identifying subtle signs of recovery of consciousness as discussed in the previous sections. Furthermore, for each item, fully operational definitions are provided and special importance is given to the consistency of behaviors assessed via the establishment of baseline observations and repeated administration of the item. This two-step procedure (baseline observation followed by repeated administration of a given item) permits greater certainty that a given behavior is not simply random or reflex, but that it is contingent upon a given stimulus. Inter-rater agreement and test-retest reliability are high for total CRS-R scores, and good concurrent validity is observed in relation to other scales such as the CRS and the Disability Rating Scale (Giacino et al., 1991, 2004, this volume). Furthermore, the CRS-R has been designed to be particularly helpful for discriminating between vegetative and minimally conscious state. As can be seen in Table 1, a number of specific items are proposed that should permit discrimination between vegetative and minimally conscious state (e.g., the observation of item 2 (fixation for more than 2 sec) on the visual function scale is supposed to be incompatible with a diagnosis of vegetative state but supports a diagnosis of minimally conscious state).

Table 1. JFK coma recovery scale — revised

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<i>Auditory function scale</i>	
4	— Consistent movement to command <sup>a</sup>
3	— Reproducible movement to command <sup>a</sup>
2	— Localization to sound
1	— Auditory startle
0	— None
<i>Visual function scale</i>	
5	— Object recognition <sup>a</sup>
4	— Object localization: reaching <sup>a</sup>
3	— Pursuit eye movements <sup>a</sup>
2	— Fixation (>2 sec) <sup>a</sup>
1	— Visual startle
0	— None
<i>Motor function scale</i>	
6	— Functional object use <sup>b</sup>
5	— Automatic motor response <sup>a</sup>
4	— Object manipulation <sup>a</sup>
3	— Localization to noxious stimulation <sup>a</sup>
2	— Flexion withdrawal
1	— Abnormal posturing
0	— None/flaccid
<i>Oromotor/verbal function scale</i>	
3	— Intelligible verbalization <sup>a</sup>
2	— Vocalization/Oral movement
1	— Oral reflexive movement
0	— None
<i>Communication scale</i>	
2	— Functional (accurate) <sup>b</sup>
1	— Non-functional (intentional) <sup>a</sup>
0	— None
<i>Arousal scale</i>	
3	— Attention
2	— Eye opening without stimulation
1	— Eye opening with stimulation
0	— Unarousable

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Adapted from Giacino et al. (2004).

<sup>a</sup>Indicates a minimally conscious state. <sup>b</sup>Indicates emergence from the minimally conscious state.

Some other scales have been explicitly designed for assessing minimal changes of recovery in response to sensory stimulation treatments and are supposed to be particularly sensitive for detecting subtle changes in the level of consciousness, and are therefore also very helpful for discriminating between vegetative state and minimally conscious state, even if these scales do not explicitly

highlight those items that are supposed to differentiate between these two states (e.g., Western Neuro Sensory Stimulation Profile (WNSSP), Ansell and Keenan, 1989; Sensory Stimulation Assessment Measure, Rader and Ellis, 1994). One of these is the SMART (Gill-Thwaites, 1997). Although the tool originated from the parameters of the GCS, further extended by Freeman (1996), it has been further enhanced since its inception in 1988 with extensive evidence from both clinical practice and research (Wilson et al., 1991, 1993, 1996a, b; Gill-Thwaites and Munday, 1999; Wilson and Gill-Thwaites, 2000). The final design categorizes all behavioral responses observed in more than 300 patients in vegetative or minimally conscious states (as previously mentioned, this latter category defines patients who present some signs of awareness but behavioral responses are still very elementary, inconsistent and sometimes difficult to elicit; see Giacino, this volume for extensive review).

The SMART was designed to identify evidence of the patient's awareness through a graded assessment of the level of sensory, motor and communicative responses to a structured and regulated sensory program and also as a treatment tool to guide future treatment to enhance the patient's potential responses. The SMART comprises two components, including the informal component that consists of information from family and carers in respect of observed behaviors and information pertaining to the patients' pre-morbid interests, likes and dislikes. This component encourages active participation from families and carers, ensures that all responses seen to be day-to-day activity are recorded and categorized and that the treatment is relevant to the patients' interest, thus optimizing the opportunity for a meaningful response to stimuli. The SMART's formal assessment comprises of the SMART Behavioral Observation Assessment and Sensory Assessment and is conducted in 10 sessions within a 3-week period with an equal number of sessions in the morning and afternoon. This time frame provides frequent assessments over a short time frame to determine whether the behavioral responses observed are both consistent and repeatable. The behavioral observation enables the assessor to become

familiar with the patients' reflexive, spontaneous and purposeful behavior during a 10-minute period prior to the commencement of the SMART Sensory Assessment.

The Sensory Assessment has eight modalities including the five sensory modalities (visual, auditory, tactile, olfactory and gustatory) and also motor function, functional communication and wakefulness/arousal. Consisting of 29 standardized techniques, the SMART provides opportunity for patients to exhibit their full behavioral repertoire, in each of the different sensory modalities. For example, to assess the patients' responses within the auditory modality, a range of standardized auditory stimuli are presented, including loud sound, voice and a variety of specifically selected verbal instructions. The verbal instructions are carefully selected from the patient's behavioral repertoire exhibited as being potentially meaningful in the SMART Behavioral Observation, such as "raise your eyebrows", "move your thumb", to provide the patient with the best opportunity to follow any one or more instructions.

The SMART's 5-point hierarchical scale is consistent and comparable across all of the sensory modalities. The five levels range from "no response" (level 1) through "reflexive" (level 2), "withdrawal" (level 3), "localizing" (level 4) and "discriminating" responses (level 5). This 5-point scale relates directly to the description of Rancho Levels 1-4 (Hagen et al., 1979); a consistent response (on five consecutive assessments) at SMART level 5 in any one of the sensory modalities demonstrates a meaningful response and thus indicates that the patient is showing behaviors indicative of a minimally conscious state or higher levels of function (Table 2).

Recent research (Gill-Thwaites and Munday, 2004) has established the reliability and validity of the SMART on 60 subjects diagnosed in vegetative state on admission and assessed at two monthly intervals. The Rancho level (Hagen et al., 1979) ratings were derived from referring physicians, SMART and WNSSP (Ansell and Keenan, 1989) for each subject and the scores of each were compared. The intra-observer intra-class correlation (ICC) was 0.97 and inter-observer ICC was 0.96, which implied very little variation within and

Table 2. Sensory Modality Assessment and Rehabilitation Technique hierarchical scale for sensory modalities and their comparison to Rancho levels

SMART level	SMART response	Rancho levels
1	<i>No response</i> To any stimulus	<i>I No response</i> In deep sleep and unresponsive to stimuli
2	<i>Reflex response</i> To stimuli reflexive and generalized responses, i.e. startle, flexor or extensor pattern	<i>II Generalized response</i> Reacting inconsistently and non-purposefully to stimuli
3	<i>Withdrawal response</i> To stimuli may, for example, turn head or eyes away or withdraw limbs from stimulus	<i>III Localized response</i> Patient reacts specifically but inconsistently to stimuli
4	<i>Localizing response</i> To stimulus may, for example, turn head or move upper limbs toward stimuli	III
5	<i>Differentiating response</i> Patient may, for example, follow visual or auditory commands or use object appropriately	<i>IV Confused-agitated</i> And subsequent Rancho levels

Adapted from Gill-Thwaites and Munday (2004).

between observers<sup>1</sup>; modest, although significant correlation was established between SMART and either physician or WNSSP scores. A total of 45% of subjects diagnosed to have been in vegetative state by the referring physician on admission demonstrated awareness of self and the environment. Of these subjects, 28% demonstrated this behavior within week 1 of admission. While this figure does not take account of those patients who required time to enable the staff to become familiar with the patient and to fully stabilize the patients' medical status, it is clear that the rate of misdiagnosis may have been greater. The research indicates that the SMART is a valid and reliable assessment for discriminating awareness in vegetative state and minimally conscious state. The SMART therefore provides a reliable and valid tool, which enables the assessor to establish consistency, quality, and meaning of specific responses within each sensory modality to specifically define evidence of awareness and discriminates vegetative from minimally conscious and higher level functioning patients.

<sup>1</sup>It must be noted that there is somewhat greater variation among the scores when considering the different subscales separately, but as the composite score is the relevant measure, the reliabilities reported here accurately reflect the performance of the scale.

The WHIM, developed by Shiel et al. (2000) and based on previous work by Horn et al. (1992, 1993) and Wilson et al. (1994), was created by observing the behaviors that occurred spontaneously or in response to stimulation in a large cohort of initially comatose patients followed longitudinally over time. Following this initial phase of empirical observation, 145 behaviors were identified. These 145 behaviors were then categorized into six subscales (communication, attention, social behavior, concentration, visual awareness, and cognition) which were then assembled to form a single main scale of 62 items. Most importantly, these 62 items are ordered in a hierarchical way, the hierarchy of behaviors assessed reflecting a statistically derived order of recovery from coma: item 1 should appear before item 2, item 2 before item 3, etc. To obtain this hierarchy, the behaviors were ranked a posteriori as a function of order of appearance observed during recovery, using a paired preference technique, similar to the paired comparisons technique often used for the construction of ordinal scales (Watson and Horn, 1992; Watson et al., 1997). The WHIM score represents the rank order of the most advanced item observed (rather than adding the different items observed). The WHIM was designed to monitor all stages of recovery from coma to emerging post-traumatic amnesia, to monitor subtle changes in patients in a minimally

conscious state and to reflect performance in everyday life. Majerus et al. (2000b) conducted a validation study of a French version of the WHIM scales (Majerus et al., 2001) showing that the WHIM scales presented good inter-rater agreement (fair to excellent inter-rater agreement was obtained for 93% of the items) and very good test-retest reliability (a correlation of 0.98 was obtained between WHIM scores obtained in a test and a retest session). Most importantly, the study confirmed that the WHIM was largely superior to the GCS and GLS scales for detecting subtle changes for patients emerging from the vegetative state and for patients being in a minimally conscious state: although GCS scores remained unchanged across time for many patients in these states, assessment with the WHIM permitted to detect an important number of changes in behavior and corresponding states of consciousness (see Fig. 4 for an illustrative example). Furthermore, WHIM scores were more than five times more variable than GLS scores for patients in the minimally conscious state or patients showing a good recovery, suggesting that the WHIM is particularly sensitive for patients in the minimally

conscious state. However, the study by Majerus et al. (2000b) also showed that the sequence of recovery proposed by Shiel et al. (2000) is very probabilistic and lacks precision, as the proposed order of recovery could not be replicated for all items of the scale. Further studies are needed to strengthen the validity of the sequence of recovery proposed by the original version of the WHIM scales.

Wilson et al. (2002) emphasized the need for “careful, repeated and reliable assessment of patients with impaired consciousness” to add accuracy to the assessment process. The CRS-R, the SMART and the WHIM have all proven to be very useful tools to monitor behaviors with head injured patients and both the features and design of these scales compliment each other in clinical practice. Both the SMART and WHIM have been recommended to provide standardized assessment protocols for patients in vegetative or minimally conscious states by the UK Royal College of Physician (2003) guidelines.

Finally, it should be noted that the administration of standardized scales might sometimes be difficult as a result of sensory and motor disturbances

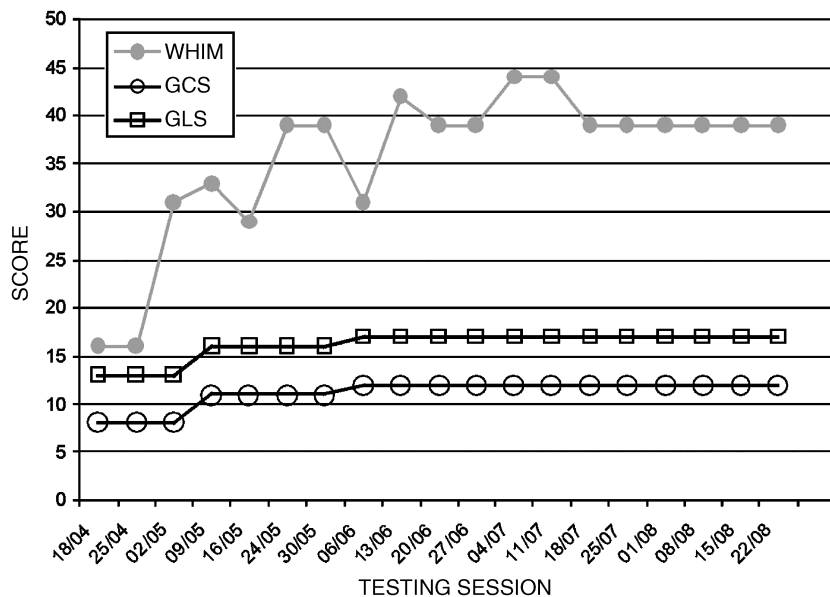


Fig. 4. Longitudinal assessment with the WHIM, GCS and GLS in an initially comatose patient, evolving to a minimally conscious state. Note the absence of notable changes for the GCS and GLS scales from test session 09/05, while WHIM scores show important behavioral changes.

that will make impossible the scoring of a number of items needing a given sensory or motor modality. This is particularly important as these sensory and motor impairments are a frequent cause of misdiagnosis. In these cases, the use of individualized assessment techniques is recommended. For example, Whyte et al. (1995, 1999) proposed a method for a reliable assessment of visual attention and command following in these patients (see also Giacino and Whyte, 2005). The principle of this method is to find, for an individual patient, at least one behavior with which the patient seems to produce voluntary responses. This behavior is likely to be different in each patient and depends on his particular sensory and motor impairments. Once this behavior has been detected, the second aim is to determine whether this behavior is really voluntary, by determining the baseline frequency of this behavior, and by determining increases in frequency of this behavior over time and as a result of stimulation (e.g., on command). In order to consider a behavior as volitional, the patient has to respond more frequently when required to produce the behavior than during baseline and he must respond less frequently when instructed not to produce the behavior. This method permits to obtain discrimination scores between the three conditions (behavior on, behavior off, baseline) for which statistical significance can be tested. Using such individualized assessment methods in combination with the standardized assessment scales presented above, both the sensitivity and reliability of behavioral assessment of altered states of consciousness is likely to be maximized. The CRS-R has incorporated parts of these individualized assessment techniques as described by Whyte et al. (1997, 1999).

As obvious time constraints in the clinical setting will not allow to assess every patient with each of the presented scales, we will conclude this section by providing some guidelines for selecting the most appropriate scale, depending on the question that is asked and the state the patient is in. In the acute setting, the GCS remains the “gold standard” in the evaluation of coma. By virtue of its simplicity, it is the most universally utilized consciousness scale worldwide and seems, despite its drawbacks, destined to be used in emergency medicine and intensive care for some time. In the post-coma phase, and

to differentiate between vegetative and minimally conscious state, the CRS-R (Giacino et al., 2004), in conjunction with the individualized assessment technique proposed by Whyte et al. (1995, 1999), might be the best solution as it was specifically designed for making this differential diagnosis. When following a patient longitudinally and documenting subtle progresses in the recovery of consciousness, the SMART and WHIM could be more appropriate. The WHIM seems more practical for assessments made on a daily basis as time needed to administer this scale is only about 10 min (range 2–35 min), while administration of the SMART takes between 30 and 40 min. The WHIM has been shown to be particularly sensitive for patients in the minimally conscious state and patients showing slow but relatively good recovery. On the other hand, one important advantage of the SMART is that it also assesses responses to a sensory stimulation program, which is not the case for the other scales. Finally, the SMART appears to be particularly suitable for patients in the vicinity of the vegetative state. Although the WHIM also shows a good sensitivity for this state, the inclusion of an olfactory function subscale in the SMART provides an additional opportunity for detecting subtle signs of responsiveness.

## Conclusions

Assessment of awareness is not a matter of all or nothing. Recovery of awareness is a very gradual process, with sometimes great leaps forwards, but more often subtle changes, and also sometimes setbacks. For the patient emerging from coma, it is of utmost importance that the medical staff adapts its assessment to the level of awareness the patient is currently in. The subtlest signs of awareness, as well as their fluctuation, have to be reliably captured as they are the only means for avoiding misdiagnosis, but also for communicating with these patients. This implies the use of standardized, sensitive and individualized assessment tools that cover a wide range of possible, although sometimes minimal, behaviors in all sensory modalities. The major challenge of the years to come will not be to develop new tools, but to effectively implement

those existing ones in the daily practice of carers of patients with impaired consciousness.

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