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The diagnostic accuracy of the Revised Westmead PTA Scale as an adjunct to the Glasgow Coma Scale in the early identification of cognitive impairment in patients with mild traumatic brain injury

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ABSTRACT

Background: The assessment of patients with mild traumatic brain injury (mTBI) is predominantly done using the Glasgow Coma Scale (GCS). While the GCS is a universally accepted for assessment of severity of Traumatic Brain Injury, it may not be appropriate to rely on the GCS alone when assessing patients with mTBI in pre-hospital settings and Emergency Departments.

Objective: To determine whether administering the Revised Westmead PTA Scale (R-WPTAS) in addition to the GCS would increase diagnostic accuracy in the early identification of cognitive impairment in patients with mTBI.

Methods: Data were collected from 82 consecutive participants with mTBI who presented to the emergency department of a Level 1 Trauma Centre in Australia. A matched sample of 88 control participants who attended the emergency department for reasons other than head trauma was also assessed. All patients were assessed using the GCS, the R-WPTAS and a battery of neuropsychological tests.

Results: Patients with mTBI scored poorly compared with control patients on all measures. The R-WPTAS showed greater concurrent validity with the neuropsychological measures than the GCS and significantly increased prediction of group membership of patients with mTBI with cognitive impairment.

Conclusions: The R-WPTAS significantly improves diagnostic accuracy in identifying patients with mTBI who may be in PTA. Administration takes less than one minute, and since early identification of a patient's cognitive status facilitates management decisions, it is recommended for routine use whenever the GCS is used.

Mild traumatic brain injuries (mTBI) constitute 70-90 percent of all head injuries.¹ The Glasgow Coma Scale (GCS) [2,3] is an important part of the clinical assessment of these patients in pre-hospital settings and Emergency Departments. The GCS measures level of consciousness via assessment of eye opening, response to commands and orientation to time, place and person. Designed to assess level of consciousness, the GCS contains no measure of the ability to lay down new memories, although it does test aspects of remote memory. This is of relevance as new learning has been demonstrated to be one of the best predictors of outcome after traumatic brain injury (TBI).[4] The Westmead PTA Scale was designed to assess the ability of TBI patients to lay down new memories over a 24-hour period.[5,6] It contains brief measures of orientation to time, place, and person as well as the ability to remember new information from one day to the next. By measuring both orientation and capacity to form new memories, the Westmead PTA Scale has been found to be clinically useful in TBI populations who may be in post-traumatic amnesia (PTA), having a high degree of inter-rater reliability as well as concurrent and predictive validity.[7,8,9] For patients with milder injuries, preliminary research has shown that a modified version of this scale can be used to reliably assess the capacity to lay down new memories over shorter time periods[10], allowing assessment of PTA soon after the injury has occurred.

Although the GCS has proved useful as an initial measure of severity of brain injury and is in common use, it has been said to have limitations when used to assess patients with minor injuries. [11] One of its senior developers, Sir Professor Teasdale, has said that the definition of mild or even minor head injury in a patient with a GCS score of 13-15 is most unsatisfactory.[12] One of the shortcomings, he has argued, is that patients with a coma score of 15 make up, by far, the overwhelming number of patients classified in this group. Therefore, the inclusion of all patients with a coma score of 13-15 in the same category underestimates the true severity of injury of patients with scores of 13 or 14. He has stressed that this classification also gives an impression of undue seriousness to those with a coma score of 15. A further concern with the use of the GCS is that there is a subgroup of patients with short or negligible coma and prolonged PTA.[13,14] Despite these limitations, given the widespread adoption of the GCS in the assessment of patients with TBI, it is unlikely health workers will cease using it[3], as it gives important baseline data in patients who may deteriorate.

It appears that only four studies have been published in recent years in which PTA has been recorded prospectively using a standardized test in patients with mild to moderate head injury. In the first, Schwartz et al., tested patients on the Galveston Orientation and Amnesia Test (GOAT) and a three-word and three-picture recall task.[15] However, this was done on a 24-hour recall basis and has not been tested over shorter time periods.

The second study was conducted by Van Der Naalt et al.[16] However the scale used in the study was predominately made up of orientation questions and did not test new learning ability. This highlights a need to develop a scale that adequately measures both orientation and new learning ability over shorter time periods.

The third study, by Ponsford et al., demonstrated that a revised version of the Westmead PTA Scale could be used for assessing adult patients with mTBI in an emergency department (ED) at hourly intervals. Scores from the revised scale were found to correlate with GCS scores and estimated duration of PTA. However, Ponsford et al.

recommended that further studies would be required using their revised scale on an independent sample of patients with mild TBI.

The fourth study was that by De Monte et al[17] who investigated whether a single determination of orientation and retrograde amnesia using eight orientation questions from the GOAT could be sufficient to provide an index of severity of mTBI within the first 24 hours. As with the Van Der Naalt et al. study, new learning ability was not measured. Results revealed that 17% of the non head injured orthopedic control group were misclassified as being in PTA.

The present study involved a prospective neuropsychological evaluation of consecutive patients presenting to an ED with a history of mTBI as well as a matched control group of patients in the ED who presented for reasons other than a TBI. During the acute treatment phase all patients were assessed on the GCS and the revised Westmead PTA Scale (R-WPTAS). In the research assessment conducted shortly prior to discharge the GCS, R-WPTAS, ImPACT Trauma© computerized neurocognitive test, Concussion Symptoms Checklist, Westmead Selective Reminding Test (WSRT) and GOAT were administered. The aim was to determine whether administering the R-WPTAS, in addition to the GCS, would increase diagnostic accuracy in identifying cognitive impairment in patients with mTBI. This study is also the first independent study to validate the R-WPTAS. We hypothesized (i) that patients with mTBI would have lower scores on all measures than control patients; (ii) the R-WPTAS would have greater concurrent validity with the neuropsychological measures than would the GCS scores; (iii) the diagnostic accuracy of the R-WPTAS in identifying significant cognitive disability in patients with mTBI would be greater than that of the GCS.

METHOD

Participants

Participants were adults, aged between 18 and 61 years, who presented for treatment to the ED at John Hunter Hospital, a Level 1 trauma centre and tertiary referral hospital, in New South Wales (NSW), Australia. For inclusion in the mTBI group, patients had to meet the American Congress of Rehabilitation Medicine (ACRM) criteria[18] with revision by World Health Organization (WHO)[19], except that patients with intracranial lesions were excluded.

Exclusion criteria were a skull fracture, transfer out of the ED for further management of the TBI, acute cognitive impairment secondary to drug or alcohol abuse (based on clinical judgment by the research psychologists), any coincident medical/neurological illness and an inability to use the dominant hand (due to computerized tests). Numbers and reasons for those excluded based on unsuitability are listed in Figure 1.

A consecutive series of patients with mTBI were approached while research assistants trained in neuropsychological test administration were on duty in the ED between February and September 2005. This represented 81% of all mTBI's who presented. GCS and R-WPTAS data were only analysed for those patients who agreed to become research participants and complete the neuropsychological research battery.

Control participants were matched by age, education and gender to the participants with mTBI. They had presented to the ED with injuries other than head injuries and did not require admission to hospital. Overall, 156 control patients were approached, 56 declined and 100 agreed to participate in the study. Exclusion criteria were acute cognitive impairment secondary to drug or alcohol abuse (based on clinical judgment by the research psychologists), any coincident medical/neurological illness and an inability to use the dominant hand.

Neither mTBI nor control patients were excluded on the basis of a history of alcohol abuse, previous head injury, neurological disorder, psychiatric problems or learning difficulties as these factors are known to influence outcome following mTBI and removing such participants would be likely to bias the results.[10]

The study was approved by the ethics committees of the Hunter New England Area Health Service, Newcastle, the Central Sydney Area Health Service, and Macquarie University, Sydney, Australia.

Measures

Revised Westmead PTA Scale (R-WPTAS)

The R-WPTAS (Figure 2) consists of a combination of the Best Verbal Response questions (BVRQs) of the GCS and the modified version of the Ponsford et al.'s revised Westmead PTA Scale.[10] The GCS's BVRQs assess the injured person's orientation to time, place and person. Since some of the GCS and R-WPTAS' BVRQs overlap, these questions were asked only once. The possible range of scores for trial 1 was 0-9 and for subsequent trials 0-12.

Figure 2 Revised Westmead PTA Scale

	<i>Answer T1</i>	<i>ST1</i>	<i>Answer T2</i>	<i>ST2</i>	<i>Answer T3</i>	<i>ST3</i>
1. What is your name?*						
2. What is the name of this place? * (If no answer, prompt by providing names of 3 hospitals)						
3. Why are you here?*						
4. What month are we in?*						
5. What year are we in?*						
6. In which town/suburb are you in?						
7. How old are you?						
8. What is your date of birth?						
9. What time of day is it? (Prompt Morning, Afternoon, or Evening)						
10. Picture 1	Show pictures for approx. 5 seconds					
11. Picture 2						
12. Picture 3						
	Total		Total		Total	

Answer T1 = verbatim answer at 1st neurological observation; ST1 = score at 1st neurological observation; Answer T2 = verbatim answer at 2nd neurological observation; ST2 = score at 2nd neurological observation; Answer T3 = verbatim answer at 3rd neurological observation; ST3 = score at 3rd neurological observation; * = overlapping orientation questions on the GCS and the R-WPTAS.

Glasgow Coma Scale (GCS)

Acute GCS scores for the patients with mTBI were obtained from their medical files.[2] For the control patients, GCS scores were computed from the GCS' BVRQ scores (overlapping with the R-WPTAS) obtained at the research assessment. To this score 10 points were added (range 3-15), based on the assumption that if control patients who were ambulant and alert and were capable of appropriately responding to orientation questions, they would be assumed to obtain a maximum score on the GCS' Best Eye Opening component (a score of 4) and Best Motor Response component (a score of 6).

ImPACT Trauma©

ImPACT Trauma© is a computer program, developed to assess patients following concussion. It measures multiple aspects of cognitive functioning and yields five summary scores which are Verbal Memory, Visual Memory, Reaction Time, Visual Motor Speed and Impulse Control (a validity index).[20]

Concussion Symptoms Checklist (CSC)

ImPACT Trauma© also includes a CSC which measures the degree of the patient's Post Concussion Syndrome based on the patient's self-reported severity of post concussion syndrome symptoms, the possible range being 0-132.

Westmead Selective Reminding Test (WSRT)

Participants are asked to remember as many words (out of ten standard items) as they can over ten repeated learning trials. Participants' Consistent Long Term Retrieval (CLTR) was scored according to the WSRT protocol, representing a count of the number of words consistently retrieved over the ten trials, the possible range being 0-100.[9]

Galveston Orientation and Amnesia Test

The Galveston Orientation and Amnesia Test (GOAT) is a quantitative rating scale that measures disorientation and amnesia during the recovery process following TBI. It consists of 16 question assessing orientation to time, place, person and memory for events preceding and following injury. The possible range in scores is 0-100. A score greater than 75 on at least two consecutive occasions indicates emergence from PTA.[21]

Procedures

mTBI participants

Acute treatment phase: The R-WPTAS was initially administered by ambulance officers at the scene of the accident or on route to hospital to 16% of patients with mTBI. In the ED, patients were administered the R-WPTAS by clinical staff every hour over the four hour routine observation period. If a patient gave incorrect or no answers, clinical

staff immediately presented the correct answer to the patient for memory storage and later recall. In respect to the picture card task, at the first neurological observation, patients were shown a set of three pictures and told to remember them. At the second and every consecutive neurological observation, patients were required to recall or recognise the pictures presented in the previous trial. If successful, a new set of three pictures was presented. If patients were not successful, the same set of pictures was presented again for memory storage and later recall. At each hourly interval patients were also assessed with the GCS, receiving a conventional GCS score.

Research assessment: Once patients with mTBI were cleared for discharge, they were formally invited to take part in the research and consent obtained. Participating patients with mTBI were breathalyzed and their alcohol reading recorded. Demographic information, a brief medical history and any history of learning difficulties and drug and alcohol abuse was obtained. Patients were administered ImpACT Trauma©, CSC, WSRT, and the GOAT.

Control participants

Research assessment: Control participants were approached for research participation while in the ED and consent obtained. They were given the same measures as the participants with mTBI at the research assessment described above. However, the R-WPTAS was only administered twice providing one measure involving recall after approximately one hour.

Statistical analysis

Group differences on demographics, learning difficulties, psychiatric and TBI histories, drug and alcohol use, blood alcohol level, and morphine administration were assessed using Mann-Whitney *U* tests or Fisher's Exact tests as appropriate. Group differences on amnesia and neuropsychological measures and their concurrent validity were analyzed using multivariate analysis of variance (MANOVA) on SPSS v15 based on the results from the time of the research assessment. Comparison of diagnostic accuracy (diagnosis of cognitive impairment in patients with mTBI) was conducted using receiver operating curve (ROC) analysis using MedCalc[22] and web based software from the Centre for Evidence Based Medicine, University of Toronto[23] based on results obtained at the second neurological observation because this was the earliest point at which new learning could be assessed.

RESULTS

The majority of participants were male (77%). The mean age was 30.74 (SD = 11.34, range = 18–61), and mean years of education was 11.65 (SD = 2.13, range = 7.0–20.0). In the mTBI group, the main cause of mTBI was through road traffic accidents (43%), followed by assault (27%), sport injury (15%), fall (10%) or hit by an airborne object (5%). In the control group, the major cause of injury was through sport injury (34%), followed by fall (25%), other causes (25%), motor vehicle accident (9%) and assault (7%). On presentation to the ED, participants with mTBI had a mean GCS score of 14.67 (SD = 0.63, range 13-15).

Twenty-one research participants (9 mTBI and 12 control patients) were excluded from the analyses as they achieved a score of 20 or higher on the Impulse Control measure of ImPACT Trauma© thus raising questions regarding the reliability of their results.[24] A further research participant was excluded as his injury did not meet mTBI criteria. Final sample size was 82 mTBI and 88 control participants (Figure 1). Not all tests were completed by all participants, marginally reducing the sample size for some analyses. No significant differences were found between groups in terms of gender, age, education, learning difficulties, psychiatric problems, alcohol use, and drug use (Table 1). Participants with mTBI received significantly more morphine administrations ($p<.001$), had significantly higher blood alcohol readings at the time of the research assessment ($p<.001$), and reported more previous head injuries than controls ($p<.001$).

Table 1 Demographic statistics for mTBI and control participants

Variable	mTBI participants (n=82)		Control participants (n=88)		p
	M	SD	M	SD	
Gender (%)	76 (males)		78 (males)		0.72 ^b
Age (years)	31.5	11.6	30.0	11.1	0.50 ^a
Education (years)	11.4	2.1	11.9	2.1	0.18 ^a
Blood alcohol level	0.01033	0.031942	0.00672	0.025338	0.032 ^{ac}
History of brain injury (number of injuries)	1.5	1.8	0.7	1.2	0.001 ^{ac}
Morphine administration (%)	17		0		0.001 ^{bc}
Learning difficulties (%)	23		24		1.0 ^b
Psychiatric problems (%)	7		7		1.0 ^b
Alcohol use (%)	57		68		0.16 ^b
Drug use (%)	13		10		0.64 ^b

P-values for age, education, blood alcohol level, and history of brain injury are from nonparametric, Man Whitney U tests. P-values for gender, morphine administration, learning difficulties, psychiatric problems, alcohol use, and drug use are from Fisher's Exact Tests.

^aMann-Whitney *U*-tests.

^bFisher's Exact tests.

^csignificant at $\alpha = 0.05$

In the mTBI group the proportion of patients at the second neurological observation with GCS scores of 13, 14 and 15 were 2%, 11% and 87% respectively. In the control group the proportions were 0%, 2% and 98% respectively.

Group comparisons

MANOVA results after controlling for blood alcohol level, number of previous head injuries, and morphine administration, showed significant group differences on all measures except Impulse Control. ImPACT Trauma©'s summary scores including CSC, R-WPTAS, WSRT, GOAT and GCS scores obtained at the research assessment were the

dependent variables. The independent variable was patient group. Wilks' Lambda revealed a significant multivariate effect of patient group on all measures of cognitive performance and concussion symptoms [$F(10,151)=8.83$, Partial Eta²= .369, $p<.001$].

When the results for the dependent variables were considered separately, all measures, except Impulse Control ($p=.207$), reached significance. Effect sizes are presented in Table 2 (amnesia tests) and Table 3 (neuropsychological measures). To obtain a reduced set of dependent variables with each contributing to differentiate the groups at $p<.01$, a stepwise discriminant function analysis (DFA) with the five ImPACT Trauma© summary scores was performed. The DFA identified Verbal Memory and Reaction Time as significant factors. Based on the DFA results, the Verbal Memory and the Reaction Time summary scores were used as dependent variables for subsequent analyses.

Table 2 Means, standard deviations and effect size for group differences on the amnesia tests at the research assessment in descending order

Variable (Possible score range)	mTBI participants (n=79) <i>M (SD)</i>	Control participants (n=86) <i>M (SD)</i>	<i>P</i>	<i>d</i>
R-WPTAS (0-12)	10.8 (1.4)	11.9 (0.4)	0.001 ^a	1.07
GOAT (0-100)	96.2 (4.2)	98.9 (2.4)	0.001 ^a	0.79

P-values are from a MANOVA, controlling for blood alcohol level, morphine administration and history of brain injury. Cohen's *d* was calculated from means and standard deviations.[25] R-WPTAS = Revised Westmead PTA Scale (Glasgow Coma Scale's Best Verbal Response questions and Westmead PTA Scale items); GOAT = Galveston Orientation and Amnesia Test.

^asignificant at $\alpha = 0.5$.

Table 3 Means, standard deviations and effect size for group differences on neuropsychological measures at the research assessment in descending order

Variable	mTBI participants (n=79) <i>M (SD)</i>	Control participants (n=86) <i>M (SD)</i>	<i>p</i>	<i>d</i>
ImPACT CSC	39.6 (20.3)	14.4 (16.8)	0.001	1.35
ImPACT Verbal Memory	0.7 (0.1)	0.8 (0.1)	0.001	1.16
ImPACT Reaction Time	0.8 (0.2)	0.6 (0.1)	0.001	1.11
ImPACT Visual Memory	0.3 (0.2)	0.6 (0.2)	0.001	0.99
ImPACT Visual Motor Speed	27.2 (7.1)	34.5 (7.8)	0.001	0.99
WSRT	36.5 (22.9)	59.4 (24.0)	0.001	0.98
ImPACT Impulse Control	8.2 (5.4)	6.6 (4.9)	0.21 ^a	0.30

P-values are from a MANOVA, controlling for blood alcohol level, morphine administration and history of brain injury. Cohen's *d* was calculated from means and

standard deviations.[25] ImPACT CSC = ImPACT Trauma© Concussion Symptom Checklist; WSRT = Westmead Selective Reminding Test.

^anon-significant at $\alpha = 0.5$.

Concurrent validity

To investigate the concurrent validity of the GCS and the R-WPTAS on cognitive functioning as assessed by ImPACT Trauma©, two MANOVAs were carried out in the mTBI group only. The independent variable in the first MANOVA was the GCS and in the second MANOVA was the R-WPTAS. In this within group analysis only blood alcohol level emerged as a covariate and was controlled for subsequently. Results for GCS were not significant, explaining less than 1% of variance in cognitive functioning [$F(2,76)=.334, p=.717, \text{Partial Eta}^2 = .009$]. Results for R-WPTAS revealed a significant multivariate effect, explaining 28% of variance in cognitive functioning [$F(2,76)=14.82, p<.001, \text{Partial Eta}^2 = .281$].

Comparison of diagnostic accuracy

ROC analysis was used to determine optimal cut-off points of group discrimination for the GCS and the R-WPTAS (maximizing sensitivity and specificity) in terms of diagnosis of cognitive impairment. Based on the GCS score at the second neurological observation (the earliest point at which new learning could be assessed) a score of ≤ 14 was considered “disease positive”. A score of 15 was considered “disease negative”. Based on the R-WPTAS score at the second clinical neurological observation a score of ≤ 11 was considered “disease positive”. A score of 12 was considered “disease negative”. The sensitivity, specificity, positive predictive value and negative predictive value are presented in Table 4. The R-WPTAS had a sensitivity of 60 % and the GCS 13%. The R-WPTAS had a larger area under the curve than the GCS [95% CI .69 - .82 and .49 - .64, respectively ($p<.001$)].

Table 4 Predictive accuracy of the R-WPTAS and the GCS at time of the second neurological observation with 95% confidence intervals

	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
R-WPTAS	0.60 (0.49-0.70)	0.91 (0.83-0.95)	0.86 (0.75-0.93)	0.71 (0.62-0.78)
GCS	0.13 (0.08-0.22)	0.98 (0.92-0.99)	0.85 (0.58-0.96)	0.55 (0.47-0.62)

R-WPTAS = revised Westmead PTA Scale; GCS = Glasgow Coma Scale.

DISCUSSION

Results of this study suggest that the R-WPTAS is more accurate than the GCS in identifying adult patients with mTBI who may be cognitively impaired in an ED.

A consecutive sample of patients with mTBI was shown to have significantly lower scores on cognitive measures than a control sample matched by age, education and

gender. The R-WPTAS showed greater concurrent validity with the neuropsychological measures from ImPACT Trauma© than the GCS. A significantly greater amount of variance was explained by the R-WPTAS, than the GCS on these measures suggesting a much stronger relationship between the R-WPTAS and neuropsychological function than that shown by the GCS. This has been shown previously in patients with more severe traumatic brain injuries using the original Westmead PTA Scale[8] confirming the utility of this measure across a range of patients with differing brain injury severity. At the second neurological observation, while the GCS only misidentified 2% of the control participants and the R-WPTAS 9%, the GCS only correctly identified 13% of the participants with mTBI whereas the R-WPTAS correctly identified 60%. Although the positive predictive values for both measures were similar, the confidence interval for the R-WPTAS was much narrower thus increasing the accuracy of the test. ROC analysis confirmed superior diagnostic accuracy on the part of the R-WPTAS. Given the high base rate in this study (48%), predictive values will be lower in centers with a lower base rate than that in the present study.

The R-WPTAS consists of items taken from Ponsford et al.[10] version of the Westmead PTA Scale and the BVRQs from the GCS. At the time of their second neurological observation 60% of participants with mTBI could not lay down simple new memories yet 87% of these had been assigned a GCS of 15. Although the GCS was not designed to measure memory (except some aspects of remote memory), in everyday use in pre-hospital settings and Emergency Departments the normal score of 15 is usually taken to imply normal brain function (which implies normal new learning capacity). The present study suggests this is not the case. It can thus be argued that the use of the R-WPTAS would contribute significantly to the accuracy of monitoring patients with mTBI to ensure that they are either not discharged from hospital or referred on for further assessment after discharge while still suffering significant cognitive impairment. While it misclassified 9% of ED control participants this is lower than the 17% reported by De Monte et al.[17] By the time the GOAT was administered at the research assessment, patients were scoring well above the cut-off of 75 which suggested that they were out of PTA. This would indicate a lack of sensitivity on the part of the GOAT as the R-WPTAS mean score was still in the PTA range.

The operational definition of PTA for moderate to severe TBI states that “a person is said to be out of PTA if they can achieve a perfect score on the [original] Westmead PTA Scale for 3 consecutive days” (Marosszeky et al.[6] p. 16). Recent research on cases of more severe head injuries has suggested that patients have probably emerged out of PTA when they first score 12/12 on the Westmead PTA Scale. [26] Results from the current study suggest that for patients with mTBI a perfect score on their second neurological observation, which is the first occasion on which new memory is assessed, may be enough to show that they have emerged from PTA. Further studies, however, will be required to validate the reliability of this finding in an independent sample of patients with mTBI while a concurrent “gold standard” cognitive test is administered. In this study it was a limitation that the concurrent neuropsychological tests were only administered at the time of the research assessment once patients’ consent to participate had been obtained. To overcome this problem, the timing of research assessments will need to be negotiated with ethics committees if the optimal time for identification of amnesia is to be determined. Ethical constraints precluded collection of demographic data

on patients who declined to become participants. Future studies would also need to attempt negotiation with ethics committees so this data can be collected.

It should be noted that the R-WPTAS procedure is only appropriate for patients with mTBI and therefore the original Westmead PTA Scale procedures which involve assessment on a daily basis, will remain appropriate for patients with more severe injuries.

The issue of whether or not patients in ED's have had a brain injury is redundant as this is determined by the presenting clinical history. The issue to be addressed is: does the patient have ongoing symptoms of brain impairment which will influence management decisions? The evidence from this study, which confirms previous studies, is that use of the R-WPTAS as an adjunct to the GCS can significantly assist in rapidly identifying those patients with mTBI who may need further management.

The administration of the R-WPTAS takes less than one minute and is thus time efficient and cost effective. This is a distinct advantage over other well established neuropsychological test protocols used for the accurate assessment of patients with mTBI. These other test protocols are not only time-consuming but also can usually only be administered by trained neuropsychologists, making such assessments impractical for routine use in acute situations. The ease of administration of the R-WPTAS makes it a practical measure that can be routinely used by a range of health professionals, including ambulance officers, nurses and medical staff, leading to greater confidence in assessing patients with mild head injuries without trading time for clinical accuracy.

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Figure Legend

Figure 1: Participants consecutively presenting to the ED following mTBI from February to September 2

