ORIGINAL ARTICLE

Cognitive Impairment 3 Months After Moderate and Severe Traumatic Brain Injury: A Prospective Follow-Up Study

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ABSTRACT. Skandsen T, Finnanger TG, Andersson S, Lydersen S, Brunner JF, Vik A. Cognitive impairment 3 months after moderate and severe traumatic brain injury: a prospective follow-up study. Arch Phys Med Rehabil 2010;91: 1904-13.

Objective: To explore the magnitude and frequency of cognitive impairment 3 months after moderate to severe traumatic brain injury (TBI), and to evaluate its relationship to disability at 1-year follow-up.

Design: Prospective follow-up study.

Setting: Regional level I trauma center.

Participants: Patients aged 15 to 65 years with definite TBI, defined as Glasgow Coma Scale score of 3 to 13 and injury documented by magnetic resonance imaging (n=59) or computed tomography (n=2); healthy volunteers (n=47) served as controls.

Interventions: Not applicable.

Main Outcome Measures: Neuropsychological assessment 3 months postinjury and Glasgow Outcome Scale Extended (GOSE) at 3 and 12 months postinjury.

Results: Patients with TBI performed worse than controls, most consistently in terms of information processing speed and verbal memory. However, a maximum of only 43% of patients with TBI had impaired test scores (defined as <1.5 SD below mean of normative data) on any one measure. Based on a selection of 9 tests, a 0 or 1 impaired score was seen in 46 (98%) of 47 controls, in 20 (57%) of 35 patients with moderate TBI, and in 9 (35%) of 26 patients with severe TBI. At 1 year postinjury, disability (defined as GOSE score ≤6) was present in 57% of those with 2 or more impaired test scores and in 21% of those with 0 or 1 impaired score (P=.005).

Conclusions: In this sample of patients with recent, definite TBI and healthy volunteers, we found that TBI affected cognition in moderate as well as severe cases. The presence of cognitive impairment was associated with future disability. However, half of the patients with moderate TBI and even one third of those with severe TBI had a normal cognitive assessment 3 months postinjury.

Key Words: Craniocerebral trauma; Longitudinal studies; Neuropsychological tests; Neuropsychology; Prognosis; Rehabilitation.

COGNITIVE IMPAIRMENT is a common sequela of moderate and severe TBI,[1] with effects particularly prominent in terms of information processing speed and attention,[2,3] memory,[4] and executive functioning.[5] Several studies demonstrated, at various time intervals postinjury, that cognitive dysfunction mediates functional problems.[6-8]

Cognition is markedly impaired around 1 month postinjury[9] or by resolution of PTA,[10,11] but studies are difficult to compare because of differences regarding duration of follow-up, proportion of severe cases, and whether patients are selected from the acute care[5] or rehabilitation setting.[10,11] A common research design has been the comparison of mean test performances between patients with TBI and a control group. The magnitude of the effect of TBI on cognition (ie, effect size) may be expressed as Cohen's d, the standardized difference of means in 2 groups. In a meta-analysis, a large mean effect size (d_{pooled}=.97) of TBI across studies was found for moderate to severe TBI within the first 6 months.[12] The authors pointed out that while cases of moderate and severe TBI typically are analyzed together in neuropsychological research, they constitute a heterogeneous group. Thus, the reported effects might be overestimated for moderate TBI or underestimated for severe TBI, or both.[12]

List of Abbreviations

CCPT-II	Conners' Continuous Performance Test II
CT	computed tomography
CVLT-II	California Verbal Learning Test II
CVMT	Continuous Visual Memory Test
CWIT	Color-Word Interference Test
DAI	diffuse axonal injury
D-KEFS	Delis Kaplan Executive Function System
GCS	Glasgow Coma Scale
GOSE	Glasgow Outcome Scale Extended
IQ	intelligence quotient
MRI	magnetic resonance imaging
PTA	posttraumatic amnesia
SDMT	Symbol Digit Modalities Test
TBI	traumatic brain injury
TCF	Taylor Complex Figure
TMT	Trail-Making Test
WAIS-III	Wechsler Adult Intelligence Scale–Third Edition

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Supported by a research grant from Liaison Committee between the Central Norway Regional Health Authority and the Norwegian University of Science and Technology.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit on the authors or on any organization with which the authors are associated.

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0003-9993/10/9112-00411$36.00/0
doi:10.1016/j.apmr.2010.08.021

In other studies of early cognitive outcome in TBI patient groups,[10,11] as well as in individual clinical assessments,[13] interpretation of neuropsychological test scores is based on comparison with normative data. In some settings, such as legal expert examinations and research, criteria defining impairment is required, but there is no such general definition.[14] The issue is further complicated by the fact that healthy people perform below the normal range in some percentage of administered tests,[14,15] and defining "impairment" remains a matter of discussion.

Taken together, there is still a need for studies exploring the extent of cognitive deficits in patients with TBI, because previous studies are heterogeneous regarding the time postinjury, the selection of patients, and the research design.

For the present study we performed neuropsychological testing 3 months postinjury as part of a large follow-up study of patients admitted with moderate or severe head injury to a regional level I trauma center. In a larger subgroup of the main cohort, we previously demonstrated that virtually all patients had parenchymal lesions detected with early MRI. DAI and contusions were frequently found, often in concert.[16]

The aim of the present study was to explore the magnitude and frequency of cognitive impairments 3 months after moderate or severe TBI in comparison with healthy controls and with normative data. Furthermore, we sought to relate the level of cognitive functioning at 3 months to measures of global functioning at 3 months and 1-year follow-up.

METHODS

The Regional Committee for Medical Research Ethics and the Norwegian Social Science Data Services approved the study. Written consent was obtained from patients and from parents of patients younger than 16 years.

Participants

Sixty-one patients (age range, 15–65y) admitted to the Neurosurgical Department, St Olavs Hospital, Trondheim University Hospital, Norway participated in the study. The hospital, a level I trauma center, has an ongoing database that includes all patients admitted with moderate to severe head injuries as defined by the Head Injury Severity Scale criteria.[17] In this main database, 97% of admitted patients have consented to registration, and less than 2% have been lost to follow-up (ie, missing GOSE score).

For the present study, patients in the main database were invited to participate in neuropsychological testing at 3 months postinjury. Inclusion criteria were (1) the ability to cooperate during testing; (2) no ongoing substance abuse, diagnosed neurologic or psychiatric condition, or previous moderate to severe head injury according to the same criteria; and (3) fluency in the Norwegian language. The main inclusion period was from October 2004 to October 2007. During this period, 52 patients were included (appendix 1); these constitute 85% of the sample in this study. For the purpose of increasing the sample, we included 9 patients who had been injured and registered in the main database after the first inclusion period and who were evaluated at 3 months follow-up. Table 1 reports patient demographic data. The control group consisted of 47 healthy persons, matched to the total sample of patients for age, sex, and education. They were recruited via advertisements, among family and friends of patients with head injury, and among acquaintances of researchers and staff.

Injury-Related Variables

Evaluated variables included mechanism of injury, MRI findings, and GCS score (scoring procedures have been described in an earlier publication[16]), with a GCS score of 9 to 13 indicating moderate TBI and a GCS score of 8 or less reflecting severe TBI.

Magnetic Resonance Imaging

MRI (1.5 Tesla) was performed at a median of 10 days postinjury (range, 1–120). The scan protocol included T1- and T2-weighted sequences, a T2*-weighted gradient echo sequence, fluid-attenuated inversion recovery sequences, and diffusion-weighted imaging. MRI parameters and procedure of evaluation have been reported previously.[16]

Procedures for Neuropsychological Testing and Scoring

Neuropsychological assessment was performed at a mean of 98 ± 10 (SD) days postinjury. Psychologists, 2 trained masters-level students, and 1 test technician at St Olav University Hospital performed all testing. To compensate for errors associated with several examiners, all were supplied with oral and written instructions regarding the protocol and the procedures. The students received training and could discuss issues with the psychologists.

Raw scores were converted to standard scores by use of normative data provided by the manufacturers of the tests, except for the Symbol Digit Modality Test, where a normative sample quoted by Lezak et al[18] was used. For participants aged 15 years, the norms for those aged 16 years were used. Standard scores were given as T scores, scaled scores (S scores), Z scores, or percentiles. An individual's standardized test score was classified as impaired if below 1.5 SD according to the reference norms for the test (T score ≤ 34, S score ≤ 5, Z score ≤ -1.5, or percentile ≤ 5). Data were also analyzed applying a cutoff criterion at 1 SD. In some cases 1 or more tests were not administered for various reasons; thus the number of patients evaluated with each test deviates from the total sample size.

Neuropsychological Measures

The 4 subtests of the Wechsler Abbreviated Scale of Intelligence[19] were administered to estimate general intellectual capacity. To avoid future retest effects in a planned reassessment, we used a split-half procedure, and a raw score was estimated. The control participants were tested with all items, but their IQ scores in this study were calculated as for the patients, by use of every second item procedure. The following neuropsychological methods were used to assess different domains of cognitive function:

1. *Motor function:* Grooved Pegboard, dominant hand,[20] TMT, condition 5 (motor speed) from the D-KEFS.[21]
2. *Information processing:* TMT, condition 1 (visual scanning), 2 (number sequencing), and 3 (letter sequencing); CWIT, condition 1 (color naming) and 2 (word reading) from D-KEFS and SDMT, oral and written versions.[22]
3. *Attention and vigilance:* CCPT-II.[23]
4. *Visual learning and memory:* CVMT,[24] TCF.[25] The TCF was not administered to controls. Raw scores for the TCF were converted to standard scores based on normative data for the Rey-Osterrieth Complex Figure.[26]
5. *Verbal learning and memory:* CVLT-II.[27]
6. *Working memory:* Digit Span Backwards from the WAIS-III,[28] Letter-Number Sequencing from WAIS-III.
7. *Executive functions:* Wisconsin Card Sorting Test computer version[29]; Verbal Fluency Test from D-KEFS; TMT, condition 4 (letter-number switching) from D-KEFS; CWIT, condition 3 and 4 (inhibition and inhibition/switching) from D-KEFS; Tower test from D-KEFS.