Neurobehavioural consequences of closed head injury in older adults

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Abstract

This study examined the neurobehavioural effects of closed head injury (CHI) in adults aged 50 years and older. Twenty two mild to moderate CHI patients who were within seven months of the injury were administered measures of language, memory, attention, and executive functioning. Compared with demographically similar normal controls, the patients exhibited significantly poorer functioning on the cognitive domains. Naming and word fluency under timed conditions, verbal and visual memory, and the ability to infer similarities were especially vulnerable. These initial findings indicate that CHI in older adults produces considerable cognitive deficits in the early stages of recovery. Future research should characterise long term outcome and the potential links between head injury and the development of progressive dementia.

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mance in patients who were 50-75 years old at the time of their injuries. Seventy patients were administered tests of general intellectual functioning, memory, language, and visuo-motor abilities. Mazzucchi and colleagues¹⁰ found that 50% of their patients exhibited generalised deterioration and dementia, whereas only 25% had minimal or no deterioration. Moreover, patients with mild head injuries, ie, no loss of consciousness, Glasgow coma scale¹¹ scores of 13-15, post-traumatic amnesia of <1 day, and normal CT head scans were no more likely to have a better outcome than those with severe injuries. Generalised deterioration and dementia were common in both groups with mild and moderate to severe injury. The study of Mazzucchi *et al*¹⁰ represents an important first step in describing neurobehavioural functioning in the older head injured population. Their research indicates that CHI produces cognitive deficits across the injury severity spectrum. However, one limitation is that Mazzucchi *et al* did not examine specific cognitive features, such as memory and language. Instead, they made a gross classification of groups according to impairment on any of these measures. Moreover, their patients were tested from six months to three years after injury. Therefore, early neurobehavioural performance was not characterised.

The present study provided an initial examination of the early neurobehavioural features of individuals who were ≥ 50 years and sustained mild to moderate head injuries. We evaluated abilities which are frequently compromised after CHI in young adults, including expressive language,¹² memory,^{13 14} attention,¹⁵ and executive processing.¹⁶ We also compared pre- and postinjury living and employment status in a subset of patients.

Methods

SUBJECTS

Prospective data were collected on 18 men and four women aged ≥ 50 years who sustained mild to moderate CHI. Patients were recruited from acute care hospitals affiliated with the Emory University School of Medicine in Atlanta and the University of Texas Medical Schools in Galveston/Houston. Review of medical records and interviews with significant others were conducted to ensure that patients did not have pre-existing or current neurological conditions (for example, cerebrovascular disease, Parkinson's disease, previous head injury),

Epidemiological studies reveal a bimodal peak incidence of closed head injury (CHI) in individuals aged 15-24 years and in those ≥ 70 years.¹⁻⁴ Research on the outcome of older adults has employed global measures such as level of independence, length of hospital stay, and discharge disposition.⁵⁻⁸ Alberico and colleagues⁵ used the Glasgow outcome scale⁹ to characterise the impact of CHI on patients up to 80 years of age. They found that the probability of resuming preinjury activities with mild or no neurological deficits declined with advancing age. Pentland *et al*⁷ reported that 86% of moderately injured patients younger than 65 years of age had good recoveries or required some assistance in the performance of activities of daily living. In contrast, 55% of moderately injured patients ≥ 65 years were severely disabled or died. Davis and Acton⁶ compared the outcome of severely injured patients who were ≤ 25 years or > 50 years of age, 2-5 years after discharge from rehabilitation. The second, older group had longer hospital stays, were more dependent in performance of activities of daily living, and were less likely to be working than younger patients.

Apart from these studies of global outcome, little is known about cognitive functioning in older CHI patients. An exception is a recent study¹⁰ which examined cognitive perfor-

and other medical illness (for example, poorly controlled diabetes, cardiac disease, cancer not in remission for two years) which could compromise cognitive functioning. In addition, patients with histories of drug/alcohol abuse, psychiatric disturbance, or learning difficulties were excluded. We also enquired about a decline during the preceding six months in cognitive functioning, personality, and the ability to perform activities of daily living to screen for pre-existing dementia.¹⁷

Table 1 summarises the demographic characteristics of the patients. Eleven patients were working at the time of their injuries, including three who were ≥ 65 years. Falls produced 50% of the injuries in our sample, a finding that is consistent with the epidemiological literature on older adults.^{2 3 7 18 19}

Sixteen controls who lived in the community were recruited. They were demographically similar to the patients. Identical criteria regarding premorbid and coexisting medical and social conditions were applied in the selection of the controls. Their mean age was 67.5 years (SD 12.5) with an average education of 11.4 years (SD 3.7). Analyses of variance (ANOVA) revealed no significant differences between the groups in age ($F [1, 36] = 0.08$) or education ($F [1, 36] = 1.54$, $p > 0.05$). Fisher's exact tests indicated that the distributions of sex ($p = 0.70$) and race ($p = 0.37$) were comparable in the two samples. The mini mental state examination²⁰ scores of the controls were within normal limits and ranged from 27 to 30 points (mean = 29.6, SD 0.84).

Table 1 also shows the clinical characteristics of the patients, including the interval from

injury to examination. Six patients sustained mild head injuries defined as a lowest recorded Glasgow coma scale¹¹ (GCS) score of 13–15, a normal neurological examination, and a normal CT scan. The remaining 16 patients had moderate injuries based on lowest GCS scores of 9–12 or 13–15 when associated with CT findings of a brain lesion (for example, contusion). Six patients underwent neurosurgery for evacuation of subdural haematomas, two of whom were initially sent home from the emergency room but returned days or weeks later as a result of a decline in mental status. One patient fell and was taken to a hospital four days later because of increasing confusion. Galveston orientation and amnesia test²¹ scores were ≥ 75 points (mean = 89.7, SD 8.8) in all patients at the time of testing, signifying the resolution of post-traumatic amnesia.

PROCEDURES

Neurobehavioural functions were examined that are frequently compromised in young adults. *Language* was measured by asking patients and controls to name pictured items (visual naming) and to generate words beginning with different letters under a 60 second limit (controlled oral word association) on the multilingual aphasia examination.²² *Memory* was assessed via a shortened dementia version of the California verbal learning test (CVLT).^{23 24} Individuals learned and recalled nine words belonging to three categories that were presented over five trials. For visual recognition memory (continuous recognition memory test),²⁵ subjects were shown 20 different line drawings of common objects, and they identified 100 additional drawings as old (previously seen) or new (never encountered). *Attention and information processing speed* were evaluated by having patients and controls perform automatized behaviours, such as reciting the alphabet and the months of the year, as well as activities requiring more effort and involving counting by threes and reversing the order of the months.²⁶ Finally, we assessed *executive processing* based on the ability to infer relationships between items on the similarities sub-test of the Wechsler adult intelligence scale-revised (WAIS-R)²⁷ and to generate hypotheses and shift response sets on the modified card sorting test.²⁸

Table 1 Demographic and clinical features of patients

	Age (years)	Average education (years)	Days after injury	GCS score	Cause of injury*	CT findings*
Mean	67.8	9.7	58.2	12.8	Falls (11)	Normal (8)
SD	12.0	4.2	61.9	1.8	MVA (7)	SDH (10)
Range	50–87	2–16	5–215	9–15	MVA–Ped (1)	SAH (3)
					Hit by bike (1)	Contusion (1)
					Assault (1)	
					Construction (1)	

*Numbers in parentheses indicate sample size.

MVA = motor vehicle accident; MVA–Ped = motor vehicle accident–pedestrian; GCS = Glasgow coma scale; SAH = subarachnoid haemorrhage; SDH = subdural haematoma.

Table 2 Data on neuropsychological test scores for patients and controls

Cognitive domain	Patients		Controls	
	Mean	SD	Mean	SD
I <i>Language</i>				
Visual naming (points out of maximum of 60)	44.2	11.2	54.8	9.9
COWA (total words for three letters)	17.1	10.3	33.1	14.2
II <i>Memory</i>				
CRM (correct responses out of maximum of 100)	77.3	9.2	84.8	8.7
CVLT (percentage words recalled for five trials)	50.0	18.4	69.6	16.7
III <i>Attention</i>				
Alphabet (seconds)	11.5	13.0	8.6	12.7
Months (seconds)	11.1	10.0	5.4	3.1
Serial threes (seconds)	29.0	18.5	18.5	10.3
Months backwards (seconds)	29.2	18.6	19.1	15.4
IV <i>Executive functions</i>				
Modified card sort (categories out of maximum of 6)	2.7	2.1	4.3	1.9
Similarities (points out of maximum of 28)	10.0	6.4	17.4	7.7

Results

NEUROBEHAVIORAL FUNCTIONING
Multivariate analyses of variance (MANOVAs) were performed separately on the cognitive domains of language, memory, attention, and executive processing using the raw scores obtained by patients and controls. Table 2 shows the means (and standard deviations) for the groups on each neuropsychological test. Group (CHI, control) and centre (Atlanta, Galveston/Houston) were between-subject variables. Centre was included to evaluate potential differences between the Atlanta and Galveston/Houston samples on the neuropsychological measures.

Language

A 2 (group) $\times$ 2 (centre) MANOVA examined naming (the number of points for correctly naming pictures) and fluency (the number of correct words provided for three letters). Four patients did not receive the naming procedure, reducing the patient sample size for this analysis to 18. The MANOVA revealed a significant main effect of group ($F [2, 29] = 7.21, p < 0.01$), but no main effect of centre ($F [2, 29] = 0.64, p > 0.05$) or interaction of group and centre ($F [2, 29] = 0.46, p > 0.05$). One-way ANOVAs, indicated significant group differences on both tests. As shown in table 2, controls more accurately named pictures ($F [1, 30] = 7.14, p < 0.05$) and they also generated a greater number of words beginning with specified letters ($F [1, 30] = 12.00, p < 0.01$). On this last task, patients exhibited a significantly ($p < 0.01$) higher proportion of non-perseverative errors, such as providing proper nouns (patients: mean = 0.19, SD 0.21; controls: mean = 0.03, SD 0.06). In contrast, the proportion of perseverative errors, such as repeating earlier items or varying them only slightly (for example, "find" and "finding"), did not significantly differ between the groups (patients: mean = 0.04, SD 0.07; controls: mean = 0.05, SD 0.05).

Memory

A 2 (group) $\times$ 2 (centre) MANOVA for the memory domain was performed on the number of correct identifications on the continuous recognition memory test and the percentage of total words recalled on the five trials of the CVLT. This analysis indicated a significant difference between patients and controls: $F [2, 33] = 5.49, p < 0.01$. As shown in table 2, controls recognised more pictures: $F [1, 34] = 5.46, p < 0.05$. Moreover, the percentage of total words recalled on the CVLT was higher for controls: $F [1, 34] = 9.15, p < 0.01$. The main effect of centre ($F [2, 33] = 0.34$) and the interaction of group and centre ($F [2, 33] = 1.65$) were non-significant.

We examined the learning curves over the five trials of the CVLT to characterise the pattern and rate of improvement. A 2 (group) $\times$ 5 (trials) repeated measures ANOVA revealed significant ($p < 0.01$) main effects of group

($F [1, 36] = 11.31$), and trials ($F [4, 144] = 16.20$). Figure 1 displays the mean percentage of words recalled on each trial of the CVLT for patients and controls. Bonferroni corrected, *post hoc* analyses ($p < 0.01$) demonstrated that controls recalled significantly more words than patients on trials 3, 4, and 5. The interaction of group and trials was non-significant ($F [4, 144] = 0.57$), revealing that patients and controls exhibited similar learning curves. The greatest increments in learning for both groups occurred between trials 1 and 2.

Attention

Automatised processing was evaluated by analysing the number of seconds required by patients and controls to say the alphabet and the months. A 2 (group) $\times$ 2 (centre) MANOVA was not significant for group ($F [2, 32] = 2.20$), centre ($F [2, 32] = 0.14$), or their interaction ($F [2, 32] = 0.67, p > 0.05$). Similarly, a MANOVA on the number of seconds necessary to perform activities requiring more effort, involving counting by threes and reversing the months, was not significant (group: $F [2, 25] = 2.04$; centre: $F [2, 25] = 1.05$; interaction: $F [2, 25] = 0.89, p > 0.05$).

These analyses undoubtedly overestimated the capabilities of the patients because they only included individuals who could perform the tasks. Qualitatively, there was a disparity in the difficulty level of the two types of attentional measures. Inspection of the data revealed that 21 of the 22 patients and all of the 16 controls could recite the alphabet/months. In contrast, seven patients versus one control could not count by threes/reverse the order of the months. Fisher's exact tests indicated non-significant differences ($p = 1.00$) in the distributions of patients and controls able to perform the automatic tasks. Differences in the distributions approached ($p = 0.11$) but missed significance for the tasks requiring more effort.

Executive functions

The executive processing domain examined the number of categories achieved on the modified card sorting test (MCST) and the maximum points achieved on the similarities sub-test of the WAIS-R. Two patients did not receive the card sorting procedure and therefore were not included in subsequent analyses. A 2 (group) $\times$ 2 (centre) MANOVA revealed a significant main effect of group ($F [2, 31] = 3.97, p < 0.05$), whereas the main effect of centre ($F [2, 31] = 2.76$) and the interaction of group and centre ($F [2, 31] = 0.98$) were not significant. Univariate analyses demonstrated that patients and controls differed on the similarities sub-test ($F [1, 32] = 8.15, p < 0.01$). As seen in table 2, controls functioned at a higher level in the ability to infer conceptual relationships between items. Although controls achieved a larger number of categories on the MCST, this difference missed significance ($F [1, 32] = 3.46, p = 0.07$).

Mean percentage recall on each of the five trials of the CVLT for patients and controls: □, closed head injury ($n = 22$); ■, controls ($n = 16$).

DISCHARGE DISPOSITION AND EMPLOYMENT STATUS

In addition to cognitive functioning, we examined discharge disposition and employment status in our sample. All of the 22 patients were living in non-institutional settings before injury. One patient died and three went on to more supervised environments, that is, personal care or nursing homes, after hospital discharge. These three patients were over 70 years and sustained moderate injuries. They lived alone before injury and did not have spouses to care for them. Eleven patients were working before injury, and six resumed employment after their accidents. There did not appear to be a difference in severity or an associated physical injury between those who did (two milds, four moderates) and those who did not return (one mild, four moderates) to work.

Discussion

Our findings indicate that mild to moderate CHI in older adults produces cognitive deficits involving the same neurobehavioural areas affected in young survivors, such as expressive language, memory, and reasoning. Consistent with Mazzucchi and colleagues,¹⁰ we observed a high frequency of impairments in over two thirds of the sample, a finding also in line with studies documenting the high incidence during the first three months after mild to moderate head injuries in young adults.¹⁴⁻²⁹ Caution must be exercised, however, in concluding that older adults necessarily have a poor outcome. As 19 of the 22 patients were tested within three months of injury, our findings characterise the initial stage of recovery and do not address long term functioning. It is conceivable that a number of patients will exhibit improvement. Furthermore, our comparison group consisted of controls living in the community as opposed to hospitalised, non-head injured controls. Future research should employ a control group, such as hospitalised orthopaedic patients, for better isolation of the neurobehavioural effects of head injury versus the stresses associated with an acute illness.

The neurobehavioural consequences of head injury in older adults have been vastly understudied in comparison to those in young survivors. Research is limited to general categories such as mortality, length of hospitalisation, and discharge disposition. There is a rise in head injury mortality^{5 18 30-32} and length of hospitalisation^{7 8} with increased age. Although these findings imply a poor outcome for the elderly, factors which frequently affect their recovery include associated medical conditions involving pulmonary or infectious disorders, cognitive status such as pre-existing dementia, and neurosurgical complications. Roy and colleagues⁸ found that a larger percentage of patients aged ≥ 65 years sustained intracranial haematomas than younger patients. Both groups were similar in overall severity of injury (mild and moderate). Psychosocial supports such as whether a

spouse is available to take care of the patient can also have an impact on discharge disposition. Older individuals may not be able to return home because of a lack of assistance. Unlike younger patients who can be discharged to rehabilitation programmes, there are few services available for those over 50 years of age. In essence, the hospital may become a temporary residence until some other means of supervision becomes available.

These considerations highlight the need for detailed investigations of the neurobehavioural effects of head injury in older patients, as well as the delineation of similarities and differences from young adults. Our data reflect a pattern for moderately injured older patients to be at risk of delayed neurosurgical complications. Two individuals with initially high GCS scores of 13–15 were sent home from the hospital, whereas one patient did not seek immediate treatment. These individuals later became confused, and CT/MRI scans indicated haematomas. In contrast to injuries from motor vehicle accidents in young adults, falls are a leading cause of CHI in patients ≥ 60 years.^{2 3 7 18 19} There is some evidence that falls produce a higher proportion of mass lesions as opposed to diffuse injuries from motor vehicle accidents.⁵ The older individual sustaining CHI may require a different set of hospital workup, admission criteria, and management techniques than those currently applied to younger people. In addition, the classification of “mild” head injury in a young person may represent a moderate injury in an older one. Neurobehavioural data on acutely injured patients will allow determination of whether these classification schemes using the GCS¹¹ are meaningful and prognostically useful.

In addition to studies focusing on the initial effects of head injury, research should examine recovery patterns in older survivors and whether a subset is at risk of developing degenerative dementia. Epidemiological studies suggest an association between head injury sustained early in life and the later manifestation of Alzheimer’s disease.³³⁻³⁵ Heyman *et al*³⁴ compared the environmental, medical, and social history of 40 patients who developed dementia before the age of 70, and 80 community control subjects. A history of severe head trauma was present in 15% of the index cases as compared to 3.8% of the controls. Graves *et al*³³ noted that the risk of developing Alzheimer’s disease diminished as a function of the postinjury interval. Recently, Mortimer and colleagues³⁵ conducted a meta-analysis of 11 case-control studies and found a significant association between head trauma resulting in loss of consciousness and Alzheimer’s disease. Postulations of the mechanism underlying post-traumatic dementia include the role of neurotrauma as a provocative or permissive event³⁶ and the effects of breaking the blood-brain barrier. Using an experimental rodent model of head trauma, Nilsson *et al*³⁷ found that extracellular fluid concentrations of energy-related metabolites (for example, glutamate) were increased as a

function of head injury severity. Marked increases in excitatory neurotransmitters released at the time of trauma have been implicated in the aetiology of neurodegenerative diseases.³⁸ Roberts and colleagues³⁹ carried out brain necropsies on 16 head trauma patients who died within 10–18 days of injury and found excessive β A4 amyloid protein deposits, a neuropathological feature of Alzheimer's disease, in six individuals who were 45–63 years old. They argued that it was unlikely that their sample had pre-existing Alzheimer's disease because the prevalence rate is less than 0.01% in people under 65 years of age. Although intriguing, these studies have been based on either retrospective case methodology or neuropathological studies with no concurrent clinical correlation. The prospective study of head injury in those older adults who are carefully screened for coexisting dementia allows a unique opportunity to identify those who exhibit progressive deterioration in neurobehavioural status.

Another area for future research is the establishment of clinicoanatomical relationships in elderly patients sustaining head injuries, particularly the association between frontal lobe lesions and impairments in neurobehavioural functioning. Neuropathological studies of fatal non-missile head injuries indicate that the frontal lobe is the most frequent site of focal lesions.⁴⁰ MRI of consecutive patients hospitalised for mild to moderate TBI has also shown that the frontal lobe is the most common location for focal areas of increased intensity on T2 weighted scans.^{14,29} The ability to exhibit productive thought and to use feedback to generate hypotheses and shift strategy is an important component of cognitive functioning after head injury. Levin *et al.*⁴¹ found that disturbances encompassing self-appraisal (for example, an exaggerated self-opinion, overrating ability in comparison with family and clinicians), and planning (poor formulation of future goals) were especially common in patients with severe injuries (GCS ≤ 8) but also occurred across the spectrum. These cognitive and personality deficits result from frontal lobe damage in other neurological populations.⁴² The generality of a "frontal lobe" syndrome and the sensitivity of tests to focal frontal lobe damage in older patients still need to be established. In addition to Alzheimer's disease, the elderly head injured patient may be vulnerable to the development of a dementia of the frontal lobe type.^{43,44} Behavioural and personality changes such as social withdrawal, unconcern, and disinhibition are prominent early features of frontal lobe dementia, whereas cognitive deficits occur later. Functional imaging techniques such as positron emission tomography will be particularly beneficial in detecting hypofusion in the frontal and temporal regions, and in correlating these changes with neurobehavioural performance.

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