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Wessex Head Injury Matrix and Glasgow/Glasgow–Liège Coma Scale: A Validation and Comparison Study

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ABSTRACT

The Wessex Head Injury Matrix (WHIM) is an assessment tool designed for use during and immediately after coma. The aim of this study was (1) to test a French adaptation of the WHIM, (2) to compare the WHIM to the Glasgow Coma Scale (GCS) and its extension, the Glasgow–Liège Coma Scale (GLS), and (3) to confirm the sequence of emergence of behaviours. The three scales were used to assess 23 patients admitted to an intensive care unit with a GCS score equal to or less than 8 for at least 1 hour, longitudinally. Results indicated that the WHIM had good concurrent validity with the GCS and GLS, good inter-rater agreement, and excellent test–retest reliability . The WHIM is more appropriate and sensitive than the GCS and the GLS for the period of emerging from coma and immediately afterwards, whereas the GLS is more appropriate than the WHIM for the deepest phase of coma, as it also assesses brainstem reflexes. Furthermore, analysis of our data confirmed the ordering of the 66 items of the WHIM as a function of sequence of recovery from coma, as suggested by its authors.

INTRODUCTION

Altered states of consciousness, especially those affecting arousal (Harris & Berger, 1991) include distinct entities such as coma, vegetative state (VS), minimally conscious state (MCS), slow-to-recover (STR) patients, akinetic mutism (AM), and locked-in syndrome (LS), where criteria for differential diagnosis are still not totally resolved. Recently, attempts have been made to establish more precise definitions (American Congress of Rehabilitation Medicine, 1995; International Working Party, 1996; Multi-Society Task Force on Persistent Vegetative State [PVS]) extending Jennett and Teasdale's original definition of coma as "the inability to obey commands, to speak or to open the eyes" (Jennett & Teasdale, 1981). The Multi-Society Task Force (1994) adds that self-awareness and sleep–wake cycles are absent, that there is no

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purposeful movement nor any experience of suffering, and that respiratory function is depressed or variable. Behaviours are restricted to reflex activity, thus indicating a dysfunction of the cortex and the reticular activating system.

Similarly, precise criteria have been proposed for VS (American Neurological Association Committee on Ethical Affairs, 1993; Duff & Wells, 1997; International Working Party, 1996; Multi-Society Task Force, 1994). The American Congress of Rehabilitation Medicine (1995) suggests that VS is characterised by periods of wakefulness with eyes open spontaneously or after stimulation, but without any evidence of meaningful environmental interactions. The term PVS adds a temporal dimension to the VS concept, by specifying that it is persistent, or even permanent (Multi-Society Task Force, 1994). The American Congress of Rehabilitation Medicine (1995) and the International Working Party (1996) however recommended avoiding the terms "persistent" and "permanent", by simply specifying the length of time a patient persists in a vegetative state.

For the MCS (Giacino, 1997) and the minimally responsive state (MIN-R) (American Congress of Rehabilitation Medicine, 1995), precise clinical features have been proposed: There is inconsistent but meaningful interaction with the environment. Ansell and Keenan (1989) proposed the term "slow-to-recover" (STR) for this type of patient if they remain minimally responsive for an extended period of time (3–6 months) (Ansell, 1991). Akinetic mutism (AM) is characterised by diminished neurological drive and orientation while arousal and visual tracking are always preserved; the fundamental problem seems to be deficient initiation or activation of behaviour and cognition. AM can be seen as a subcategory of MIN-R (American Congress of Rehabilitation Medicine, 1995).

For LS no motor response is possible because of quadriplegia and pseudo- bulbar palsy; only eye movements can be controlled, but self-awareness is mostly preserved (American Neurological Association, 1993; Multi-Society Task Force on PVS, 1994).

There are still many unanswered questions concerning these definitions. The PVS concept has been criticised by the American Congress of Rehabilitation Medicine (1995) and the International Working Party (1996) as the term "persistent" is too pejorative and definitive and may result in a reduction in the amount of rehabilitation provided. More importantly, there is no 100% certainty in qualifying a VS as persistent, even after several months. In particular, there is no consensus concerning clear clinical criteria for VS (American Congress of Rehabilitation Medicine, 1995; Celesia, 1997; Giacino, 1997; Kallert, 1994). There is debate as to whether visual tracking, smiling, crying, frowning, and localisation of noxious stimuli are compatible with VS or not. This shows the need for valid, precise, and sensible behavioural assessment tools in order to avoid misdiagnosis, as could be the case in LS versus VS (Ostrum, 1994), with serious consequences for the LS patient who is fully aware of the environment. An extensive and systematic observation of the defining behaviours for different altered states of consciousness is further necessary to solve the definitional questions raised above, but also in order to monitor change and progress in and between these syndromes.

Indeed, a great number of behavioural assessment tools have been described (for a synopsis, see Horn et al., 1993). Some are simple rating scales that permit classification of the state of

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consciousness observed in broad categories. These instruments are not very sensitive and cannot be considered as real clinical assessment tools as they force the rater to put the patient in a broad category instead of systematically assessing the behaviours presented by the patient (e.g. the five levels of consciousness, Ommaya, 1966; Rancho Los Amigos Levels of Cognitive Functioning, Hagen, Malkmus, & Durham, 1979; Recovery Level Scale 85 of Stalhammar et al., 1988). Then there are the more traditional assessment scales for coma and altered states of consciousness: They aim to evaluate the behavioural evolution of comatose patients, from coma to recovery, but are still rather crude evaluation tools because they have too few items and do not monitor subtle changes as is needed for STR, MCS, and VS patients.

The Glasgow Coma Scale of Teasdale and Jennett (1974, 1975, 1976) is probably the most widely used scale of this type. This 15-item scale assesses responses to stimulation and spontaneous reactions in verbal, motor, and visual subscales, the results of which are summed to form the GCS score. The GCS has a good sensitivity, high reliability, and well-established cross-sectional construct validity (Fielding & Rowley, 1990; Rowley & Fielding, 1991) but its longitudinal construct validity and its predictive validity have not been adequately studied (Prasad, 1996). A GCS score of 8 or less is also often used to establish, in an objective manner, a diagnosis of coma (American Congress of Rehabilitation Medicine, 1995); but since a score of 8 is only the sum of behaviours observed, a group of patients all scoring 8 on the GCS may show consider- able heterogeneity in relation to the individual behaviours comprising the GCS score (American Congress of Rehabilitation Medicine, 1995). The sensitivity of the GCS for monitoring change in STR or VS patients has also been questioned (Horn et al., 1993), as the number of the items is very limited. There is also excessive reliance on verbal output, so that intubated patients may score below their real capacity (Moskopp, Stähle, & Wassermann, 1995). The Glasgow–Liège Coma Scale (GLS) (Born, 1988) extends the GCS by the addition of five brainstem reflex assessments. This extended scale has been shown to increase sensitivity of assessment of patients who have low scores on the GCS. The predictive validity of the five brainstem reflexes is particularly high for evolution during the first 24 hours (Born, 1988) after admission to an intensive care unit for coma. Other scales of this type are the Comprehensive Levels of Consciousness Scale (CLOCS, Stanczak et al., 1984) and the Innsbruck Coma Scale (ICS, Benzer et al., 1991).

A third category of scales comprises those that have been developed especially to assess rate of recovery in VS and STR patients. These scales should be more sensitive as they include more items and the items are designed to be more sensitive to subtle change (Coma/Near Coma Scale; Rappaport, Dougherty, & Kelting, 1992; Visual Response Evaluation, Davis, 1991; and Coma Exit Chart, Freeman, 1996). Finally there are assessment tools created in order to assess minimal changes of recovery in response to sensory stimulation treatments: The Sensory Stimulation Assessment Measure (SSAM, Rader, Alston, & Ellis, 1989; Rader & Ellis, 1994), and the Western NeuroSensory Stimulation Profile (WNSSP, Ansell & Keenan, 1989). Theoretically, these scales should be more sensitive to subtle changes in recovery, but there are no data supporting this.

There is one important common point to the four categories of scales presented: They are all based on theoretical and a priori assumptions concerning the behaviours that should be observed in

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altered states of consciousness.

An innovative approach has been adopted by Shiel et al., (in press), Horn, Watson, Wilson and McLellan (1992), Horn et al. (1993), and Wilson et al. (1994): They have created the Wessex Head Injury Matrix (WHIM) first by observing behaviours that occurred spontaneously or in response to stimulation in 97 initially comatose patients selected longitudinally (GCS on admission of 8 or less for at least 6 hours). An initial set of 145 behaviours were assessed. These 145 items were then categorised into 10 subscales of which 6 showed frequent overlaps. These 6 subscales (communication, attention, social behaviour, concentration, visual awareness, and cognition) were then amalgamated to form a single main scale of 58 items. The 58 (66) items of the WHIM were ordered in a hierarchical way. This hierarchy reflects an order of recovery for patients emerging from coma: item 1 should appear before item 2, item 2 before item 3, etc. To obtain this hierarchy, the behaviours were ranked a posteriori as a function of order of appearance during recovery, using a paired preferences technique that is similar to the paired comparisons technique often used for the construction of ordinal scales (Watson & Horn, 1992; Watson, Horn, Shiel, & McLellan, 1997). The scale also includes clear and precise operational definitions for most items. The WHIM is designed (1) to monitor all stages of recovery, starting from coma to emerging post-traumatic amnesia; (2) to monitor subtle changes in STR patients; (3) to reflect performance in everyday life; (4) to identify appropriate short-term objectives and realistic goals for those working with the patient; (5) to specify a sequence of recovery; and (6) to measure what a patient actually does—his performance, rather what the patient is theoretically capable of doing—his capacity.

As the WHIM seems to be a very promising tool in comparison to the other scales described, especially the most widely used GCS, and because an adequate assessment of altered states of consciousness is indispensable for the clinical and theoretical reasons cited above, we wanted (1) to establish normative data for a French version of a 66-item WHIM; (2) to establish the relationship between the 66-item WHIM and the GCS and its extension, the GLS, especially to provide supporting data for the presumed superior sensitivity of the WHIM to monitor subtle changes in MCS, STR, and also VS patients; and (3) to test the validity of the order of recovery proposed for the 66 items of the WHIM used in this study.

SUBJECTS

Patients with a GCS on admission of 8 or less for at least 1 hour (as assessed by the medical and nursing staff) were included in the study. Mean age was 50 years (range 16–75), and there were 6 females and 17 males. Mean coma length (GCS ≤ 8, according to the American Congress of Rehabilitation Medicine, 1995) was 12.7 days (range 1–136). Coma resulted from traumatic brain injury (*n* = 12), cerebral vascular accident (*n* = 9), or toxic origin (*n* = 2). Patients were assessed first in an intensive care unit of the Centre Hospitalier Régional La Citadelle in Liège (Belgium) as soon as possible after the onset of coma; they were followed after transfer to another unit of the hospital. Mean onset of study assessments was 6 days after onset of coma (range 0–18). Patients

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were seen until recovery, death, transfer to another hospital, or return home. Mean longitudinal follow-up was 23 days (range 1–134). Five patients (21.74%) died (2 females and 3 males); their mean age was 49.3 years (range 41–75) and mean length of coma was 10.5 days (range 2–18). Eighteen patients (78.2%) survived; their mean age was 47.5 years (range 16–67) and mean length of coma was 12.72 days (range 1–136). Table 1 gives details of the patients.

VALIDITY

PROCEDURE

Concurrent (correlational) validity with GCS and GLS was calculated, since the GCS is considered a valid tool for behavioural assessment of the coma and post-coma period, and since GLS is the validated extension of GCS. The 23 patients were evaluated with both WHIM and GCS/GLS on two consecutive days each week. A 66-item experimental version of the WHIM main scale, a later version of the 58-item scale presented in Shiel et al. (in press) was used.

Table 1 *- Age, sex, length of coma in days (GCS ≤ 8), longitudinal follow-up in days, onset of assessment (number of days passed from the onset of coma until first assessment), and origin of coma*

Age	*Sex*	*Coma length*	*Follow-up*	*Onset assessment*	*Origin*
66	f	1	82	13	CVA*
53	f	12	96	14	CVA
25	m	16	16	6	Trauma
28	m	4	2	3	Tox
50	f	1	22	0	Trauma
33	f	140	134	6	Trauma
38	m	1	15	5	Trauma
42	m	3	1	2	Tox*
41	m	12	8	4	CVA*
16	m	21	127	6	Trauma
43	m	1	1	4	Trauma
21	m	1	1	8	Trauma
39	m	1	1	3	Trauma
62	f	7	2	15	CVA
73	f	2	1	1	CVA*

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42	m	10	36	0	CVA
47	m	1	2	4	Trauma
39	m	32	7	7	Trauma
67	m	2	2	0	CVA
29	m	10	14	13	Trauma
64	m	10	29	18	Trauma
75	m	7	2	5	CVA*
41	m	14	8	5	CVA*

**patient died; Tox: metabolic intoxication; CVA: cerebral vascular accident*

The additional items were grinding teeth/clamping down of teeth (item 7), marked arousal and agitation prior to urination, defecation (item 12), speaks in whispered tones (item 21), crying (item 23), chooses an object when requested (item 32), laughs (item 33), speech is established, but the content is indicative of problems with word-finding or difficulty in comprehension (item 53), normal conversational speech (item 66). The order of assessments with WHIM and GCS/GLS were alternated. The GLS was administrated and the GCS scores were calculated by subtracting the brainstem reflex subscale from the GLS score. (The GCS the GLS only differ by the addition of the brainstem reflex subscale for GLS. The eye, motor, and verbal subscales are exactly the same for both scales). Assessment was performed on five different occasions between 9 a.m. and midday (see Table 2). Test occasions were randomly changed for each assessment and for each patient, as far as possible.

Table 2 *- Test occasions (time of testing); code for each test occasion; number associated with each test occasion; mean GCS score, mean GLS score and mean WHIM score, as a function of test occasion and with standard deviations*

Test occasion	*code*	*n*	*GCS*	*GLS*	*WHIM*
9:00– 9:44	1	32	10 (3.9)	15 (5)	31 (23.4)
9:45–10:14	2	39	10 (3.2)	15 (3.6)	26 (20.6)
10:15–10:44	3	40	9 (3.8)	14 (4.7)	29 (24.5)
10:45–11:14	4	39	11 (2.9)	16 (3.5)	38 (20.4)
11:15–12:00	5	26	12 (1.6)	17 (2)	45 (14.3)

A total of 176 assessments were obtained between February and August 1998. Scoring for the WHIM

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was done by taking the rank order of the most advanced item observed as the WHIM score. Concurrent validity was tested using a Spearman rank order correlation between the 176 WHIM and GCS scores.

Results

The correlation was highly significant ($r = .94$, $P < .001$), demonstrating that the WHIM has good concurrent validity with the GCS. Similar results were obtained for concurrent validity when WHIM and GLS were correlated: Spearman rank order correlation between WHIM and GLS scores is .94 ($P < .001$). A potential problem with this analysis is that the 176 assessments comprise both independent assessments of different patients and dependent assessments of the same patients who were followed longitudinally. Therefore the WHIM scores and GCS scores of the first and the last assessment for each of the 23 patients were correlated, thus only comparing independent assessments. There was a correlation of $r = .83$ ($P < .00001$) between WHIM and GCS initial scores and a correlation of $r = .95$ ($P < .00001$) between WHIM and GCS final scores. There was no significant difference between the correlations obtained by means of the complete data set or by means of a reduced data set, containing only independent variables.

The order of assessment (GCS/GLS used first or WHIM used first) did not reach statistical significance; for the WHIM scores, we obtained the following *t* test result: t (174) = –0.43, $P = .66$; the same results were found for GLS and GCS scores [t (174) = –0.53, $P = .6$]. With regard to test occasions, a simple one-way ANOVA showed a significant effect on mean WHIM scores [$F(4,171) = 4.25$, $P < .003$]; post-hoc comparison with Tukey statistics indicated a significant difference between test occasions 2 and 5 ($P < .002$) and between test occasions 3 and 5 ($P < .01$). The same significant differences for test occasions are obtained for mean GCS scores: a significant effect of test occasion [$F(4,171) = 3.7$, $P < .006$] with post-hoc comparisons indicating significant change between test occasions 2 and 5 ($P < .02$) and between test occasions 3 and 5 ($P < .03$); the same significant differences were found for test occasions for mean GLS scores: Significant effect of test occasion [$F(4,171) = 3.29$, $P < .01$] with post-hoc comparisons showing a significant difference between test occasions 3 and 5 ($P < .02$).[1]

This indicates that the majority of patients showed good recovery and that high WHIM and GCS/GLS scores could only be assessed at later time periods (time 4 and 5) for organisational reasons: At time periods 1–3 these patients were receiving nursing care and assessment could only be carried out afterwards.

RELIABILITY

PROCEDURE

Two aspects of reliability, inter-rater agreement using the Kappa statistics (Cohen, 1960; Fleiss,

[1] An analysis conducted by means of non-parametric tests has globally shown the same results.

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1971), and test–retest reliability, using Spearman rank order correlations, were investigated.

To assess *inter-rater agreement*, two independent raters observed and scored the behaviours presented by five patients from the study sample who had previously been recorded on video. The five patients were chosen in order to cover the whole range of altered states of consciousness (two VS patients, one MCS patient, two moderate to good recovery patients). The raters were experienced intensive care nurses, and they were independent and blind to the study. Prior to data collection, they were trained using the videotaped sequences of the University of Southampton WHIM training package (used with permission); duration of training was at least 4 hours. The training completed, the raters were asked to score the five videotaped sequences of this study using the WHIM, on two different occasions (test and retest situation). Kappa statistics were calculated for a total of 20 assessments. *Test–retest reliability* was determined by correlating the WHIM scores obtained by the two raters for a first (test) session and a second (retest) assessment session of the same five videotaped sequences as before. The second assessment was done at a later time period (at least 1 day after the first assessment).

RESULTS

Inter-rater agreement was excellent for 73% of the 66 items (K = 0.8–1), fair to good for 20% (K = 0.4–0.73) and poor for 7% (K = –0.1–0.07). Kappa coefficients could not be computed for six items as there was no variability in the assessments for these items. The mean Kappa for the overall scale was 0.84. Spearman rank order correlations between the WHIM scores observed by the two raters was 0.927 ($P < .0001$).

Test–retest reliability was assessed with Spearman rank order correlation between the WHIM scores obtained in the test and retest sessions. This was 0.981 ($P < .0001$).

RELATIONSHIP BETWEEN GCS, GLS, AND WHIM

The relationship between GCS, GLS, and WHIM was examined in three different steps. It is also illustrated by a brief case study.

STEP 1

Procedure. In order to examine the relationship between GCS/GLS and WHIM, the 176 assessments with GCS/GLS and WHIM were further divided in four subgroups as a function of the GCS/GLS score assessed to reflect different severity levels of alteration of consciousness: subgroup 1 ≤6(deep coma); subgroup 2 GCS between ≥ 7 and ≤ 10 (coma, exit from coma, and VS); subgroup 3 GCS between ≥ 11 and ≤ 12 (recovery from coma, STR, MCS); supgroup 4 GCS ≥ 13 (relatively good recovery from coma). The same procedure was used to define the relationship between GLS and WHIM (see Table 3). This relationship between GCS/GLS scores and a state of altered consciousness was somewhat hypothetical, but was proposed to describe in more concrete terms the relationship between parts of GCS/GLS and WHIM; the individual behaviours that composed these GCS/GLS scores were compatible with the clinical criteria given

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for VS, MCS, and STR by the American Congress of Rehabilitation Medicine (1995) and the Multi-Society Task Force (1994): e.g. the patients in our sample that were in a VS (no volitional vocalisation, no following of commands, spontaneous eye opening) had a maximum GCS score of 8 and this score was composed of E4 (spontaneous eye opening), V1 (no verbal response), and M3 (abnormal flexion to pain); patients that were in MCS (minimal and inconsistent signs of awareness) had a maximum GCS score of 12 that was composed of E4, V2 (nonspecific sounds) and M6 (follows command). The GCS scores and the WHIM scores were then correlated within each subgroup. This was done in order to see if the WHIM scales were behaving in the same way (i.e. measuring the same changes) as the GCS/GLS when different levels of alteration of consciousness were considered separately. Table 3 shows the results of relationship between GCS and WHIM scores as a function of GCS subgroup and between GLS and WHIM scores as a function of GLS subgroup.

Results. Significant correlations between WHIM and GCS scores were obtained for the subgroups 1, 3, and 4. For subgroup 2, correlations were non-significant, that is, when patients begin to emerge from coma (GCS ≥ 7 and ≤ 10) or when they are in VS, the GCS and the WHIM did not measure the same changes. Exactly the same results are obtained when the WHIM is compared to the GLS.

STEP 2

Procedure. In order to explore further this non-significant relationship between GCS, GLS, and WHIM when patients have a GCS between 7 and 10, all the scores of the176 assessments were plotted on a bi-dimensional graph, the WHIM scores on the X-axis, the corresponding GCS scores on the Y-axis (Fig. 1; see Fig. 2 for GLS scores).

Table 3 - Spearman rank order correlations between WHIM and GCS/GLS scores within four subgroups of states of altered consciousness as a function of GCS/GLS subgroup

Sub-group	*Score*	*State of consciousness*	*n*	*Spearman r*	*P*
GCS1	GCS ≤ 6	Deep coma	27	.46	< .02
GCS2	7 ≤ GCS ≤ 10	Exit from coma; VS	35	–.18	.29
GCS3	11 ≤ GCS ≤ 12	STR; MCS	63	.66	< .0001
GCS4	GCS ≤ 13	Good recovery	51	.57	< .0001
GLS1	GLS ≤ 11	Deep coma	29	.54	< .01
GLS2	12 ≤ GLS ≤ 15	Exit from coma; VS	36	–.18	.3
GLS3	16 ≤ GLS ≤ 17	STR; MCS	60	.65	< .0001
GLS4	GLS ≤ 18	Good recovery	51	.57	< .0001

Results. Figure 1 shows that when GCS varies between 7 and 10, there is an important horizontal variability, reflecting many different WHIM scores, especially when GCS is constant at 8. When this is so, assessment with the WHIM monitors very different behaviours: There are behaviours

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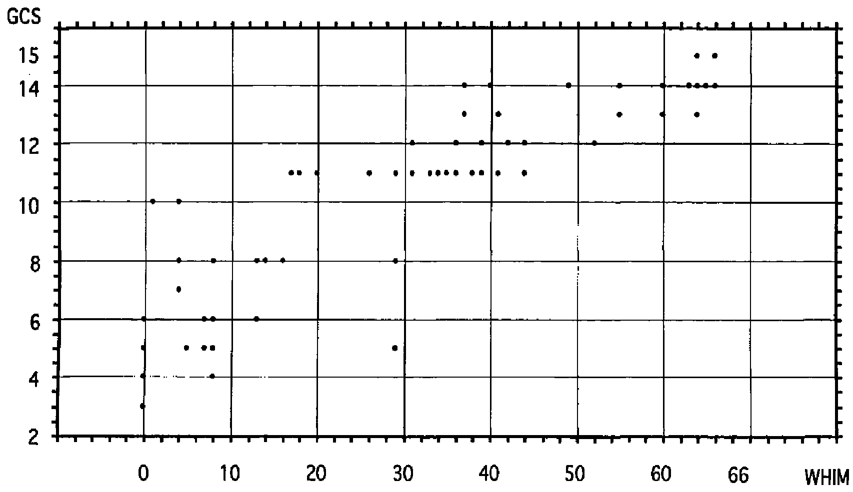
such as item 4 (attention held momentarily by dominant stimulus), item 8 (distressed when cloth put on face), item 13 (eyes follow person moving in line of vision), item 14 (looks at person giving attention), item 16 (mechanical vocalisation), item 26 (maintains eye-contact over 5 seconds), and item 29 (frowns, grimaces, etc. to show dislike). These heterogeneous behaviours reflect different levels of consciousness whereas the GCS score remains at 8. The same observations were made when comparing GLS and WHIM scores. The WHIM appears to be a more sensitive assessment tool for the exit from coma and VS period than GCS or GLS. Additionally, it assesses some of the critical behaviours for VS (visual tracking and frowning) and therefore could permit conceptual clarification for diagnosis of VS through a systematic observation of the possible behaviours in this condition.

Figure 1 *- Distribution of WHIM scores and GCS scores for the 176 assessments.*



STEP 3

Procedure. To explore further the relationship between GCS/GLS and WHIM, additional analysis was used. For the same 176 assessments the number of different WHIM scores observed were compared with the number of different GLS scores, in relation to the same four subgroups as a function of GLS score as before (only GLS scores were used for this analysis as the range of the GLS is greater than that of GCS and because results for GCS and GLS were equivalent on the preceding analysis). Ratios were calculated by dividing, for each subgroup, the number of different WHIM scores by the number of different GLS scores for that subgroup. A theoretical ratio should be expected regarding the number of possible different scores for the two overall scales (theoretical ratio 67/18 = 3.7); this theoretical ratio represents the higher sensitivity of the WHIM as this scale has more items (66) than the GLS (20 items). By comparing the ratios obtained for the different subgroups, we could see if the WHIM maintained this higher sensibility for all subgroups.

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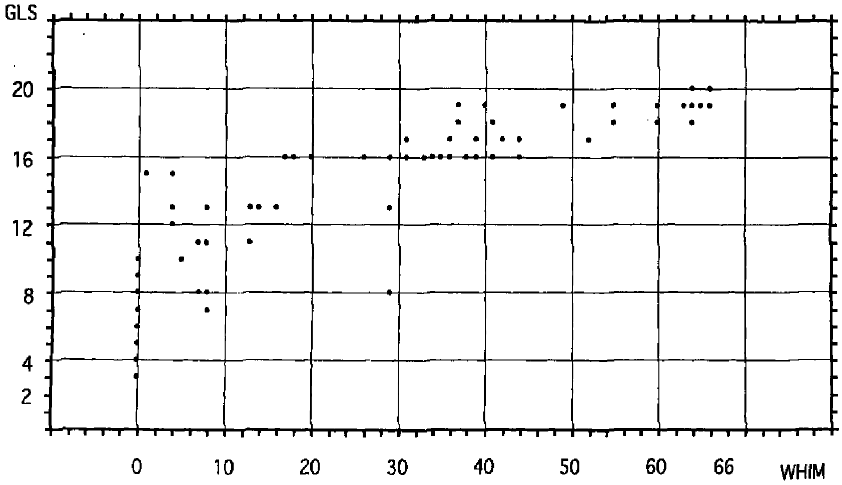
Figure 2 *- Distribution of WHIM scores and GLS scores for the 176 assessments.*



Results. For subgroup 1 (GLS ≤ 11; deep coma) we obtained a ratio WHIM/GLS for different scores of 1.77. Thus sensitivity of the WHIM is not better than the GLS when GLS ≤ 11 (= GCS ≤ 6). This is even more apparent if we consider Fig. 2. For a WHIM score of 0, there are 8 different GLS scores (3–10). This is largely due to the evaluation of brain stem reflexes by the GLS. For the other three subgroups (VS and exit from coma, MCS and STR, and relatively good recovery), we obtain ratios of 4, 8.5, and 5.3, respectively, which are clearly superior to the theoretical ratio (3.7). The WHIM shows greater sensitivity in assessing change for the period of emergence of coma, VS, MCS and STR patients, and normal recovery patients (GLS ≥ 12 = GCS ≥ 7).

CASE STUDY

This case demonstrates the sensitivity of the WHIM in a case of VS, and also the sensitivity of the GCS and GLS for the deep coma period. Patient L.A. had a severe head injury resulting from a road traffic accident; she was aged 33 at the time of the accident. Her GLS score on admission to the intensive care unit was 5/20 (15.03.98). She was intubated and sedated until 04.03.98, then a tracheotomy was carried out. She was in coma until 12.04.98 when she first began to open her eyes. She remained in VS until 02.05.98 when she first obeyed a verbal command and was responding to her environment, albeit inconsistently. However, after 06.06.98, this behaviour was extinguished and was never observed again (either on formal evaluation or by the nursing staff). She showed no sign of responding to her environment, but her eyes were open. She was then considered to be in a VS (American Congress of Rehabilitation Medicine, 1995). Table 4 shows results of assessments with GCS, GLS, and WHIM as a function of time and assessment day.

First, for the deep coma period (GCS ≤ 8), we observed variability for the GCS and GLS scales, but not at all for the WHIM. Second, when the patient was considered vegetative after 06.06.98, we observed important variations for WHIM scores whereas GCS and GLS scores remained invariably at 8 and 13, respectively. This variability existed for both weekly and daily measures. The assessments carried out for this patient also showed that different behaviours may be

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observed in a VS patient: item 8 is "distressed when cloth put on face", item 14 is "patient looks at person giving attention", and item 29 is "grimacing". Here one could argue that a patient who looks at another person giving attention is no longer in a vegetative state. However, L.A. was not responsive to her environment in any other way. The relevant issue here is not to discuss whether or not the patient is still in VS when these behaviours occur, but rather to demonstrate with these results that the WHIM allows observation of behaviours that are not included in either GCS and GLS for patients in VS or close to VS. These observations, based on only dependent measures, confirm the nature of the relationship between the WHIM and GCS/GLS as analysed in the preceding section (Steps 1–3).

SEQUENCE OF RECOVERY

The third objective of this study was to validate the sequence of recovery from coma proposed by Shiel et al. (in press). We used a similar methodology to that for the paired preferences technique (Watson et al., 1997), with a 66-item WHIM scale that was identical to the 58-item scale presented by Shiel et al. except for the 8 additional items listed previously. From our sample of 23 patients, only the assessments of 17 surviving patients were used. Each item was compared with each other to see if one item appeared before the other. This was done for the data of the 17 patients. A total of 2145 pairs of comparisons were obtained for the 66 items for each patient; for item 1, there were 65 pairs, for item 2, there were 64 pairs, etc. If the first item of the pair appeared for the first time before the other, the pair was coded 1. If this was not the case, the pair was coded 0. Each pair was considered 17 times (for each patient), and an index was computed for each pair; this index represents the number of cases where the first item of a pair recovered before the second, the total number was divided by 17 and varied from 0 to 1. After this, for each of the 66 items, the indexes of all the pairs where this item had been compared to another item, were summed. Thus for each item, we obtained an index sum and this index sum was used to order this item by comparing it to the index sum of the other items. This ordering then represented the sequence of recovery. Item 1 should theoretically have presented an index sum of 65, item 2 a theoretical index sum of 64, etc. If this was not true, and if for example, we obtained for item 1 an index sum of 63, and for item 2 an index sum of 64, then we could place item 2 before item 1 in the sequence of recovery. Proceeding like this for the 66 items, we identified a sequence of recovery that could be compared to that proposed for the WHIM.

Table 4 *- Results of assessments with GCS, GLS, and WHIM for L.A. as a function of time and assessment day*

Week	*Whim DAY 1*	*Whim DAY 2*	*GCS (DAY 1 + 2)*	*GLS (DAY 1+2)*
21.03.98	0	0	3	4
28.03.98	0	0	4	5
04.03.98	0	0	4–5	7–8
11.04.98	8	8	5–8	8–13

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18.04.98	8	8	8	13
25.04.98	16	29	8	13
02.05.98	29	29	11	16
09.05.98	29	29	11	16
16.05.98	29	29	11	16
24.05.98	16	29	8	13
31.05.98	29	29	5–8	8–13
06.06.98	29	8	11–8	16–13
13.06.98	29	14	8	13
20.06.98	/	8	8	13
27.06.98	29	29	8	13
04.07.98	8	14	8	13
11.07.98	14	8	8	13
18.07.98	8	8	8	13
25.07.98	8	14	8	13
01.08.98	8	8	8	13

The obtained sequence of recovery is presented in Table 5. Items 6, 7, 11, 12, 23, and 25 had to be eliminated because they were not observed often enough in our sample (e.g. tracheotomy rendering observation impossible for items 6 and 7). Item 12 was never observed in this study. In the 58-item WHIM presented by Shiel et al. (in press), items 7, 12, and 23 were removed.

The sequence of recovery we obtained is globally similar to that proposed for the WHIM. There are only minor changes with certain items appearing later in our study than for the proposed sequence (item 8 "distress when cloth put on face"; item 15 "closes eyes and becomes quiescent when cloth put on face"; and item 22 "vocalises to express mood or needs"); others appeared earlier (item 31 "looks at object when requested").

Table 5 *- The 66 items of the WHIM ordered as a function of their index sums, the resulting order representing a sequence of recovery from coma*

Item	*Index sum*	*Item*	*Index sum*	*Item*	*Index sum*
1	64.88	27	29.89	50	14.65

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2	61.98	36	29.29	46	13.78
3	60.85	34	28.66	48	13.31
5	60.5	32	28.56	25	12.96
4	60.37	29	28.38	53	12.2
9	56.25	22	28.03	47	10.97
10	55.37	37	28	54	10.8
13	51.8	38	26.57	55	10.2
14	50.19	35	26.43	56	9.8
17	48.94	28	24.45	52	8.35
16	45.54	40	22.88	58	7.38
18	44.95	41	21.98	57	5.78
8	44.69	15	20.67	60	5.6
19	44.31	11	20.58	62	2.82
20	43.03	33	20.19	63	2.6
7	42.3	44	19.38	61	2.08
26	38.97	39	19.09	59	2.03
24	38.76	43	18.65	64	1.9
31	33.19	45	18.21	23	1.2
21	32.83	42	16.59	65	0.14
6	31.2	49	15.83	12	0
30	30.73	51	14.73	66	0

CONCLUSION

The main results of this study are: (1) the WHIM showed good concurrent validity with GCS; (2) both inter-rater agreement and test–retest reliability for total WHIM were high; (3) the WHIM had greater sensitivity than the GCS and the GLS for the exit from coma, the VS and the post-coma period (MCS, STR, good recovery from coma); (4) GLS, but not GCS, showed greater sensitivity than the WHIM for the deep coma period, as this extension of the GCS additionally assesses brain stem reflexes; and (5) for emergence from coma, VS and the post-coma period, the WHIM facilitates monitoring of subtle changes from week to week and from one day to another. As the period of emergence from coma also comprised the VS period, the WHIM appears to be a better tool to assess VS than the GCS or the GLS. Finally, in relation to the validity of the order of recovery proposed for the 66 items of the WHIM, we could mostly confirm the proposed sequence of

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recovery from coma.

In the light of these results, we conclude that the WHIM has achieved its claim as a tool to monitor recovery, at all stages, starting from coma to emerging from post-traumatic amnesia. The WHIM scales have great potential to monitor changes for patients that are VS, MCS or STR, and for patients when they are emerging from coma. This assessment is sensitive, reliable, and valid. However, some limitations do exist in relation to the reliability obtained in this study: Inter-rater agreement, even if globally satisfactory, could be better for some items. One reason for this could be the limited number of assessments taken into account for the reliability analysis; better results may be obtained by increasing the number of patients or assessments for reliability study. Nevertheless, qualitative analysis of the reliability results and discussion with the raters reveal that there is a need to develop and specify further the operational definitions for some items, especially for items 29 (frowning, grimacing) and 44 (is momentarily distracted by external stimulus, but can return to task). The implementation of baselines is also important, mostly for some of the first 10 items, but is especially important for VS and STR patients as item 4 (attention held momentarily by dominant stimulus), item 9 (makes eye contact following verbal request), and item 10 (looks at the person who is talking to the patient) can be ambiguous. A patient who exhibits stereotyped behaviours (e.g. head moving or constant random eye movement) could be judged as not reacting to a verbal request (e.g. look me in the eyes) if the behaviours after the request cannot be compared to pre-request behaviour. A detailed baseline (number of eye movements per minute, number of eye movements to the left, to the right, etc.) could be helpful and could show that eyes are moving more often to the examiner after request than before. This would be difficult and more time-consuming than standard assessment, but its clinical benefits would be invaluable if it enabled the awareness of the patient to be evaluated more accurately.

The sequence of recovery proposed in this 66-item WHIM is also interesting, as the ordering of the items of the scale was mostly confirmed by our empirical results. This shows that there is a certain regularity in the timing of reappearance of types of behaviours among patients, even if no patient follows exactly the same sequence of recovery all the time. This is in agreement with the results of the study by Shiel et al. (in press) as the sequence proposed was not considered conclusive.

Assessment with the WHIM in comparison to GCS also produced interesting results particularly when the GCS score is 8, a cut-off score that is often used to establish objectively the existence or absence of a coma. The results of this study, in agreement with the conclusions of the American Congress of Rehabilitation Medicine, have shown that this can lead to underestimation of the real state of consciousness of the patient. A score of 8 can be composed of different behaviours incompatible with coma (M3, V1, E4); in particular, assessment with the WHIM for patients with a GCS of 8 shows that many different behaviours are possible (eye contact for 5 seconds or longer, grimacing, eye tracking). We can confirm the recommendations of the American Congress of Rehabilitation Medicine (1995) that extensive clinical examination and not only GCS score must be used to diagnose coma; the WHIM scales appear to be a very useful tool in carrying out this task, since they offer a broad set of behaviours to be assessed, and each behaviour is based on operational definitions.

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The WHIM has also proved to be sensitive to subtle changes in patients diagnosed as VS or MCS. If the patient is offered a broader set of stimuli and tasks, s/he can show improvement even when traditional assessment with GCS would show no such improvement. Through assessment with the WHIM, the patient could seem less severely disabled than a GCS score taken at the same time would predict, which confirms the "functionality" of the WHIM; indeed, the authors of the WHIM wanted to measure performance—what a patient actually does, and not only capacity—what a patient can do. For VS or MCS patients, assessment with WHIM constitutes a unique opportunity to monitor a broader range of behaviours in a systematic and controlled manner; this in return makes it possible to validate the definitions and the clinical criteria proposed for VS or MCS, and to lead to better understanding of these states.

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