

Traumatic Brain Injury in Patients With Traumatic Spinal Cord Injury: Clinical and Economic Consequences

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Objective: To evaluate the clinical and economic burden of traumatic brain injury (TBI) in people with traumatic spinal cord injury (SCI).

Design: Prospective, case-matched control study.

Setting: Inpatient spinal cord rehabilitation program.

Participants: Patients (n=10) diagnosed with traumatic SCI and concomitant TBI matched to an SCI only control group.

Interventions: Not applicable.

Main Outcome Measures: Inpatient rehabilitation length of stay, health care costs (patient care hours), clinician resource allocation, behavioral and critical incidents, FIM, Personality Assessment Inventory, and neuropsychological assessment findings.

Results: Prolonged loss of consciousness, increased rehabilitation costs, and greater demands on clinician resources (trend) were found in the SCI with TBI group relative to the SCI-only group. Neuropsychological test performance was significantly worse in the SCI with TBI group, while the FIM cognition score did not discriminate because of ceiling effects. Greater evidence of psychopathology was observed in the SCI with TBI group.

Conclusions: The presence of TBI in SCI has a range of clinical and economic consequences. This dual diagnosis has the potential to affect SCI rehabilitation negatively, as well as quality of life and reintegration in the community. Specialized care appears to be needed to improve outcomes and to minimize clinical and economic burden, but further research is required.

Key Words: Brain injuries; Rehabilitation; Spinal cord injuries.

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THE CO-OCCURRENCE OF TBI with traumatic SCI represents a comorbidity with debilitating consequences. This dual diagnosis can pose clinical challenges that are more complex than either of these traumas on its own.¹ At present, there is a paucity of specialized dual diagnosis care, although it has been suggested that specialized care is critically needed to improve rehabilitation outcomes.^{1,2} Aside from the complexity and expense, we suggest that the lack of specialized care may be a result of a dearth of information regarding the clinical and economic impact of TBI on patients with SCI. Thus, a fuller understanding of the impact of TBI on SCI may well be of significant clinical import.

In most cases of traumatic SCI and TBI, the causes of injury are the same, with motor vehicle collisions and falls accounting for approximately 70% of all TBI and traumatic SCI.^{3,4} Co-occurrence is common, with estimates of dual diagnosis ranging from approximating 25% of all traumatic SCIs to over 70%.⁵⁻¹⁴ Methodologic differences across studies likely explain this disparity.¹⁵ For example, incidence studies have differed in experimental design (eg, prospective vs retrospective),^{10,12-14} inclusion criteria,¹⁶ time postinjury,^{7,11,17} sampling techniques,¹⁶ and diagnostic criteria for TBI.^{1,15}

While even the most conservative estimates of dual diagnosis are of scientific interest and clinical concern, there is little research to date on its clinical and economic consequences. Conventional SCI rehabilitation involves the acquisition of new knowledge and skills in order to regain functional independence and facilitate recovery.¹⁸⁻²⁰ Cognitive sequelae would logically hamper or prolong this relearning.²¹ Moreover, behavioral sequelae might impede progress by causing patients to be branded as "difficult."²⁰ Rehabilitation costs should also be higher if rehabilitation takes longer and/or is less effective. Arzaga et al² speculated that the post-SCI medical and adjustment difficulties would be compounded by the presence of concurrent TBI; however, to our knowledge, only 2 studies have empirically examined this speculation. Richards et al²² conducted a prospective evaluation of the long-term consequences of TBI on SCI. Here, patients with dual diagnosis were compared with a matched SCI-only group on measures of

List of Abbreviations

GCS	Glasgow Coma Scale
LOC	loss of consciousness
LOS	length of stay
MRI	magnetic resonance imaging
PAI	Personality Assessment Inventory
PTA	posttraumatic amnesia
SCI	spinal cord injury
TBI	traumatic brain injury
WAIS-III	Wechsler Adult Intelligence Scale- Third Edition
WMS-III	Wechsler Memory Scale- Third Edition
WTAR	Wechsler Test of Adult Reading

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family, vocational, social, and personal adjustment. Diagnosis of TBI was made by consensus agreement among 3 neuropsychologists. At 2 years postinjury, patients with SCI and moderate to severe TBI had greater personal and family adjustment difficulties compared with patients with SCI only and mild TBI.

Macciocchi et al²¹ conducted a retrospective comparison of 41 patients with SCI and concurrent TBI (based on GCS, LOC, PTA, or positive neuroimaging) to a matched cohort of 41 patients with SCI only. The groups were compared on admission and discharge FIM,²³ LOS, and rehabilitation costs. No differences in LOS or costs were revealed, but the patients with SCI and TBI made fewer functional gains from pretreatment to posttreatment on the FIM. However, these findings may underestimate the true consequences of TBI because patients with normative GCS and without positive neuroimaging findings were included in the TBI-positive group. While patients were assigned based on the presence of PTA or LOC, previous research has demonstrated that the validity of PTA and LOC for people with SCI is compromised by issues such as hypoxia and substance abuse.^{24,25}

Given the limited research into the impact of TBI on SCI outcomes and the clinical evidence to suggest at least some deleterious effects, the aim of this study was to examine empirically the clinical and economic impact of TBI on patients with SCI.

We compared a group of patients with SCI and TBI to a group of patients with SCI only on 8 parameters concerning their inpatient rehabilitation. These included the number of critical and behavioral incidents, emotional/neurobehavioral sequelae of TBI on SCI, duration of inpatient stay, functional gains on the FIM, hours of therapy and hours of nursing care, and health care costs. We predicted that the dual diagnosis group would demonstrate more incidents, greater psychiatric sequelae, longer stays, smaller gains on the FIM, greater hours of therapy and nursing, and greater costs. Given that the diagnosis of TBI is often missed in acute care,²⁶ we also examined the diagnostic sensitivity of neuropsychological testing for TBI in comparison with that of the FIM cognition score. Based on the findings of Davidoff et al,²⁷ we predicted greater sensitivity to cognitive impairment of the neuropsychological tests than the FIM cognitive subscale.

Our study extended previous research in several ways. The study by Macciocchi²¹ examined differences between inpatients with dual diagnosis versus SCI only, and employed a retrospective, group-matched design. The current study was prospective and used a combination of case-matching (general level of injury) and group-matching (injury severity and demographics). A wider number of variables was studied, and assignment to group was based on strict inclusion criteria in order to minimize the risk of errors in assignment to group. For the dual diagnosis group, definitive TBI diagnosis was based in most cases on positive MRI findings and in some cases on positive computed tomography scans with corroborative neurologic findings. For the SCI only group, patients needed to demonstrate normative neuroimaging and neurologic findings.

METHODS

Participants

The study protocol was approved by the research ethics board at the Toronto Rehabilitation Institute, and the procedures of the study were in accordance with the standards of the research ethics board.

Ten patients with traumatic SCI with TBI and SCI-only controls were recruited from the Spinal Cord Rehabilitation

Program of Toronto Rehabilitation Institute, a large, urban rehabilitation hospital. Traumatic SCI was defined as an insult to the spinal cord from an external physical force resulting in varying severities of sensory and/or motor deficits as a result of impediments to conduction across the lesions.²⁸

Participants were drawn from a sample of 30 patients who had been consecutively recruited from a larger study examining the incidence of TBI in SCI. From the larger sample, all participants with confirmed TBI (the SCI with TBI group) were identified, and then a group of patients with SCI without TBI (the SCI only group) were matched to the SCI with TBI group.

Diagnosis of TBI was made on the basis of (1) MRI findings at 2 to 6 months postinjury, or computed tomography findings plus corroborative clinical evidence from acute care, and (2) collateral data indicative of a positive TBI, including any or all of the following: presence of PTA, LOC, or positive neuropsychological results. MRIs were read by a neuroradiologist. Criteria for diagnosis included increased T2 signal intensity, iron deposition, encephalomalacia, cerebral hemorrhage, and contusion or infarct consistent with traumatic injury (rather than a primary cerebrovascular event). The absence of TBI was similarly confirmed by the absence of positive neuroimaging and other injury-related findings (table 1).

The control group (SCI only) was case-matched for general level of injury (ie, cervical, thoracic, lumbar) and then group-matched on completeness of injury, sex, age, and years of education.

All participants were between the ages of 18 and 55 years, were able to provide informed consent, and had sustained the injury within the previous 2 to 6 months. Exclusion criteria were the presence of a known or suspected neurodegenerative disorder (eg, multiple sclerosis, Parkinson disease), acquired language disorder that would preclude neuropsychological testing, and a diagnosed psychotic disorder.

Outcome Measures

Critical incidents/behavioral incidents. *Behavioral incidents* were defined as aggressive, emotional outbursts toward clinical staff or others that were characterized as verbal tirades with aggressive language or violent outburst that included throwing of items or verbal threats. *Critical incidents* were defined as accidents or injuries that occurred because of patients initiating unsafe actions (usually unsupervised) such as unsafe transfers or "wheelies" resulting in falls. Both types of incidents were identified and recorded by clinicians on the inpatient program. These incidents were obtained from medical records by trained chart reviewers blind to brain-injury status of patients; only items confirmed as behavioral or critical incidents by both reviewers were included.

Psychologic measures. Mood and psychopathology were measured by the PAI.²⁹ This is a 344-item self-report instrument composed of 22 nonoverlapping full scales consisting of 4 validity scales, 11 clinical scales, 5 treatment scales, and 2 interpersonal style scales. Respondents assess the degree to which each item is true of themselves on a 4-point Likert scale ranging from false to very true. The PAI has been shown to be reliable and valid in assessing personality and psychopathology among normative and clinical populations.^{29,30}

Length of stay. Number of days from inpatient rehabilitation admission to discharge was obtained from medical records.

FIM instrument. The FIM²³ was administered on admission and discharge from inpatient SCI rehabilitation. The FIM is designed to assess the degree of independence in motor, cognitive, and global activities of daily living and is based on

Table 1: Individual Subject Demographic and Injury Variables for the SCI With TBI and the SCI Only Groups

ID	Injury Level	Severity	Injury Type	PTA	Neuroimaging of Brain	Age (y)	Years of Education	Sex
SCI with TBI group								
1	C5	Complete	Sports	Not* available	+ MRI findings	29	17	M
2	T10	Incomplete	MVC	Yes	+ MRI findings	26	14	F
3	T6	Incomplete	MVC	Yes	+ CT findings	39	8	M
4	C4	Incomplete	Fall	Yes	+ CT findings	55	16	F
5	C5	Incomplete	Fall	Yes	+ CT findings	42	8	M
6	T3	Complete	MVC	Yes	+ MRI findings	20	12	F
7	C4	Incomplete	Fall	Not available*	+ MRI findings	50	9	M
8	L4	Incomplete	Fall	No	+ MRI findings	39	16	M
9	C4	Incomplete	Blunt force	Yes	+ MRI findings	40	9	M
10	C4	Complete	MVC	Yes	+ MRI findings	19	12	M
					Mean ± SD	35.90±12.11	12.10±3.53	
SCI only group								
1	C5	Incomplete	Sports	None	- MRI findings	28	12	M
2	T11	Complete	Sports	None	- MRI findings	44	10	F
3	T12	Complete	Fall	None	- MRI findings	42	12	M
4	C4	Incomplete	Blunt force	None	- MRI findings	54	14	M
5	C5	Incomplete	Fall	None	- MRI findings	29	10	M
6	T11	Complete	MVC	None	- MRI findings	53	19	M
7	C4	Incomplete	Assault	None	- MRI findings	55	10	M
8	L1	Incomplete	Fall	None	- MRI findings	19	14	F
9	C7	Incomplete	Fall	None	- MRI findings	18	12	F
10	C5	Incomplete	Fall	Not available	- MRI findings	21	12	M
					Mean ± SD	36.30±15.00	12.50±2.71	

Abbreviations: CT, computed tomography; F, female; M, male; MVC, moving vehicle collision. *PTA was not available; however, patient had documented LOC.

a person's observed functioning. Cognitive and motor performance are scored using an ordinal scale ranging from 1 (total assistance) to 7 (complete independence) with 13 motor and 5 cognitive items. Scores from both domains can be added together to produce an overall FIM score (range, 18–126), with higher scores indicating greater functional independence.

A FIM efficiency score to calculate the efficacy of rehabilitation taking FIM change and LOS into consideration (ie, the ratio of FIM change to LOS) was computed.

Neuropsychological measures. Widely used clinical tests with confirmed validity and reliability for TBI that did not require upper extremity use were included in the neuropsychological test battery. The tests included were as follows. For estimated premorbid intelligence quotient, the WTAR³¹ was employed. For attention and speed of processing, the WAIS-III digit span forwards, Symbol Digits Modalities Test,³² and Stroop Color Word Test³³ (word reading condition, color naming condition, and color-word conditions) were used. Language and visuospatial skills were tested with the WAIS-III similarities test, the Hooper Visual Organization Test,³⁴ and the WAIS-III³⁵ matrix reasoning subtest. Verbal memory was assessed with the WMS-III³⁶ logical memory immediate recall (logical memory 1) and delayed recall (logical memory 2) and the California Verbal Learning Test-Second Edition³⁷ (total learning, immediate and delayed recall, and recognition discrimination). For visuospatial memory, the WMS-III family pictures, immediate recall (family pictures 1), and delayed recall (family pictures 2) were employed. Executive functions were measured with the Controlled Oral Word Association Test,³⁸ verbal fluency test, and the Wisconsin Card Sorting Test³⁹ (number of categories correctly sorted and percentage of perseverative errors).

Therapist/nursing hours. Clinician workload (minutes of direct care per patient) was extracted from hospital records

using a computerized extraction system designed for our hospital called "workload measurement." Hours of direct care/per patient were computed separately for nursing and for all health care therapists combined (ie, physiotherapy, occupational therapy, rehabilitation therapy, and speech language pathology).

Rehabilitation care costs. Total care costs were calculated for each patient using FIM-based rehabilitation client groups (in this case, traumatic SCI or major multiple trauma with brain or SCI) according to a rehabilitation case-costing methodology devised for the province of Ontario.⁴⁰ Here, patients were first identified by their rehabilitation group, then by the FIM motor admission score and, for patients in the mid-range of FIM scores (motor score, 17–41), also by age. LOS was also determined. Patients were assigned rehabilitation case-cost weights adjusted for LOS according to the National Rehabilitation Reporting System guidelines and Ontario-specific case-cost weights.⁴⁰ A case-cost weight for each rehabilitation group was then multiplied by the provincial average case cost (\$14,139).⁴⁰

The cost/patient divided by FIM change scores (cost a patient/FIM change score) was also calculated. The total cost an FIM change score was also computed by dividing the LOS cost by the FIM change score.

Procedures

FIM scores were collected on admission and discharge to the clinical program. Clinicians on the inpatient SCI program trained in FIM administration administered the FIM. The timing of the initial FIM relative to the time of injury differed from patient to patient because of differences in admission dates.

The neuropsychological and psychologic evaluations were administered between 2 and 6 months postinjury. Trained psychometrists (supervised by a clinical neuropsychologist) completed the neuropsychological testing and were blind to neuroimaging findings at the time of the evaluation. A master's-level

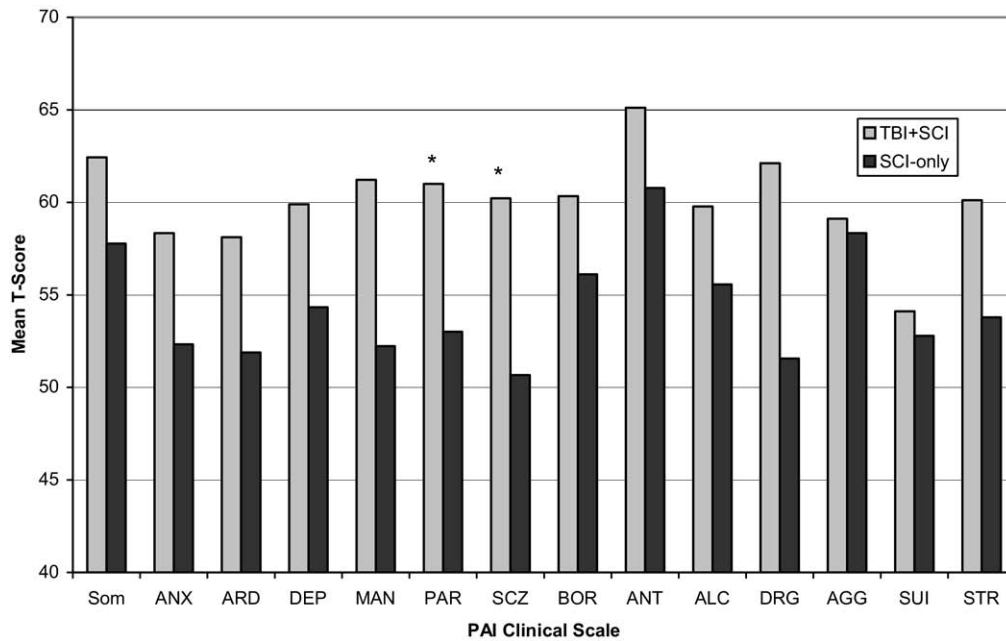


Fig 1. PAI clinical scale scores for the SCI with TBI versus SCI-only groups.

graduate student supervised by a clinical psychologist oversaw the administration of the self-report psychologic questionnaires. MRI, used to confirm presence or absence of TBI, was undertaken within 2 weeks of neuropsychological assessment. A neuroradiologist read all MRIs and determined the acquisition parameters of the scan, which were tailored to TBI (ie, dual-spin echo, fluid-attenuated inversion recovery, T2-weighted gradient echo).

Data Analyses

Descriptive statistics were calculated for demographic and injury variables to provide characterization of the 2 groups. In order to examine the hypotheses, statistical comparisons between patients with SCI only and those with SCI with TBI were completed using chi-square tests for all categorical variables and paired *t* tests for continuous variables. For all comparisons with specific, directional hypotheses, 1-tailed, unpaired *t* tests were performed.

Effect sizes (Cohen's *d*) were calculated for all comparisons. Because of the size of our clinical sample ($N=20$), the risk of type I and type II error was greater than that for a larger sample, with a risk of spurious significant findings at low effect sizes and nonsignificant findings at high effect sizes. Using null hypothesis significance testing could misrepresent the findings, and we thus employed effect sizes to interpret the data (see discussion^{41,42}). We employed a moderate cutoff of 0.4 as our index of clinical significance, which is considered high, given the low magnitude of correlations observed in well related phenomena in nature.⁴³

RESULTS

Table 1 shows the demographic and injury variables of all participants in the 2 groups individually. The groups were closely matched on all parameters with the exception of time between injury and inpatient admission. There was a difference between the groups on this parameter, with the SCI with TBI group arriving at 55.00 ± 40.81 days postinjury versus

32.90 ± 20.66 days postinjury for the SCI-only group. Although not significant on a 2-tailed unpaired *t* test ($t_{18} = -1.53$; $P = .14$), there was a large Cohen's *d* effect size of -0.68 . The admission FIM was also administered commensurately later in the SCI with TBI group. Otherwise, none of the differences between the groups approached significance, including time from injury and time to assessment.

Critical and behavioral incidents during rehabilitation.

The SCI with TBI group showed an average of 1.22 ± 1.56 behavioral incidents a person over the course of their stay compared with less than half of that, 0.44 ± 0.52 , for the SCI-only group. When corrected for LOS (which was longer in the SCI with TBI group), between-group differences approached significance ($t_{17} = 1.66$; $P = .06$), with a large Cohen's *d* effect size ($d = 0.72$).

With respect to critical incidents, the SCI with TBI group had an average of 0.44 ± 0.53 critical incidents a person, compared with 0.22 ± 0.42 incidents a person in the SCI-only control group, with a moderate effect size (Cohen's $d = 0.46$). However, when LOS was controlled for, comparable levels of critical incidents a patient per day were observed in both groups, with a negligible effect size ($d = 0.04$).

Psychologic findings. Consistent with elevated behavioral incidents, the 2 groups showed differences of greater than 10 *t* scores on most clinical subscales of the PAI, as illustrated in figure 1. These differences reached significance on the paranoia and schizophrenia subscales ($t_{16} = 1.72$, $P = .05$, Cohen's $d = 0.81$; and $t_{16} = 1.82$, $P < .05$, Cohen's $d = 0.65$, respectively). Note that the average elevation in the SCI with TBI group was not in range for clinical diagnosis of paranoia or schizophrenia. Trends toward significant between-group differences were observed on the anxiety and mania subscales, with large effect sizes ($t_{16} = 1.52$, $P = .07$, Cohen's $d = 0.71$; and $t_{16} = 1.58$, $P = .07$, Cohen's $d = 0.93$, respectively).

Neuropsychological assessment versus FIM cognitive subscale. As expected, the neuropsychological performance was poorer in the SCI with TBI group. As indicated in table 2, there

Table 2: Between Groups Neuropsychological Test Performance for SCI With TBI and SCI Only Groups

Neuropsychological Domain Test	SCI With TBI Group (n=9)	SCI Only Group (n=10)
Estimated Premorbid IQ		
WTAR [†]	98.56±17.53	105.60±13.16
Attention/speed of processing		
Digit span forwards	62.67±31.20	83.60±21.87
Symbol Digit Modalities Test	-1.11±1.27	-0.75±0.79
Stroop Word [#]	44.00±7.14	53.30±12.68*
Stroop Color Naming [#]	38.67±5.43	46.40±6.48 [†]
Stroop Color Word [#]	41.89±9.24	52.10±11.44*
Verbal Memory		
WMS-III logical memory 1 [§]	10.11±5.04	12.70±2.41
WMS-III logical memory 2 [§]	10.33±5.22	13.30±2.83
CVLT-II, short delay	-0.39±1.36	0.44±0.68
CVLT-II, long delay	-.167±1.54	0.40±0.61
CVLT-II, discriminability	-0.50±1.27	0.45±0.50*
Visual Memory		
WMS-III family pictures 1 [§]	8.44±3.71	8.70±4.14
WMS-III family pictures 2 [§]	8.00±3.97	8.90±3.64
Language/visuospatial similarities [†]	9.67±2.74	10.50±2.12
Hooper Visual Orientation Test [#]	53.56±6.86	53.10±5.69
Matrix Reasoning [§]	10.33±3.94	11.3±2.58
Executive Functions		
Digit span backwards	33.56±31.40	55.60±18.31*
Verbal Fluency (category)	-0.78±0.87	-0.07±1.03
WSCT, perseverative errors [#]	47.33±16.65	52.80±14.27

NOTE. Values are means ± SDs.

Abbreviations: CVLT, California Verbal Learning Test; WSCT, Wisconsin Card Sort Test.

* $P < .05$.

[†] $P < .01$.

[‡]standard score.

[§]scaled score.

^{||}percentile score.

^{||}z score.

[#]T score.

were no significant differences between the groups on a measure used to estimate premorbid intelligence, the WTAR. However, significant differences on 1-tailed, unpaired t tests were observed on measures of current cognitive functioning. Differences were observed on tests of attention and speed of processing: digit span backwards ($t_{17} = -1.89$, $P < .05$, Cohen's $d = -0.92$), Stroop color naming ($t_{17} = -2.80$, $P < .01$, Cohen's $d = -1.29$), and Stroop word reading ($t_{17} = -1.94$, $P < .05$, Cohen's $d = -0.90$). Verbal recognition memory also significantly differed between the groups ($t_{17} = -2.19$, $P < .05$, Cohen's $d = -0.87$). Trends toward poorer performance by the SCI with TBI group with medium to large effect sizes were observed on measures of verbal recall (logical memory, immediate recall, $t_{17} = -1.45$, $P = .08$, Cohen's $d = -0.60$; California Verbal Learning Test, short delay free recall, $t_{17} = -1.64$, $P = .06$, Cohen's $d = -1.76$; digit span forwards, $t_{17} = -1.71$, $P = .05$, Cohen's $d = -0.78$; and verbal fluency, $t_{17} = -1.60$, $P = .06$, Cohen's $d = -0.74$).

Functional outcome. Although the neuropsychological findings clearly distinguished the groups, the FIM admission cognitive subscale did not because of ceiling effects. Indeed, 10 of 10 participants in the SCI only group and 7 of 10 patients in the SCI with TBI group scored at ceiling (35 of 35).

With regard to the motor FIM subscale, the patients with SCI with TBI were tested significantly later postinjury than those in the SCI only group and were matched for severity of injury; however, their motor scores were still slightly lower, with a mean motor FIM ± SD of 24.80±13.42 in the SCI with TBI group versus a mean ± SD of 29.20±19.41 in the SCI only group. The difference was not significant ($t_{17} = -0.59$; $P = .28$), with a small Cohen's d of -0.26. However, given that the SCI with TBI group had longer recovery time, their FIM scores should logically have been higher unless the brain-injury was compromising performance on the FIM.

Length of stay. The SCI with TBI group remained in inpatient rehabilitation longer than the SCI only group, with mean LOSs ± SD of 138.3±69.71 days versus 100.30±41.41 days, respectively, with a difference that approached significance ($t_{18} = 1.48$; $P = .08$) and a medium to large effect size of Cohen's d equal to 0.66. However, the SCI with TBI group did not surpass the SCI only group on the FIM motor subscale; motor FIM discharge scores were 54.7±27.35 for the SCI with TBI group versus 62.67±23.83 for the SCI only group.

Therapy/nursing hours. Level of nursing care required revealed greatest differences, with an average ± SD of 262.34±197.56 hours of care within a 2-month period required by the SCI with TBI group compared with 185.47±107.69 hours required by the SCI only group ($t_{15} = 1.01$, $P = .16$) and a medium Cohen's d effect size of 0.48. The difference in the number of therapy hours between groups was smaller, with the SCI with TBI group requiring an average ± SD of 204.68±155.38 hours, compared with the SCI only group, which received an average ± SD of 184.05±108.74 hours ($t_{15} = -0.32$; $P = .38$; $d = 0.15$).

Economic burden. The average cost ± SD for a dual diagnosis patient to complete SCI rehabilitation was \$169,638±\$83,945, compared with \$130,773±\$90,630 for a patient with SCI only, a difference that did not reach significance ($t_{18} = -.99$; $P = .17$) but showed a medium Cohen's d effect size of 0.44. The total cost per FIM change score was also not found to differ between groups ($t_{17} = -1.18$; $P = .13$) but revealed a medium Cohen's d effect size ($d = -0.56$). Thus, these differences were of clinical significance in both cases.

DISCUSSION

Taken together, the results from the present study show a substantive, deleterious impact of comorbid TBI with SCI. First, we found that patients with SCI with TBI displayed significantly more behavioral incidents, greater psychopathology, and more severe neuropsychological impairment than patients with SCI without TBI. These findings are compatible with the previous research of Richards et al,²² who also examined psychosocial functioning (but in an outpatient population) and found poorer adjustment in patients with SCI with comorbid TBI. In the current study, increased behavioral incidents may have been associated with elevated psychopathology and neuropsychological impairment. It has previously been suggested that undiagnosed TBI with associated executive dysfunction and compromised ability to attend to and/or remember instructions leads to confusion, frustration, and tension among the patient, treating clinicians, nurses, and fellow patients.^{2,19} Anecdotal experience on our inpatient clinical program is consistent with these findings. It is unclear whether elevated psychopathology here is a consequence of brain injury or a premorbid risk factor. Ascertainment of preinjury psychopathology with the help of family members would be of interest.

As well, further research with larger sample sizes and predictive models, such as path analysis, would be helpful to understand better the interrelationships between behavioral incidents, psychopathology, and neuropsychological impairment.

A second consequence of comorbid TBI in the current study was the need for greater nursing care hours. A number of factors may have contributed to this finding. For example, given greater behavioral incidents and emotional disturbance in the SCI with TBI group, one might speculate that recorded behavioral incidents along with milder unrecorded incidents may have added to nursing hours. In addition, speed of information processing was slower in the SCI with TBI group; consequently, activities under nursing supervision (many of which are unstructured, in contrast with structured therapeutic activities) may simply have required more time. Other factors not measured in the current study may have also contributed, such as slower achievement of independence in bowel and bladder care, transfers, and self-medication. Further research is needed to examine these speculations to anticipate where added nursing hours and nursing support might be valuable to allow for the most efficient use of nursing resources.

A third difference between the groups concerned the FIM results. Despite a later arrival to inpatient rehabilitation of the SCI with TBI group, intake motor FIM scores were comparable between the SCI with TBI and SCI only groups. Moreover, despite a longer LOS, and group matching for severity of SCI injury and demographics, the SCI with TBI group did not exceed the SCI only group on FIM score by the time of discharge. These findings were compatible with those of Macciocchi et al.,²¹ who did not find differences in LOS, but did find a difference in FIM motor scores at discharge. Taken together, these results indicate that more time is needed to achieve comparable gains in independence of activities of daily living in patients with a concomitant brain injury. The findings suggest several interpretations: first, the cognitive and neurobehavioral consequences of TBI may impede SCI rehabilitation, with impairments to attention and memory—for example, diminishing the capacity for learning self-maintenance routines. A second interpretation is that the TBI itself causes motor impairments. Deficits of incoordination, motor planning, and postural control are often seen in TBI.⁴⁴ However, in our context, TBI-related motor deficits would not have been treated with interventions with demonstrated efficacy for TBI, such as forced use/constraint-induced movement.¹⁹

The findings also revealed the inadequacy of the FIM cognitive subscale to detect cognitive impairments, consistent with the findings of Davidoff et al.²⁷ Only 3 of the 10 patients in the SCI with TBI group fell below ceiling on the FIM cognitive subscale at intake. This finding has important clinical implications: The FIM is often the only screening of cognitive status that is employed on admission to inpatient spinal cord rehabilitation programs. Because the diagnosis of TBI is often missed in acute care,¹ and neuropsychological assessment is unlikely to be administered without a TBI diagnosis, there is no diagnostic safety net. One consequence of missed diagnoses is that cognitive and neurobehavioral symptoms of TBI may be misattributed, with patients labeled as “unmotivated,” “noncompliant,” or “difficult.” Perhaps more importantly, the failure to identify TBI either in acute care or inpatient rehabilitation settings would result in a failure to provide specialized services for brain injury, where available.

Last, and perhaps not surprisingly, the daily costs of inpatient spinal cord rehabilitation were greater for patients with TBI than for patients with SCI only, as were the costs/FIM change. These costs might be decreased if specialized dual diagnosis care to improve the speed and quality of learning of

self-care routines were implemented. For example, specialized care could incorporate those learning approaches that are most effective for people with explicit memory deficits, such as procedural learning^{45,46} and errorless learning.⁴⁷ For the learning of self-care routines, these approaches might prove more effective for acquisition in the short term, and more resistant to decay in the longer term.

Study Limitations

One limitation of the current study concerned matching. While patients were case-matched based on general level of injury (cervical, thoracic, lumbar), they were not case-matched for vertebral level. Overall, there were slightly higher levels of injury in the SCI with TBI group. Therefore, 1 alternative interpretation of the differences observed between the groups is that level of injury differences between the groups, rather than concomitant brain injury, played a causal role, contributing to some or all outcome variance. A close inspection of the individual data points does not support this alternative interpretation, however. When we examined each case-matched pair, there were no systematic outcome differences as a function of vertebral level. There was not a greater decrement in performance for those pairs for which the patient with SCI with TBI had a higher injury than the SCI only case-matched control versus those pairs for which the patient with SCI with TBI had a lower injury.

Another limitation concerns the patient sample. The sample size was small. Therefore, the study may have been underpowered to detect significant differences between the groups. As well, all recruitment was undertaken from a single, inpatient spinal cord treatment facility in an urban center associated with a teaching hospital. Therefore, the findings may not generalize to other types of treatment facilities or rural patient populations. The presence of pain and medication effects over time was not controlled, although we do not expect these factors to differ significantly between the groups.

As well, the presence of self-awareness deficits in TBI may have resulted in a more positive response bias on self-report questionnaires of mood and psychopathology, thereby underestimating psychopathology in the SCI with TBI group. Also, there are limitations to the validity of the PAI for patients with TBI; elevations on some subscales, including schizophrenia and somatization, may occur because of the neurologic and medical features of brain injury rather than psychopathology.

Finally, there were no differences between the groups with regard to secondary neurologic complications of the brain. However, we did not control for secondary medical complications in the study. Therefore, 1 possible explanation for differences in LOS between the groups concerns secondary medical complications. Logically, any increased risk in secondary complications caused by cognitive impairment (eg, because of poorer self-care or self-monitoring) would be likely to emerge postdischarge and would be unlikely to emerge while patients are being closely monitored during their inpatient stay. For example, patients receive daily therapy and nursing supervision, and have regular physician contact. Nonetheless, it would be valuable to control for this factor in future research.

CONCLUSIONS

The clinical and economic impact of dual diagnosis observed in this study would likely be unsurprising to clinicians working with the SCI population. In addition to the present findings and those of Macciocchi et al.,²¹ who found reduced FIM gains during rehabilitation of an SCI with TBI group, long-term

effects of dual diagnosis (on personal and family adjustment) have also been observed.²² Taken together, these findings support the need for further research on larger populations, both in the early subacute and chronic stages of injury. An understanding of the relationship, for example, between specific cognitive deficits and poor long-term outcomes could allow for prophylactic, targeted interventions. We suggest that early identification and specialized intervention could help to meet the unique and complex needs of this special population, thereby improving quality of life and reducing the negative impact on health care systems and society.

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