The Sensory Modality Assessment
Rehabilitation Technique — A tool for
assessment and treatment of patients with
severe brain injury in a vegetative state

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An analysis of data from 30 subjects diagnosed as being in vegetative state (VS) on admission to a specialized Brain Injury Unit was carried out. Rancho Level ratings given by the referring physician were compared with those of the units occupational therapists (OT). Scores were obtained from the Sensory Modality Assessment Technique (SMART) and the Western Neuro Sensory Stimulation Profile (WNSSP) on admission and at 2 monthly intervals and converted to Rancho Level ratings to allow comparison. The comparison of the assessments within one week of admission showed agreement between Rancho Level scores derived from the WNSSP and those from the referring physicians. The Rancho scores derived from the SMART were significantly different from the physicians’ and the WNSSP ($P < 0.01$), with the SMART rating the patient at a higher level of cognitive functioning. Although all 30 subjects were diagnosed as VS on admission, the SMART assessed six subjects not to be in VS within 2 to 4 months from admission and this was established at least 6 weeks earlier than the comparable conclusion from the WNSSP in four subjects. This initial validation study shows that the SMART is a useful tool in discriminating awareness and more sensitive at detecting the higher cognitive functions than both the WNSSP and referring physician, thus indicating the need to conduct a specifically designed prospective study to validate and further evaluate the SMART.

Introduction

Jennett and Plum (1) coined the term Persistent Vegetative State (PVS) to describe the patient who shows no evidence of mental function, but is no longer comatose. Patients have periods of wakefulness when their eyes are open and move, but their responses are limited to postural and reflexive movements of their limbs and they never speak. The Royal College of Physicians (2) described the patient in what they called continuing vegetative state as showing no evidence of awareness of self or the environment at any time, with no volitional response to sensory or noxious stimuli and no level of language comprehension or expression.

Although some authors consider Vegetative State (VS) as a specific syndrome, others have considered it a poorly defined category (3,4). The question as to whether the term itself should be used is under debate. Definition of the syndrome have been provided by a number of working parties including, the Multi-Society Task Force and the International Working Party on the management of the
Vegetative State patient on PVS (4), the Council of Scientific Affairs (5) and the American Academy of Neurology (6). These papers have made recommendations on the use of the terms persistent, permanent and continuing vegetative state. The working party convened by the Royal College of Physicians (2) suggested the term continuing vegetative state to describe the patient in VS for more than 4 weeks and permanent after 1 year.

Recent judicial decisions have highlighted the controversial issue of the withdrawal of feeding from patients diagnosed as VS. In 1992 the BMA Ethics Committee (7) concluded that artificial feeding was medical treatment and that it could be justifiably discontinued. The report stated that these decisions were based on the premise that a ‘correct and incontrovertible’ diagnosis by two experienced medical physicians had been established and was deemed morally justifiable where VS was assumed irreversible. The recommendations and standards provided by the Royal College of Physicians Working Party (2) state that to reach the diagnosis of PVS the two medical physicians must ‘use their own assessments separately and write clearly the details of their findings’.

**The limitations of existing assessments**

Horn et al. (8) identified in their review that although existing assessment scales go some way to addressing the assessment of the minimally responsive patient, none of these methods are entirely satisfactory and lack the sensitivity required to show subtle changes in the VS patient. A review of the literature (9) reveals that these existing assessment tools comprise of behavioural rating scales and assessments of the impact of sensory stimulation. However, none of these tools have been developed exclusively to assess and discriminate awareness in the patient diagnosed in VS.

Those assessments designed specifically to assess this group of patients in response to sensory stimulation included the Coma Near Coma Scale (CNC) (10), the Sensory Stimulation Assessment Measure (SSAM) (11) and the Western Neuro Sensory Stimulation Profile (WNSSP) (12). The CNC scale was designed to measure small clinical changes in patients with severe brain injury. Horn et al. (8) in their review concluded that studies into its efficacy ran on short term projects and that the tool required further validation to establish its usefulness in long-term settings. The SSAM (11) scale was developed to provide an accurate replicable assessment to assist in treatment planning and in scientific research but was not designed to discriminate the initial point of awareness.

**The development of the SMART**

The Sensory Modality Assessment and Rehabilitation Technique (SMART) was introduced in 1988 and further refined as a result of the experience of the occupational therapy (OT) staff at the Royal Hospital for Neuro-disability. The SMART is a categorization of levels of function described by Freeman (13,14) which in turn was developed from the parameters of the Glasgow Coma Scale (15). These categories have since been further extended to categorize all behavioural responses observed during the administration of the graded and structured sensory stimulation programme over a period of 8 years at the Royal Hospital for Neuro-disability.
to achieve arousal but also to increase the level of awareness of the patient. The SMART programme was designed to provide a structured sensory input and at the same time to assess the patient’s ability to process information and to enable the assessor to clearly differentiate the initial point of awareness. A state of awareness is demonstrated by distinct cognitive capacities which imply that these thought processes are being integrated by cortical activity (16). Therefore, although the patient in VS is aroused, indicated by eye opening and sleep wake cycles, they are unaware since they are unable to interact meaningfully with the environment.

The purpose of the study

The purpose of the present study is to compare the categorization of patients diagnosed as being in vegetative state using the SMART with that of a validated assessment tool (WNSSP) and that of the referring physician. At the time this study commenced the existing assessments were reviewed (9). Although assessments for patients in coma were widely accepted there were few empirically validated scales available to assess in detail low level functioning patients (8,10). A review of the test content of both the CNC (10) and the SSAM (11) revealed that the range of the assessments was limited in comparison to the WNSSP. Therefore, although not a gold standard, the WNSSP was selected to provide a measure by which to compare assessment results in the pilot study.

Freeman (17) stated that a patient’s response to stimulation and the environment needs to be measured and defined both more scientifically and methodically to assess and discriminate the point of the patient’s initial awareness, thus indicating emergence from VS. The study aimed to evaluate the efficacy of the SMART as a tool to enable the assessor to provide an incontrovertible diagnosis of the VS patient.

Method

Design

The research design used was a comparative study of the referring physician’s Rancho Level ratings (18) and data collected during the routine administration of the SMART and the WNSSP by the OTs. The data were collected from patients admitted to the specialized Brain Injury Unit at the Royal Hospital for Neurodisability over a five year period from 1989 to 1994.

Subjects

Inclusion criteria were all patients diagnosed as being in VS by the referring physicians on admission. Of the 30 patients who met the criteria of the study 15 (50%) had sustained traumatic brain injury, 5 (17%) had suffered anoxic or hypoxic
Assessment tools

Rancho Levels of Cognitive Functioning
The Rancho Levels of Cognitive Function scale (18) provides a set of definitions of specific behavioural functional at eight levels and was developed to aid the assessment process. The admission form for the hospital gives the Rancho scale and descriptions and asks referring physicians to assign patients appropriately. Both the SMART and WNNSP assessments can be used to assign patients to a rating on the Rancho scale to allow comparison.

Western Neuro Sensory Stimulation Profile
When the SMART was being developed prior to 1988, there was no objective measure of cognitive and communicative function in response to a sensory stimulation programme in the severely head injured patient. The WNNSP (12) subscales evaluate arousal/attention, visual comprehension, visual tracking, object manipulation and expressive communication on a multi-point scale. The scales are based on maturational data and on recovery sequences seen in the neurologically impaired person and were designed to assess function in patient in Rancho Levels 2,3,4 and early stages of 5. The manual for the WNNSP gives a criterion related validity for the WNNSP was established by computing a Kendall rank order correlation between subjects total scores on the WNNSP and their classification on the Rancho Scale. The WNNSP scores could therefore be converted to Rancho Level scores to allow comparison of the SMART and WNNSP. The WNNSP score was obtained from the WNNSP conversion table (12) to allow comparison with the SMART and where there was overlap with the WNNSP mean score the higher Rancho Level rating value was used.

Sensory Modality Assessment and Rehabilitation Technique
The SMART provides a hierarchically categorization of all the observed behavioural responses seen in patients diagnosed as in VS. The scale categorizes the responses observed to a sensory stimulation programme involving visual, tactile, auditory, olfactory, gustatory stimuli, and the patient’s level of wakefulness and functional motor and communicative ability. The SMART is designed to provide quantitative data on the assessment of the patient’s cognitive function and potential awareness in the patient through hierarchical categorization of observations of the patients response to a sensory stimulation programme. However, unlike other assessment scales the SMART also provides qualitative information on the level of response to sensory stimulation which is comparable across sensory modalities and clearly identifies evidence of awareness.

The hierarchical scale assesses responses at five levels—no response (Level 1) through reflexive, withdrawal, localizing and finally discriminating response (Level 5). A consistent response (on five consecutive occasions) at the discriminating level in all modalities (except wakefulness) indicates awareness and emergence from VS. For instance, for the auditory modality, level 1 is no response, level 2 indicates a reflexive response which might be repetitive blinking, startled or reflexive facial expression to auditory stimulus from clackers, blocks or a whistle. Level 3 is a withdrawal response includes blinking and then habituation to loud sound or move-
differentiating response which includes ability to follow basic command such as ‘close your eyes’ or ‘press the buzzer once’ or to differentiate by pointing at a named object, picture, word, shape, colour, letter or a ‘yes’ or ‘no’ card. A consistent response at level 5 in any modality (except wakefulness) e.g. the ability to follow verbal or visual command demonstrates awareness and therefore emergence from VS. The SMART hierarchical scoring system directly relates to the descriptions in the Rancho scale (9). The scale enables the assessor to allocate an equivalent Rancho Level rating for the patients response to each sensory modality and also allow comparisons across modalities. This system facilitates the identification of the best response for modality and clarifies the initial point of awareness. For the purpose of this study the highest SMART and therefore, Rancho score across the modalities was taken.

Procedure
The SMART is routinely administered by the OTs as part of the daily treatment programme and the WNNSP on admission and at two-monthly intervals on the Brain Injury Unit at the Royal Hospital for Neuro-disability. The Rancho Level rating by the referring physician and the relevant patient data were retrieved from the referral form. The SMART and WNNSP data were obtained from the initial assessment which was carried out in the first week of admission and subsequently for those carried out at two-monthly intervals until discharge. For the purposes of the study, the subtest and total scores of the SMART and WNNSP, and their related Rancho Level ratings were obtained from the assessment forms completed on the same day. The information retrieved was coded and analysed on a computer database using the SPSS statistical package.

All 30 subjects were assessed on two occasions, 22 on three occasions and 9 on four occasions, with 92 assessments administrations in total. Both the SMART and the WNNSP assessments were administered by the same assessor for each subject throughout the duration of the study. All of the assessors were occupational therapists. Assessor One (the author) assessed 19 subjects, six were assessed by Assessor Two, two by Assessor Three and three by Assessor Four. All the assessors received a comprehensive training and monthly review to ensure a consistent administration procedure was followed.

Results
The mean age of the subjects at the time of injury was 33.9 years (standard deviation (SD) 11.8 years, range 16.4–57.8 years). The mean time since injury on inclusion in the study was 14.3 months (SD 13.5 months, range 2.1–59.7 months).

The first analysis compared the Rancho Level rating of the referring physician, the SMART and the WNNSP on admission. A Wilcoxon z value test was conducted and the results ($z = -0.53, p = 0.59$) illustrated that there was no significant difference between the Rancho Level rating scale attributed by the referring physician and those attributed by the WNNSP. However, a moderately significant difference ($z = 2.93, p < 0.01$) was found between the Rancho Level scores attributed by the referring physician and the SMART.
The second analysis reviewed the distribution of Rancho ratings obtained from the SMART and WNNSP for each patient. Figures 1–4 illustrate the number of patients categorized in Rancho Level 2, 3, 4 and 5 by SMART and WNNSP on Occasions 1–4 showing that the SMART rates patients at a higher level of cognitive function according to the Rancho Level rating than the WNNSP. The distribution of the Rancho score obtained from the SMART and the WNNSP were compared using the Wilcoxon z value test and the results are indicated in Figures 1–4.

The resulting probabilities indicated a significant differences \( p < 0.01 \) between the distribution of the Rancho Level ratings obtained from the SMART and

<table>
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<th>Rancho level</th>
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<th>SMART Level Occasion 1</th>
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Figure 2. Distribution of Rancho level rating achieved from the SMART and WNSSP for patients on Occasion 2. $z$ value = 3.18 $p < 0.01$. 
WNSSP assessments on occasions 1, 2, and 3, the higher score being derived from the SMART.

The onset of awareness was identified in six patients during the study. The SMART identified onset of awareness 2 months ahead of the WNSSP in two patients, and at the same time in another two. With the remaining two patients only the SMART assessed signs of awareness. Evidence of awareness was confirmed independently by other experienced member of the multi-disciplinary team.

An inspection of qualitative data from these patients was carried out to identify the behaviours which signified a return to awareness. One patient’s awareness was identified by his ability to follow a written command. The other five patients demonstrated an ability to follow auditory commands. Their capacity for movement in all cases was extremely limited and difficult to detect through assessors’ observations. However, they were all found to be able to operate a buzzer switch which was sensitive to slight active movement. Once a consistent response was established the patients all progressed to communicate ‘yes’ and ‘no’ using one buzz for ‘yes’ and two for ‘no’.

Discussion

In the comparisons of the Rancho Level ratings obtained from the SMART, WNSSP and the referring physician it was found that the SMART consistently indicated a higher level of cognitive function than the WNSSP and also that given by the referring physician. Of those six patients who recovered awareness, in two
WNSSP and in the last two cases the SMART identified awareness but the WNSSP did not.

The need for a sensitive assessment scale to assess patients optimum potential function

The results conversion table in the WNSSP (12) assessment provides the assessor with the comparison of the maximum and mean score of selected subtests, and the total score of results gained from patients during the validation studies. These are compared to the Rancho Level rating of the patients included in the study. Ansell and Keenan (12) stated that since criterion related validation was established for the WNSSP, a high score on the WNSSP would reflect recovery of cognitive function. This provides a useful tool to assess change in the patient’s response and helps to identify the patient’s areas of abilities. However, unlike the SMART the WNSSP multi-point scoring system does not allow for comparison of responses across sensory modality nor can the initial point of awareness be clearly discriminated in terms of behavioural output.

A review of the structure of the scoring systems for both tests gives further indication why the SMART appears to rate patients at a higher level of cognitive function. The WNSSP relies on the patient to be able to perform all given tasks. An example can be seen in the auditory modality section of the WNSSP where the patient's scores are added up. Therefore the patient will receive a low score if they are only able to respond to one command. The patient may be cognitively intact but their ability to respond may be confounded by their limited physical ability. The SMART however will assign a score for all responses up to the highest level response. Therefore the patient will be attributed a maximum score of 5 out of 5 for demonstrating only one consistent response to verbal commands since their ability to respond to other commands may be due to their limited motor function rather than their inability to comprehend the instruction. The SMART therefore provides a clear indication of the patient’s best functional response.

The range and diversity of the SMART assessment

Of the six patients assessed to have emerged from VS, five demonstrated ability to follow verbal commands although this movement was minimal and therefore difficult to detect through visual observation. The auditory discrimination subtest using a specific motor function to elicit an auditory response on a single switch buzzer is an assessment component exclusive to the SMART. It seems unlikely that the level of awareness of these patients would have been detected on other existing assessment tools. The SMART may show greater sensitivity because of a wider range of alternative methods of stimuli offered for the patient to be able to show their potential for functional ability.

A review of the test content of the SMART, WNSSP (12) and SSAM (11) and the CNC (10) illustrated that although all the assessments test the same areas of function, the SMART offers a wider range of assessments of patient responses to enable the patients to have the opportunity to express their functional ability and cognitive capacities. Wilson et al. (19) stated that existing views of the VS patient
perception of the patient’s abilities may change. Wilson et al. (19) therefore recommend offering the patient as many pathways as possible to elicit the best response. The SMART shows greater sensitivity because of wider range of alternative methods offered for the patient to demonstrate their functional ability compared to the test components of the existing assessment tools.

Two cases, not included in the study can be used to illustrate this point. One was a patient diagnosed as being in VS by experienced physicians for the previous 7 years. Following assessment on the SMART he was able to use small motor function to operate a buzzer to select letters to enable him to write letters to his wife and communicate his feelings. The other patient was referred 2 years post injury as vegetative following extensive assessment at a specialized neurological unit. He was subsequently assessed to be out of VS by the SMART within one week of admission and he is now able to access a computer to spell words and form sentences. He has since been able to recount his statement of events leading to his injury.

Establishing a correct diagnosis — the need for frequent assessment over time

The Royal College of Physicians of London have recently published recommendations and standards (2) which state that the physician designated to assess if patients are in PVS should ‘use their own assessment’. Berrol (20) emphasized that the failure of the assessor to recognize the distinguishing cognitive functions has led to confusion in diagnostic classifications. In a study by Childs, Mercer and Childs (21) behaviour indicative of cognitive responsiveness was found in 37% of the patients admitted diagnosed to be in coma or VS. This is reflected in the experience with patients admitted to the Brain Injury Unit at Royal Hospital for Neuro-disability. Andrews et al. (22) reported that of 40 patients admitted with a diagnosis of the vegetative state 43% were considered to be misdiagnosed. Evidence of awareness was established by the occupational therapy staff using the SMART. This study suggests that physicians assessment measures may at present be insufficiently sensitive to reach a correct diagnosis of VS.

The SMART was designed to provide treatment and also enable the patient’s response to be assessed on a daily basis to optimize opportunity to observe the potential for functional and meaningful interaction with the environment. Berrol (20) suggested that single evaluation of the patient was an inadequate basis from which to establish a diagnosis and that accurate assessment requires serial neurological evaluation since the patient in VS exhibits a behavioural repertoire at infrequent and unpredictable intervals. However, the recent paper by the Royal College of Physicians (2) stipulates that whilst assessing a patient to ascertain if they are in PVS the patient should receive one assessment by two separate medical physicians. If there is doubt over the diagnosis this process is repeated. The paper concludes that when diagnosis of PVS has been established by identification of cause of injury, the clinical state of the patient and the lapse of time then a decision can be made that recovery cannot be achieved. This decision may ultimately lead to the termination of the patients life. In the light of the results of this study and considering the controversial issue of withdrawal of feed from patients diagnosed in PVS it is clear that more stringent guidelines on the method, frequency and duration of
Rader and Ellis (11) stated that existing measures rarely demonstrate sensitivity to the subtle shifts in the VS patient’s function. The present results introduce the SMART as a tool with a scoring system which relates directly to the levels of function and possess the sensitivity to identify these ‘subtle shifts in function’ in the VS patient and identify initial point of awareness.

The SMART as a potential diagnostic and research tool

The findings also revealed that six patients were diagnosed as having emerged from VS within 2 to 6 months of admission to the Unit. Although this may be attributed to spontaneous recovery, the results reveal the need for further study to assess the factors which may contribute to the patient’s ability to respond meaningfully to a sensory stimulation programme on admission to the Unit. These factors may include changes in the patient’s medical and nutritional status or the optimization of the patient’s position, through provision of a wheelchair seating system, to maximize their potential functional ability to respond to the assessment process. The study introduces the potential for the SMART to be used as a diagnostic and research tool to accurately monitor subtle changes in the patient’s behavioural responses and level of awareness.

Summary

It would appear that there may be many patients who are wrongly given the label of VS (21,22) as a direct result of the diverse variations on assessment procedures currently used, the lack of sensitivity and scope of existing assessment tools and the infrequency of assessment with the PVS patient. Since this preliminary analysis indicates the greater sensitivity of the SMART compared to existing tools, there is a need to continue the evaluation of this tool and validation research as is presently in progress at Royal Hospital for Neuro-disability. The results suggest that the SMART may potentially provide a structured and discriminating assessment tool for the accurate assessment of awareness in the patient diagnosed in VS in the future.

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