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The acute period of recovery from traumatic brain injury: posttraumatic amnesia or posttraumatic confusional state?

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Object. The goal of this study was to characterize more fully the cognitive changes that occur during the period of acute recovery after traumatic brain injury (TBI).

Methods. The pattern of performance recovery on attention and memory tests was compared with the results of the Galveston Orientation and Amnesia Test (GOAT). Tests of memory and attention were administered serially to a hospitalized group of patients with TBI of varying severity. The tests differed in their level of complexity and/or requirement for more effortful or strategic processing. The authors found a regular pattern to recovery. As expected, ability to perform on simpler tests was recovered before performance on more effortful ones. The ability to recall three words freely after a 24-hour delay (the operational definition in this study of return to continuous memory) was recovered last, later than normal performance on the GOAT. Ability to perform simple attentional tasks was recovered before the less demanding memory task (recognition); ability to perform more complex attentional tasks was recovered before the free recall of three words after a 24-hour delay. This recovery of attention before memory was most notable and distinct in the group with mild TBI.

Conclusions. The period of recovery after TBI, which is currently termed posttraumatic amnesia, appears to be primarily a confusional state and should be labeled as such. The authors propose a new definition for this acute recovery period and argue that the term posttraumatic confusional state should be used, because it more appropriately and completely characterizes the early period of recovery after TBI.

Key Words • traumatic brain injury • acute recovery • posttraumatic amnesia • posttraumatic confusional state • attention • memory

The duration of posttraumatic amnesia (PA) has been considered by many to be both the best indicator of traumatic brain injury (TBI) severity[25,44] and the most reliable index of outcome prediction,[7,10,11,22,39] even in mild cases.[14] Although there is no general agreement that PA is a better predictor than initial measures of depth and duration of unconsciousness, such as that provided by the Glasgow Coma Scale (GCS),[3,44] the understanding of this early recovery period after TBI and the establishment of a more precise prediction of early cognitive recovery remain important clinical goals.

One impediment to achieving these goals has been variation in the definition and assessment of PA. The definition of PA differs with the investigator: the key characteristics may include impaired orientation (and different aspects of orientation may be used); retrograde amnesia; and anterograde amnesia.[15,20,29,39] There is also variation in how anterograde memory is defined.[9,20,29]

Different tests of PA emphasize the assessment of different cognitive functions.[4,17] The Galveston Orientation and Amnesia Test (GOAT)[29] is used to assess orientation and retrograde memory; the Westmead PA Scale[39] is used to measure orientation and anterograde memory; and the Julia Farr Centre PA Scale[20] is used to measure orientation, recognition, and free recall. The course of recovery of these different cognitive processes may vary. Geffen, et al.,[20] discovered by analyzing orientation and memory separately that orientation was recovered first, followed by recognition and cued recall, and free recall last. The finer-grained definitions of memory, and the separation of orientation from memory, allowed the dissociation of the stages of recovery and the identification of how much each added to the prediction of daily memory functioning at 1 month.

None of the tests, however, includes attention as a major component. Alexander[2] and Katz[26] suggested that PA is at least concurrent with a confusional state. Daniel, et al.,[15] noted that disorientation usually occurs in confusional states and that disordered orientation may actually represent a failure of memory in which past learned information has become temporarily inaccessible because of confusion.[6] The concept of a confusional state would lead to the conclusion that disturbed attention may be an important component of the stage of recovery labeled PA.[12]

Thus, our objective was to broaden the investigation of the major cognitive deficits that occur during the period of PA and to evaluate the relationship of the cognitive measures to each other and to the initial classification of severity as defined by the GCS score at 6 hours postinjury (our most consistent measurement). Based on the previous literature, we emphasized two major cognitive domains (attention and memory) and isolated specific measures of each. For attention, we adopted widely used clinical measures ranging from less difficult, more automatic processing (counting forward from 1 to 20 [CF]; reciting months forward [MF]) to more effortful tasks, including the demands of working memory (counting backward from 20 to 1 [CB]; reciting months backward [MB]; counting by threes from 1 [C3]). Sustained attention was assessed using a modified version of the Continuous Performance Test.

For memory, we measured free recall of three learned words (WRL) after a 24-hour period.[38] We compared verbal (three words) and visual (three pictures of objects) memory to assess the recovery pattern of each. To compare more automatic recall with effortful strategic recall, we assessed word recognition (WRG) and free recall. These two measures also provide an index of encoding (WRG) compared with retrieval (WRL). Finally, we compared these attentional and memory measures to the GOAT, which places a heavy emphasis on orientation. These tests were administered over repeated sessions to a consecutive series of patients with TBI. We hypothesized that PA is in essence a confusional state, defined by impaired performance on attentional tasks, and that even the ability to perform effortful attentional tasks would be recovered before free recall. Whether this would be true for all degrees of severity and all pathological classifications of TBI[27] was uncertain. For more severely injured patients, for example, differentiation might not be possible because of the greater involvement of limbic regions that affect memory.

To ensure that our results were due directly to TBI and not extraneous factors such as patient hospitalization, pain, socioeconomic status, or having sustained a comparable trauma without evidence of TBI, we compared 108 patients with TBI with four different control groups.

Clinical Material and Methods

Patient Population

During a 15-month period, 187 consecutive patients who were admitted to a level I trauma center with nonpenetrating TBI were considered eligible for the study. Patients were included if they were between 16 and 65 years old, responsive within 1 month of injury, had no evidence of significant hypotensive or hypoxic episodes during resuscitation, no previous head or spinal cord injury, no significant alcohol or drug abuse, and no serious medical or psychiatric illness. Patients were also excluded if they were illiterate or spoke no English. Twenty individuals could not be tested because of medical reasons and 50 refused to participate. Of the remaining 117, in 108 there was sufficient data for this study (for example, individuals who were not admitted or were discharged after 1 day would have insufficient data). There were no significant differences between the patients who participated and those who refused in terms of gender distribution, duration of hospitalization, the GCS score, or the Injury Severity Scale score.[5,38] Approval of the study was granted by a University of Toronto Ethical Review Committee.

Four control groups were tested to minimize the effects of extraneous factors other than the TBI:[9,31,32,36,42] 1) patients who were undergoing orthopedic treatment (16 patients); 2) those with nontraumatic spinal disorders (five patients); 3) those with traumatic spinal injury but no documented TBI (10 patients); and 4) socioeconomically equivalent normal volunteers (19 participants). The majority of individuals in all four control groups performed at the upper limits at the initial testing or very soon after. Therefore, a statistical comparison of the performance of the relatively simple attention and memory tasks during a period of recovery in control and TBI populations was not obtained because of an inadequate range of data. These control groups were dropped from further comparative analyses for this study; the descriptive data are presented in *Results*.

The severity of head injury was determined by the GCS score at 6 hours postinjury (prorated to a 15-point scale in patients who were inbutated) and was used to subdivide the patients into three categories of severity: mild (GCS score 13–15), moderate (9–12), and severe (3–8). Other measures of severity were computerized tomography classification; duration of loss of consciousness defined as the time from injury to a GCS score greater than 8; and the injury severity scale score. Table 1 summarizes the clinical and demographic characteristics of patients and control volunteers included in this study.

Testing Procedures

As soon as possible after the injury, consent for participation was obtained and testing was begun. Participants were tested at approximately the same time every day. Missing days occurred for several reasons: no weekend testing, inability to be tested on the scheduled day, or refusal to participate that day. Patients remained in the study until they had attained performance criteria, refused to participate further, or were discharged from the hospital.

The GOAT was administered daily until a perfect score was achieved. The other tests were administered directly after the GOAT, in a randomized order.

Types of Tests

Memory and Orientation. The GOAT is a bedside assessment that measures orientation to person, place, and time as well as recall of historical events before and after injury. The GOAT scores are calculated from a possible 100, and a score of 75 or higher is considered to be within the normal range.[28,29]

Free recall and recognition of three words over a 24-hour period was tested by presenting the patient with a set of three words with instructions to try to remember them for the next day's session.[38] This was based on Brook's[8] observation that continuous memory over 24 hours indicates PA termination. On the following day the patient was asked to recall the words that had been presented. If free recall was not perfect, recognition was tested by presenting nine words (the three target words and six dis-

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*Demographic profile of 108 patients with TBI and control volunteers**

Variable	TBI			Control Group			
	Severe	Moderate	Mild	Spinal Trauma	Spinal Nontrauma	Orthopedic Treatment	Normal
no. tested	20	22	66	10	5	16	19
female/male	8:12	14:8	25:41	2:8	2:3	6:10	12:7
percentage female	40	64	38	20	40	38	63
age (yrs)							
mean ± SD	28.7 ± 8	26.2 ± 9.6	29.3 ± 11.8	26.7 ± 3.7	39.4 ± 4.6	32.3 ± 11.9	30.4 ± 9.6
range	17–44	16–52	16–63	19–32	33–45	16–58	18–55
duration of LOC (days)							
mean ± SD	4 ± 4.5	1 ± 1.3	0.03 ± 0.10	NA	NA	NA	NA
range	0.25–18	0.01–5	0–0.75	NA	NA	NA	NA
6-hr GCS score							
mean ± SD	6.5 ± 1.5	10.6 ± 1.4	14.5 ± 0.77	15 ± 0	NA	NA	NA
range	3–8	9–12	13–15	15–15	NA	NA	NA

* LOC = loss of consciousness; NA = not applicable; SD = standard deviation.

tracter words) and asking the patient to indicate whether each item presented was shown the day before. Daily testing continued (the three words were changed after correct recall) until the patient was discharged, transferred, or attained perfect free recall over 2 consecutive days.

Attention. The choice of attentional tests was based on several factors: variation in the level of complexity of the cognitive processes required for each of the tests administered; relatively common usage to provide a broader framework of normative data for interpretation; and ability to be administered at the bedside.

Auditory Continuous Performance Test. The Auditory Continuous Performance Test (ACPT; Levine, et al., unpublished data) is a vigilance task that requires sustained attention to detect infrequent target stimuli over a defined period of time. The ACPT consisted of single-digit numbers (1–9) presented orally in a pseudorandom order at a rate of one every 3 seconds for a duration of 3 minutes. The odd numbers were designated as the targets with a 33% likelihood of occurrence, with no two targets occurring consecutively. The participant identified each target by saying "yes," raising his/her hand, or making some other appropriate response. Although the duration of our test was shorter than regular vigilance tasks, this shorter period was believed to be within the capabilities of most patients.

Mental Control. Standard bedside tests of mental control were administered. Tests were designated as simple or complex according to the relative difference in the effortful nature of the tasks. For all of these tests, participants were asked to complete the task as quickly as possible. The two simple attentional tests, although demanding some attentional resources and speed, reflected more routine, overlearned abilities: counting forward from 1 to 20 as quickly as possible, and reciting the months of the year forward from January to December. A slightly more demanding simple attentional task was counting backward from 20 to 1. The more complex attentional tasks demanded greater attentional resources and other cognitive processes. These cognitive processes included working memory, demands for rapid responses, and ongoing manipulation of information. The two tasks consisted of reciting the months of the year backward and counting by threes to 40, starting with 1 (1, 4, 7, and so on).

Statistical Analysis

Observed Events. Nine events were investigated in this study, all defined by the date of recovery to a defined level of performance of that particular test. The dates of these events were defined according to the following criteria: 1) the 2nd consecutive day that the patient achieved a score greater than or equal to 75 on the GOAT (G75, Event 1); 2) the 1st day on which the patient was able to complete without error (speed was not considered) each of the attentional tasks (that is, MF, MB CF, CB C3, and the ACPT, Events 2–7); and 3) the earliest day on which the patient managed perfect recognition of the three words (WRG), and the earliest day of perfect free recall (WRL, Events 8 and 9).

Censoring. In some instances we were not able to record the actual date of an event because the event occurred outside the period of observation. This situation arose if the patient's performance exceeded the criteria on the 1st day (or pair of days) of testing (that is, the patient performed normally before testing) or if the patient never succeeded in attaining the criteria during the testing period (for example, the patient was discharged before achieving normal performance). In the former case the observation of that event was said to be "left censored" and in the latter case it was "right censored." If an event was left censored, the recorded date was the latest that the event could have occurred. If an event was right censored, the day after the recorded date was the earliest that the event could have occurred. This procedure enabled us to use potentially lost information, because the censored data provided us with a conservative estimate of relative times of recovery. That is, if a patient was discharged before full recovery, we were certain that at least a minimum time difference exist-

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ed between observed recovery on one test and censored recovery on another.

Patterns of Recovery

Attention and Memory Measures. A primary objective was to examine the temporal relationship between the recovery of attention and memory as measured by our tests. Sign tests were used to determine the relative ordering of the recovery of performance on the aforementioned tests. The null hypotheses were that the median differences between potentially censored recovery times on pairs of tests were equal to zero. Calculations for the sign tests were performed using the univariate procedure in the SAS System[37] and were conducted at an α level of 0.05.

Association of Recovery. Whereas ability to perform on one test may be recovered before ability to perform on another, this does not necessarily show that recovery of performance on the first test is required for recovery of performance on the second. Because word recall was our defined standard of recovery, we wanted to examine how specific tests related to word recall.

To investigate these associations, we first calculated the variances of the time to recovery for each of the measures independently (ACPT, C3, CB, CF, G75, MB, MF, WRG, and WRL). We then calculated the variance of the difference between time to recovery of WRL and each of these other measures. These calculations yield two basic indexes: the degree of variability in the times to recovery of each measure from the date of injury, and the degree of variability in the times to recovery of WRL recall and recovery of each of the other measures. With this information we were able to assess directly the relationship of the recovery of each variable to WRL by evaluating the ratios of the sum of variances [Var(WRL) + Var(other measure)] for each of the eight measures to the variance of the difference [Var(WRL − other measure)] and comparing these ratios to the F distribution.

Results

Control Volunteers

Almost all of the control volunteers, who were equivalent in age, education, and socioeconomic status to the patients with TBI, achieved perfect word recall on the 1st or 2nd day of retrieval (that is, excluding the 1st day of encoding). Approximately half (44%) were correct on the 1st day.

For control patients with spinal disorders (no trauma), all had a GOAT score greater than 95, and all those tested demonstrated either rapid recovery or no loss of recognition. Of those with sufficient data, one had perfect free recall by the 1st day and three recalled two of the three words in the 2 or 3 days of testing before discharge. The control patients with spinal trauma all had GOAT scores exceeding 90; half demonstrated perfect free recall on the 1st day, two more by the 3rd day, and one was discharged after the 1st day of testing, on which two words were recalled. We observed recovery after the 3rd day in only one patient, whose performance fluctuated for 11 days. This individual was consistently oriented (with GOAT scores of 99 or 100) and reported severe pain.

Of the 16 control patients undergoing orthopedic treatment who were tested, all had GOAT scores greater than 95 by the 2nd day of testing; the worst score on the 1st day was 90. Six were discharged within 1 day after encoding, and adequate free recall data were not available. Of the remaining 10, six achieved perfect free recall within 1 day, three more by 3 days, and one was discharged after the 3rd day without showing perfect free recall.

These results indicated that the three-word test was relatively easy and could be performed well by patients hospitalized for reasons other than TBI. Of all control volunteers tested, 63% were observed to attain perfect three-word recall by the 3rd day of testing compared with 4% of patients with TBI on the 4th day postinjury (allowing 1 day for encoding). Thirty-three percent of control patients, compared with 10% of patients with TBI, were discharged without attaining perfect performance in 3 days of testing (4th day postinjury for patients). Of the control patients who were observed to recover three-word recall, only one did so after the 3rd day of testing. Because of the rapid recovery and minimum data available for control volunteers, a statistical comparison with the patients with TBI was not performed.

Patients With Traumatic Brain Injury

Patterns of Recovery of Attention and Memory Measures. Figure 1 depicts the recovery of the patients with TBI according to the verbal measures administered. Memory for pictures is presented later. The *bold outline* denotes the attentional scores; the *dotted outline* represents the memory scores. The *light outline* represents the GOAT score, the most commonly used index of termination of PA, as a guidemark. The *horizontal bar* depicts the order of recovery. The lack of vertical overlap between any two tests indicates a significant difference, using the sign test ($p < 0.05$), in the time of recovery according to the specified criteria for that test. For example, in the group with mild TBI, CF was recovered significantly faster than all other measures; C3 was recovered before WRL.

The pattern of recovery of both the attentional and memory measures is clear. For attention, the ability to perform a very simple automatic task (CF) is recovered first, and this occurs at all levels of TBI severity. The ability to perform the somewhat more demanding but still routinized tasks (CB and MF) is recovered next, and ability to complete all three less effortful attentional tasks is recovered significantly before the more difficult ones (MB and C3). This also occurred in our study at all three levels of TBI severity. The vigilance task as defined by the ACPT was not consistently temporally distinguishable. In general, success on the ACPT appears to be closest in timing to recovery of CB and MF. In the group with mild TBI, the GOAT recovery period is clearly contemporary with these three tests (CB, MF, and ACPT). In the group with moderate TBI, the GOAT score seems to overlap at both levels of attentional deficiency. In the group with severe TBI, ability to perform the more automatic attentional tasks is recovered before the GOAT.

Memory recovery followed a similar pattern from less to more effortful. In all levels of TBI severity, WRG performance was recovered significantly earlier than WRL. The ability to perform on the GOAT was recovered before

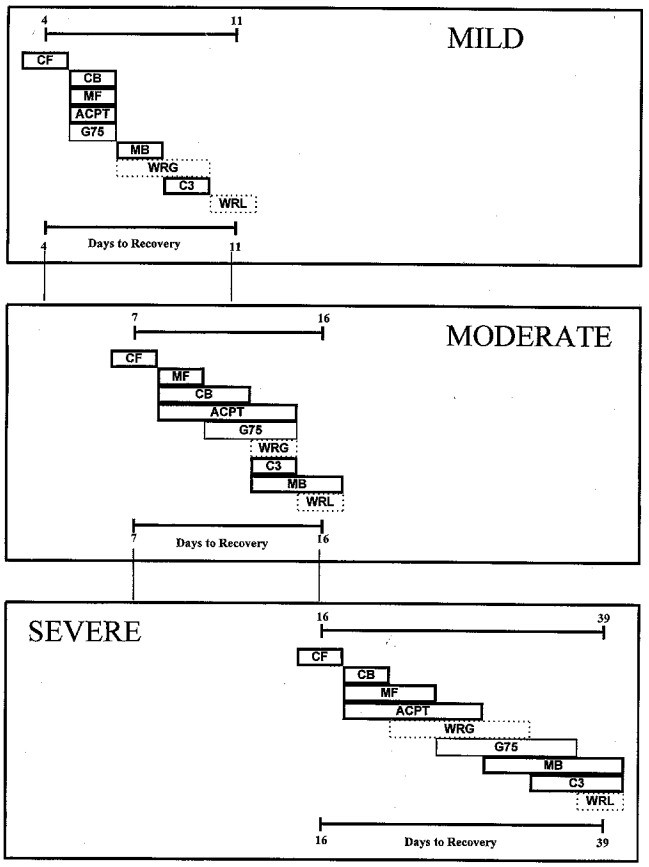

FIG. 1. Charts showing the order of recovery of performance on the tests of memory *(dotted outline)* and attention *(bold outline)* for each of the three severity levels of TBI. The lack of overlap indicates a significant difference ($p < 0.05$).

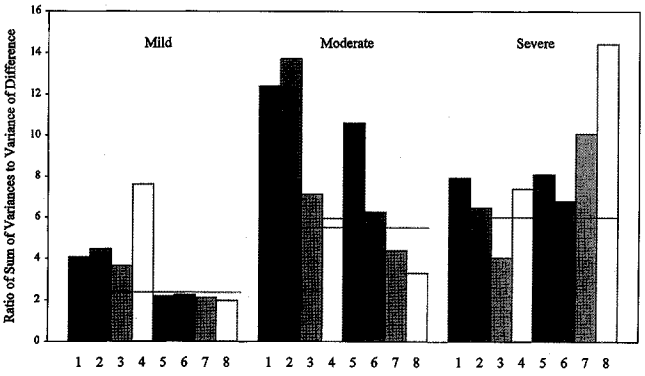

FIG. 2. Bar graph showing the relationship of recovery of WRL to the recovery of ability to complete each of the tests (1 = C3; 2 = WRG; 3 = MB; 4 = MF; 5 = CF; 6 = CB; 7 = ACPT; and 8 = GOAT [G75]), presented for the three levels of TBI severity. The higher the bar, the greater the association. The *horizontal line* for each severity group indicates $p = 0.0005$.

WRL for all levels of TBI severity but showed overlap with WRG in the two more severely injured patient groups. In the group with mild TBI, all three measures related to memory were significantly dissociated: orientation (GOAT), recognition (WRG), and retrieval (WRL).

The comparison of attention and memory measures addresses whether PA is primarily an amnesic or a confusional state, which also affects encoding and retrieval. Clearly, for all levels of severity of TBI, patients must recover automatic attentional processes, at least CF and CB, before they can adequately encode and recognize material (WRG). These attentional measures are recovered significantly earlier (Fig. 1). Whereas MF performance is recovered significantly earlier than WRG memory for the group with mild and moderate TBI, these measures overlap in time to recovery in the group with severe TBI.

When attentional measures are compared with WRL, the results are less clear but strongly indicate that the major cognitive disturbance of PA is a confusional state, at least for the majority of patients. This is best demonstrated in the group with mild TBI, who likely have less diffuse axonal injury.[21,35] All attentional measures recover to perfect performance before patients in this group are able to retrieve three words perfectly over a 24-hour period. In the moderately and severely impaired groups, there is an overlap between performance on MB and WRL tests (and C3 in the group with severe TBI). This likely reflects more severe injury accompanied by continuing attentional and memory problems.

Association of Recovery of WRL With Other Measures. The relationship of the recovery of each variable to WRL is illustrated in Fig. 2. If there is no association between time to recovery of WRL from the date of injury and time to recovery of another measure from the same date, the sum of the variance of the two times [Var(WRL) + Var (other measure)] would equal the variance of the difference between the time to recovery of WRK and the time to recovery of the other measure [Var(WRL − other measure)], and this ratio would equal 1. The level of the association between any single measure and WRL would be indicated by the deviation of the ratio from 1. We took an α level of 0.0005 to be a conservative significance threshold. This is indicated in Fig. 2 by a horizontal line, although the exact threshold may vary slightly from test to test because of sample size differences. These variance ratios are represented for the mildly, moderately, and severely injured groups, and actual numbers are presented in Table 2.

For the memory tasks there is a significant association (indexed by the second column in each group) between recovery of performance on WRG and WRL tasks (second column in each group) for all three severity levels. Only two of the attention measures were found to be significantly associated with WRL at all three severity levels: C3 and MF. Counting by threes is one of the more effortful of the attention tasks. As we saw in the results of the sign test, C3 ability was recovered significantly later than all of the other attention measures (except MB in the moderate and severe injury groups). Similarly, WRL is a fairly effortful memory task with median recovery times of 11 (mild TBI), 16 (moderate TBI), and 39 (severe TBI) days. Significant findings of associations between WRL and the other attention measures did not occur uniformly across all severity groups. Recovery of reciting MB was found to be significantly associated with WRL recovery in the groups with mild and moderate injury. In the group with

TABLE 2

Data on correlation of attention and memory measures with WRL in patients recovering from TBI

TBI Level	Target Measure	Variance of WRL	Variance of Target Measure	Difference	Ratio
mild	C3	21.34	19.00	9.91	4.07
	WRG	21.98	11.72	7.55	4.47
	MB	21.89	14.63	10.03	3.64
	MF	21.55	10.82	4.25	7.61
	CF	21.55	9.33	14.13	2.19
	CB	21.64	9.92	13.98	2.26
	ACPT	21.64	11.18	15.52	2.11
	G75	21.64	9.23	15.67	1.97
moderate	C3	143.43	91.89	18.99	12.39
	WRG	128.28	48.65	12.91	13.71
	MB	118.74	144.02	36.83	7.13
	MF	129.45	48.53	29.93	5.95
	CF	143.43	45.31	17.80	10.60
	CB	143.43	55.79	31.85	6.25
	ACPT	171.33	66.89	54.31	4.39
	G75	118.74	69.17	56.86	3.30
severe	C3	92.34	95.62	23.71	7.93
	WRG	79.65	116.13	30.27	6.47
	MB	93.17	78.08	42.39	4.04
	MF	83.60	91.36	23.68	7.39
	CF	79.63	111.89	23.68	8.09
	CB	77.77	156.58	34.51	6.79
	ACPT	90.52	92.88	18.18	10.09
	G75	81.08	141.20	15.41	14.43

moderate TBI, CF and CB were also shown to be significant; and in the group with severe TBI, ACPT was also found to be significant.

Only in the group with severe TBI was the clinical gold standard for determining termination of PA (that is, GOAT score > 75 over 2 consecutive days [G75]) significantly associated with the recovered ability to learn new verbal information and to recall it 24 hours later (the criteria for WRL).

Patterns of Recovery of Pictures and Word Memory. Finally, recall and recognition of pictures and words were compared (Fig. 3). For the groups with mild and severe TBI, picture recognition (PRG) was recovered significantly earlier than WRG. For all groups, picture recall (PRL) was recovered before WRL. When these variables were compared with GOAT scores, there was a notable overlap in recovery between PRG and G75 scores in the groups with mild and moderate TBI, indicating some similarity in recovery between the GOAT score and PRG.

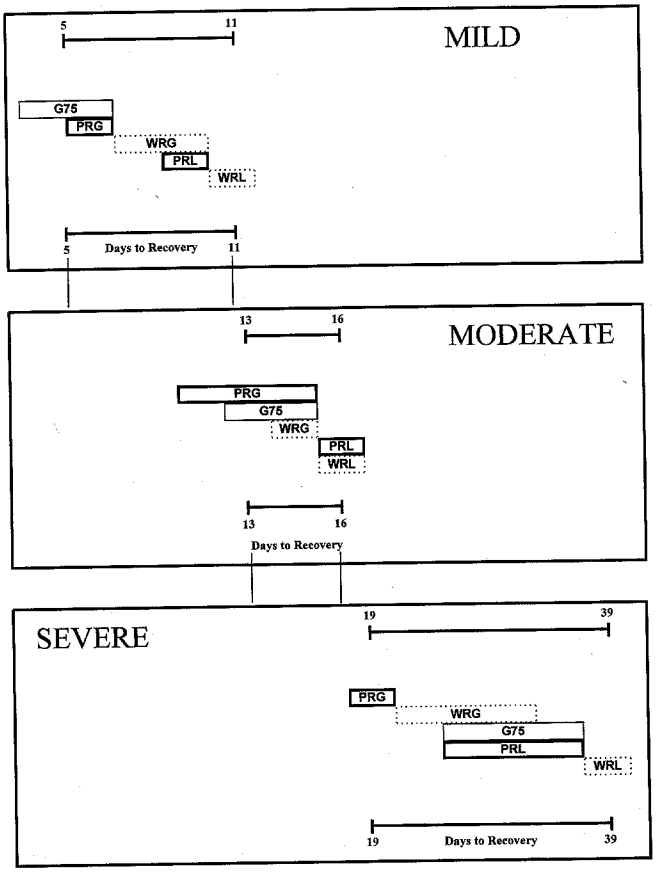

FIG. 3. Charts showing patterns of picture and word memory recovery by a direct comparison of the recovery of PRG and PRL with WRG and WRL, and the GOAT.

Discussion

The first important conclusion derives from the results in the four control groups. To control for many of the factors that might influence recovery from TBI, such as hospitalization, general trauma, surgery, pain, and socioeconomic status, we tested control groups of patients who were undergoing orthopedic treatment, those with nontraumatic spinal disorders, traumatic spinal injury, and a socioeconomically and educationally equivalent group. All four control groups performed at the ceiling on initial testing or very soon thereafter. The simplicity of these tasks and relative ease of their completion for the control volunteers emphasizes the effect of even mild TBI. The findings in our groups of patients with TBI are therefore related primarily to the brain damage caused by the trauma and not to extraneous factors.

There are clinical corollaries to this observation. If there is evidence of PA in individuals such as those comprising our control groups, in particular the trauma groups, it is very likely that they have suffered a TBI. If there is not, it is extremely unlikely that they have suffered a TBI, regardless of what subsequent neuropsychological testing or other functional imaging measures reveal. These measures are indexes of function, and the determinants of such can be attributed to multiple factors.[1,40]

Our second conclusion is that PA is in essence a posttraumatic confusional state (PCS). A confusional state can be defined as a transient organic mental syndrome with acute onset characterized by a global impairment of cognitive functions with a concurrent disturbance of consciousness, attentional abnormalities, reduced or increased psychomotor activity, and a disrupted sleep/wake cycle.[30] Our data support the cognitive characteristics of this definition. Moreover, there is a consistent relationship in the pattern of recovery of attention and memory: ability to perform simple attentional tasks is recovered before

word recognition; ability to perform more demanding attentional tasks is recovered before effortful free recall. Although differences in task difficulty may play a role, it is clear that attention as measured by our tests recovers before memory processes can operate. The "amnesia" of PA appears to be secondary to the inability to attend during encoding (measured by recognition) or to retrieve information effortfully (measured by free recall). Our data corroborate and amplify the suggestions of others that attentional problems are prominent, if not the most dominant, disorder in the acute phase of recovery after TBI.[1,6,12,15,26]

Two alternative explanations might be considered. The PA could just be concurrent with a confusional state.[26] However, data recorded in the group with mild TBI, in which there is a clear ordering of attention recovery before memory, do not support this conclusion. In the groups with more severe injury, on the other hand, the PCS and the amnesia could be concurrent. This is suggested by the overlap of recovery of recall and the more complex attentional tasks in the group with severe injury, and to some degree in the moderately injured group.

It is also possible that the amnesia might terminate before the attentional results recover, which would directly counter the PCS hypothesis. We identified only seven patients among the 108 in whom at least one of the simple attention tasks (CF, CB, and MF), ACPT, or GOAT recovered after WRL. The TBI in four of these patients was classified as moderate, in two it was severe, and in one it was mild. There was generally a typical pattern of performance for these individuals: the ability to perform the simple attentional tasks was recovered earlier and impaired ACPT, GOAT, and/or MB scores persisted. However, performance on word recall was sporadic (perfect, then zero for 1 or 2 days, then two-thirds correct, and so on). Because ACPT and MB had the greatest sustained attention and working memory demands, the sporadic WRL success may be specifically related to a separate sustained attention problem persisting after the general PCS had resolved. Although the physiological basis of sustained attention has not been extensively investigated, there is evidence that the right frontal lobe plays an important role in some aspects of sustained attention.[41] This differentiation in the pattern of performance recovery provides a potential marker for early discovery of distinct and/or additional deficits that may require a different mode of management or treatment. It is also important to consider potential adverse drug effects, which may affect test performance.[23]

There are several notes of caution: it is evident that word recall performance over a single 24-hour period is not an infallible index of the presence of a TBI or of the definite recovery of continuous memory. We did not manipulate the depth of encoding or provide techniques to assist encoding, and doing this might provide a finer, or more consistent, differentiation. In spite of these drawbacks, this simple method shows potential for minimizing the uncertainty of prediction in the acute phase of TBI.

Finally, in looking at times to recovery, we examined the relationship of single time points of recovery. Another method would be to look at rates of change.[16,18] However, this technique may be more appropriate for longer-term prediction.

These results are compatible with the known pathophysiological course of TBI.[26,27,34] In patients with mild TBI, the pathological findings are likely to consist primarily of less severe diffuse axonal and perhaps brainstem injury, usually without focal damage.[24,33,35] This would likely cause a primarily attentional deficit without a true amnesia (as suggested by the performance of patients with mild TBI). In more severely brain damaged patients, the preponderance of temporal (as well as frontal) lobe damage with contusions, hemorrhages, or even white matter damage[13] could result in amnesia. This could also be secondary to focal or diffuse hypoxic/ischemic injury, but investigation of this possibility was limited in our study because of our exclusion criteria. Even in such cases, however, the acute confusional state would still be present. Further research is needed, including the use of superior structural and functional imaging techniques.

The GOAT score identifies a stage in recovery that seems most concurrent with the recovery of recognition, which occurs after recovery of performance on the simpler attentional tasks. This finding is consistent with the structure of the GOAT, in which the predominant orientation measures are less demanding than free word recall. The GOAT remains a useful measure, provided its content limitations are understood. In more severely brain injured patients, actual amnesia contributes to the GOAT score, but in more mildly injured patients, attention and confusion are the primary contributing factors.

Other tests provide a more comprehensive assessment, by adding measures of new learning (anterograde memory; Westmead PA Scale[39]), and preferably separating the memory processes, such as word recognition and free recall (Julia Farr Centre PA Scale[20]). We strongly advocate also adding measures of attention (our test battery [TOTART—Toronto Test of Acute Recovery After TBI] is available on request). Our data also confirm the statement by Symonds and Russell[43] that one cannot assume that any information presented while a patient is aware of what is happening around him or her (that is, oriented) will necessarily be recalled later.

The association of recovery of word recall and the other measures has one main message. Counting by threes is a good index of the impending recovery of word recall. In addition, the ability to perform this test recovers just before (mild and moderate injury) or contemporaneously with (severe injury) word recall, providing a temporal index as well. Reciting months forward is also associated with word recall and is recovered earlier. This simple test may prove a valuable adjunct to the neurosurgeon's or other healthcare professionals' bedside examination.

There was noticeable overlap in the recovery of picture recognition and the G75 score. Picture recognition is clearly a less demanding task than word recognition. Pictures are more salient than isolated words and provide more cues; the recognition of a picture may consist of template matching and, therefore, may be less effortful. These picture recognition data provide a potential explanation as to why orientation (as measured by the GOAT, for example) is recovered earlier than free recall. Orientation questions often relate to a constant visual environment and facial recognition, and the questions are frequently repeated. Learning during the acute recovery period seems to be primarily passive.[19] Clearly the diag-

nosis of termination of PA depends on how one defines "continuous memory" and how this is measured. Our data do not support the necessary inclusion of picture recognition or recall, because the information obtained was of no added value.

Conclusions

We propose a new definition of the acute recovery period, previously labeled PA, and suggest the term posttraumatic confusional state (PCS). If the presence of an amnesia can be identified (for example, if word recognition, which relates to encoding of information, is recovered much later than counting by threes), the modifier "with amnesia" could be used, as in "PCS with amnesia." Regardless, we believe that the isolation of specific cognitive disturbances, the identification of their recovery pattern, and the relationships of both with the identified pathophysiological conditions, will potentially provide direction for acute management, rehabilitation, and the allocation of resources. For example, our results indicate that some patients in our study were discharged while still in a PCS.

The implications of these data are theoretical and clinical. We believe that a more specific distinction of cognitive processes, even with the simple methods we used, will yield much clearer information for pathophysiological correlation and for development of long-term predictive formulas. The concurrent study should be replicated using superior neuroimaging procedures to assess if our finer differentiation of recovery can be correlated with different pathophysiological patterns.

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