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Factors Associated With Functional Impairment After Pediatric Injury

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Supplemental content

IMPORTANCE Short- and long-term functional impairment after pediatric injury may be more sensitive for measuring quality of care compared with mortality alone. The characteristics of injured children and adolescents who are at the highest risk for functional impairment are unknown.

OBJECTIVE To evaluate categories of injuries associated with higher prevalence of impaired functional status at hospital discharge among children and adolescents and to estimate the number of those with injuries in these categories who received treatment at pediatric trauma centers.

DESIGN, SETTING, AND PARTICIPANTS This prospective cohort study (Assessment of Functional Outcomes and Health-Related Quality of Life After Pediatric Trauma) included children and adolescents younger than 15 years who were hospitalized with at least 1 serious injury at 1 of 7 level 1 pediatric trauma centers from March 2018 to February 2020.

EXPOSURE At least 1 serious injury (Abbreviated Injury Scale score, ≥3 [scores range from 1 to 6, with higher scores indicating more severe injury]) classified into 9 categories based on the body region injured and the presence of a severe traumatic brain injury (Glasgow Coma Scale score <9 or Glasgow Coma Scale motor score <5).

MAIN OUTCOMES AND MEASURES New domain morbidity defined as a 2 points or more change in any of 6 domains (mental status, sensory, communication, motor function, feeding, and respiratory) measured using the Functional Status Scale (FSS) (scores range from 1 [normal] to 5 [very severe dysfunction] for each domain) in each injury category at hospital discharge. The estimated prevalence of impairment associated with each injury category was assessed in the population of seriously injured children and adolescents treated at participating sites.

RESULTS This study included a sample of 427 injured children and adolescents (271 [63.5%] male; median age, 7.2 years [interquartile range, 2.5-11.7 years]), 74 (17.3%) of whom had new FSS domain morbidity at discharge. The proportion of new FSS domain morbidity was highest among those with multiple injured body regions and severe head injury (20 of 24 [83.3%]) and lowest among those with an isolated head injury of mild or moderate severity (1 of 84 [1.2%]). After adjusting for oversampling of specific injuries in the study sample, 749 of 5195 seriously injured children and adolescents (14.4%) were estimated to have functional impairment at hospital discharge. Children and adolescents with extremity injuries (302 of 749 [40.3%]) and those with severe traumatic brain injuries (258 of 749 [34.4%]) comprised the largest proportions of those estimated to have impairment at discharge.

CONCLUSIONS AND RELEVANCE In this cohort study, most injured children and adolescents returned to baseline functional status by hospital discharge. These findings suggest that functional status assessments can be limited to cohorts of injured children and adolescents at the highest risk for impairment.

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More than 100 000 children annually are admitted to trauma centers in the US, with almost half having a serious injury.[1,2] Up to 40% of these children have a residual functional impairment 1 month after injury.[3] Despite the frequency of acquired disability, evaluating care in this population depends mainly on mortality assessment.[4,5] The percentage of children with a serious injury not surviving to discharge is low; thus, mortality is limited as a metric for assessing quality of care.[2] Measures that are more granular than mortality are needed as health care quality indicators for injured children.

Despite this need for more granular measures of quality, several factors have limited the assessment of functional status as standard practice at trauma centers, including a lack of consensus regarding the optimal measure and the required resources for obtaining assessments.[6] A single method for functional status assessment has not been identified for children with a range of injury types or multiple injuries,[6,7] with current assessments usually focused on single injury types, such as traumatic brain injury.[8,9] Studies reporting functional outcomes in children with injuries to multiple body regions have had small samples, have not evaluated those treated outside the intensive care unit (ICU), or have excluded populations such as infants.[3,10,11]

This study aimed to (1) identify categories of injuries among children and adolescents that are associated with higher prevalence of functional impairment at hospital discharge and (2) estimate the number of children and adolescents with injuries in these categories who received treatment at pediatric trauma centers. We conducted a 2-year, multicenter study evaluating functional status at hospital discharge in a sample of children and adolescents hospitalized for at least 1 serious injury. We applied these results to the trauma populations at the participating sites to estimate the overall prevalence of functional impairment. We hypothesized that the change in functional status from preinjury baseline to hospital discharge would be associated with the body regions injured and the number of body regions injured.

Key Points

Question Are certain categories of injury associated with higher prevalence of functional impairment among children and adolescents at hospital discharge?

Findings In this cohort study, 17.3% of seriously injured children and adolescents had functional impairment at hospital discharge. After adjusting for oversampled injuries, the prevalence of functional impairment at discharge among all patients admitted for serious injuries at participating centers was 14.4%, with this prevalence being highest among patients with extremity injuries and severe traumatic brain injuries.

Meaning The findings suggest that functional status assessments can be limited to cohorts of injured children and adolescents at the highest risk for impairment.

Methods

Study Overview

This prospective cohort study (Assessment of Functional Outcomes and Health-Related Quality of Life After Pediatric Trauma) was performed from March 2018 to February 2020 at 7 sites participating in the National Institutes of Health–funded Collaborative Pediatric Critical Care Research Network. Each site is a designated level 1 pediatric trauma center. The institutional review board at the University of Utah approved this study through a central mechanism. Written informed consent for participation was attained from parents or guardians of the patients. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.

Enrollment

Children and adolescents injured by a blunt or penetrating mechanism who survived to discharge were eligible if treated for a serious, severe, or critical injury (Abbreviated Injury Scale score, ≥3 [scores range from 1 to 6, with higher scores indicating more severe injury]) in a major body region (head, thorax, abdomen, spine, or upper or lower extremity). We included only individuals younger than 15 years because the individuals in this age group were the most frequently seen at the trauma centers at all sites. We excluded patients with burn injuries because of their unique functional outcomes[12] as well as children and adolescents with caregivers who did not speak English or Spanish to ensure the applicability of surveys and assessments.

We used an enrollment approach that promoted sampling of children and adolescents with less commonly injured body regions and injuries in more than 1 body region. All patients meeting eligibility criteria were considered. Potential participants were distributed into predefined enrollment categories based on (1) the body region or regions with a severe injury (head, extremity, thorax, abdomen, and spine) and (2) the presence of severe injury in 1 or more body region. The first 5 enrollment categories were used for patients with 1 or more serious injury in only 1 of the 5 body regions (ie, single body region). The remaining 5 enrollment categories were used for those with a serious injury in more than 1 body region (ie, multiple body regions). These 5 multiple-injury categories were labeled with each body region. When a patient had injuries to multiple body regions, we identified which body region had the lowest relative prevalence of injuries, with the lowest being the spine followed by the thorax, abdomen, extremities, and head.[2] We then assigned the patient to the multiple-injury category labeled with the body region with the lowest prevalence of injuries. For example, a child or adolescent with a serious injury in the head and spine regions was placed in the spine multiple-injury category because spine injuries are less frequent than head injuries. Every 3 months, enrollment was adjusted across all sites to enhance sampling. Enrollment targets were 50 patients per site per year, with a goal of 70% of participants with 1 injured body region and 30% with multiple injured body regions.

Data Collection

Research coordinators were trained centrally to ensure consistent enrollment, data collection practices, and outcome measurement. A data coordinating center monitored enrollment, validated collated data, and conducted statistical analyses. Self-reported race/ethnicity and insurance status of the participants were obtained from parents or guardians. We identified preinjury comorbidities using the medical record (eAppendix 1 in the Supplement). Discharge disposition was grouped as going home with parents or guardians, to foster care, to an inpatient rehabilitation facility, to a long-term care or skilled nursing facility, or to another acute care hospital. Additional data were obtained from the trauma registry, including injury type (blunt vs penetrating) and mechanism, initial systolic blood pressure and heart rate, initial Glasgow Coma Scale (GCS) score, and ICU and hospital length of stay. Child physical abuse was designated as the mechanism regardless of other assignments. Owing to inconsistencies and lack of standardization of *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision* diagnosis codes or external cause codes for child abuse in trauma registries, we used medical record review to assess for an abuse mechanism.[13] Child physical abuse was designated by research coordinators if health care professional, child advocacy team, or social work records showed that it was suspected to be the primary mechanism of injury. Blood pressure and heart rate were standardized to *z* scores using age-based means and SDs.[14-16]

The Functional Status Scale (FSS) was used for assessments before injury and at discharge, and the Pediatric Cerebral Performance Category (PCPC) and Pediatric Overall Performance Category (POPC) scales were used at discharge. These measures were acquired using the medical record as well as parent or guardian and clinical care team interviews. The FSS is a validated, rapidly performed, and age-independent objective measure applicable for large-scale studies of critically ill children.[17] The FSS assesses function in 6 domains: mental status, sensory, communication, motor, feeding, and respiratory. Scores range from 1 (normal) to 5 (very severe dysfunction) for each domain. The overall FSS scores range from 1 to 30; less than 8 is considered normal, whereas a score of 8 or 9 indicates mild impairment and a score greater than 9 indicates moderate or greater impairment. The POPC and PCPC scales are rapidly performed, subjective assessments applicable to large-scale studies.[18] Scores range from 1 to 5, with scores greater than 2 indicating more than mild impairment.

Statistical Analysis

The primary outcome was a change of 2 or more in any FSS domain between preinjury and discharge status (ie, new domain morbidity); this change indicates marked new impairment.[19] Secondary outcomes included discharge POPC and PCPC scale scores. We placed each patient into 1 of 9 injury categories based on (1) the body region injured, (2) whether single or multiple body regions were injured, and (3) the severity of the head injury when applicable. We used a GCS total score less than 9 or a GCS motor score less than 5 to define severe head injury. We classified head injuries with a missing GCS value as severe because of associations of missingness with abnormal GCS and mortality.[20] The 9 injury categories included (1) multiple body regions including a severe head injury, (2) multiple body regions with a less than severe head injury, (3) multiple body regions excluding the head, (4) isolated severe head injury, (5) isolated less than severe head injury, (6) isolated thoracic injury, (7) isolated abdominal injury, (8) isolated spinal injury, and (9) isolated extremity injury.

Estimates of impairment among seriously injured children at the sites were calculated using the number of children and adolescents in each injury category in the trauma registry and the percentage of impairment associated with each category among the sampled patients. We performed univariate comparisons using the χ^2 and Wilcoxon rank sum tests. Logistic regression assessing new domain morbidity at discharge used the 9 injury categories, demographic variables (age, race/ethnicity, and insurance status), physiological measures (systolic blood pressure, heart rate), injury type (blunt or penetrating), child physical abuse, and study site. We selected covariates for multivariate modeling a priori based on assessment of the potential for influencing functional outcomes based on a literature review and domain knowledge. We used inverse probability weights to allow inferences for the population of children in the trauma registry. To address missing data (**Table 1** and **Table 2**), we imputed 10 data sets using chained regressions under the assumption of a missing-at-random pattern, combining results using standard techniques.[21,22] To make comparisons between all possible pairs of injury categories, we varied the injury category used as the reference group in the multivariate model. We then constructed a matrix representing the odds ratios (ORs) using different reference and comparison injury categories. Using these pairwise ORs, we ranked the risk of new domain morbidity among injury categories. We defined significance at 2-sided $P < .05$. Analyses were performed used SAS, version 9.4 (SAS Institute Inc).

Results

Among the 835 patients assessed for eligibility, 654 met the inclusion criteria; 493 of their parents or guardians were approached for consent, and 428 provided consent. One patient was withdrawn because of the absence of a qualifying injury. The final sample included 427 patients (median age, 7.2 years [interquartile range, 2.5-11.7 years]). A median of 59 patients (range, 28-88 patients) were enrolled per site. Most patients were male (271 [63.5%]), White (277 [64.9%]), and non-Hispanic (376 [88.1%]) and had either private insurance (188 [44.0%]) or Medicaid or Medicare (198 [46.4%]) as primary coverage (Table 1). Among the enrolled patients, blunt trauma was the predominant injury type (380 injuries [89.0%]), with falls being the most frequent injury mechanism (125 [29.3%]) (Table 2). Most patients had a single body region injury (354 [82.9%]), which was usually an extremity or head injury. Most patients presented with normal physiological parameters as assessed by systolic blood pressure, heart rate, and GCS. Preinjury comorbidities were observed in 66 children and adolescents (15.5%), with asthma being the most frequent (13 patients [3.0%]) (Table 1). The preinjury functional status was normal for most patients (414 [97.0%]). A total of 174 patients

Table 1. Associations of New Domain Morbidity With Demographic and Baseline Characteristics

Characteristic	Patients, No. (%)[a] Overall (N = 427)	No new domain morbidity (n = 353)	New domain morbidity (n = 74)	*P* value[b]
Age group, y				
<1	64 (15.0)	53 (15.0)	11 (14.9)	.77
1-4	102 (23.9)	81 (22.9)	21 (28.4)	
5-9	111 (26.0)	94 (26.6)	17 (23.0)	
10-14	150 (35.1)	125 (35.4)	25 (33.8)	
Sex				
Male	271 (63.5)	227 (64.3)	44 (59.5)	.43
Female	156 (36.5)	126 (35.7)	30 (40.5)	
Race				
White	277 (64.9)	235 (66.6)	42 (56.8)	.13
Black	95 (22.2)	72 (20.4)	23 (31.1)	
Other[c]	54 (12.6)	45 (12.7)	9 (12.2)	
Missing[d]	1 (0.2)	1 (0.3)	0	
Ethnicity				
Hispanic or Latino	49 (11.5)	40 (11.3)	9 (12.2)	.81
Not Hispanic or Latino	376 (88.1)	312 (88.4)	64 (86.5)	
Missing[d]	2 (0.5)	1 (0.3)	1 (1.4)	
Insurance				
Private or commercial	188 (44.0)	155 (43.9)	33 (44.6)	.95
Medicaid or Medicare	198 (46.4)	162 (45.9)	36 (48.6)	
Self-pay or no insurance	12 (2.8)	10 (2.8)	2 (2.7)	
>1 Type	11 (2.6)	10 (2.8)	1 (1.4)	
Other	14 (3.3)	12 (3.4)	2 (2.7)	
Missing[d]	4 (0.9)	4 (1.1)	0	
FSS at baseline by category[e]				
6 or 7	414 (97.0)	342 (96.9)	72 (97.3)	.85
>7	13 (3.0)	11 (3.1)	2 (2.7)	
Underlying medical conditions				
None	361 (84.5)	297 (84.1)	64 (86.5)	.85
Asthma	13 (3.0)	10 (2.8)	3 (4.1)	
Cardiovascular disease[f]	3 (0.7)	3 (0.8)	0	
Neurologic disease[g]	6 (1.4)	5 (1.4)	1 (1.4)	
Other[h]	44 (10.3)	38 (10.8)	6 (8.1)	

Abbreviation: FSS, Functional Status Scale.

[a] Percentages may not add to 100% because of rounding.

[b] Determined using the χ^2 test or Wilcoxon rank sum test.

[c] Included American Indian or Alaska Native, Asian, Native Hawaiian or Other Pacific Islander, more than 1 race, and other.

[d] Not included in the χ^2 or Wilcoxon tests.

[e] An overall FSS score of 6 or 7 indicated normal function and more than 7 indicated abnormal function.

[f] Arrhythmias or congenital cardiovascular disease.

[g] Seizure disorders and other neurologic disease.

[h] Other underlying medical conditions are given in eTable 1 in the Supplement.

(40.8%) were admitted to the ICU, with a median ICU length of stay of 4.0 days (range, 2.0-7.0 days) (Table 2). The median hospital length of stay for all patients in the study was 3.0 days (range, 2.0-8.0 days). Most patients were discharged to their home or to foster care (373 [87.4%]). Overall, 45 patients (10.5%) required inpatient rehabilitation after discharge, and 1 patient (0.2%) was admitted to a skilled nursing facility.

Although most patients returned to or continued to have normal functional status at hospital discharge (353 [82.7%]), new domain morbidity occurred in 74 patients (17.3%) (Table 1 and Table 2). Patients with multiple injured body regions that included a severe head injury had the highest percentage of new domain morbidity (83.3% [20 of 24 patients]), and those with isolated mild or moderate head injuries had the lowest percentage (1.2% [1 of 84]) (**Table 3**). New domain morbidity was also common among patients with multiple injured body regions with less severe head injury (30.8% [4 of 13]), those with multiple injured body regions not including head injury (27.8% [10 of 36]), those with isolated severe head injury (30.4% [7 of 23]), and those with isolated spine injury (28.6% [6 of 21]). New domain morbidity was similar among children with isolated extremity injury (16.5% [19 of 115]) and those with isolated thoracic injury (13.3% [4 of 30]). Among the 13 patients with at least mild impairment before injury, only 2 had new domain morbidity at discharge. Analysis of POPC and PCPC scale scores showed more than mild impairment (score >2) at discharge in 99 patients (23.2%) and 27 patients (6.3%) patients, respectively. The proportions of patients in each injury category with more than mild impairment on the POPC scale were similar to the proportions of patients with new domain morbidity (Table 3). Consistent with its value for measuring of neurologic function, the PCPC scale score more often showed more than abnormal impairment among those with a severe head injury alone or combined with another body region (36.2% [17 of 47]). The domains of FSS with morbidity were associated with injury category (**Figure**). Patients with iso-

Table 2. Associations of New Domain Morbidity With Injury Characteristics and Outcomes

Characteristic	Patients[a] Overall (N = 427)	No new domain morbidity (n = 353)	New domain morbidity (n = 74)	*P* value[b]
Injury category				
Multiple, including severe head injury	24 (5.6)	4 (1.1)	20 (27.0)	<.001
Multiple, including nonsevere head injury	13 (3.0)	9 (2.5)	4 (5.4)	
Multiple, excluding head injury	36 (8.4)	26 (7.4)	10 (13.5)	
Isolated severe head injury	23 (5.4)	16 (4.5)	7 (9.5)	
Isolated nonsevere head injury	84 (19.7)	83 (23.5)	1 (1.4)	
Isolated thoracic injury	30 (7.0)	26 (7.4)	4 (5.4)	
Isolated abdominal injury	81 (19.0)	78 (22.1)	3 (4.1)	
Isolated spinal injury	21 (4.9)	15 (4.2)	6 (8.1)	
Isolated extremity injury	115 (26.9)	96 (27.2)	19 (25.7)	
Body regions with an AIS≥3, No.[c]				
1	354 (82.9)	314 (89.0)	40 (54.1)	<.001
2	46 (10.8)	32 (9.1)	14 (18.9)	
>2	27 (6.3)	7 (2.0)	20 (27.0)	
Injury type				
Blunt	380 (89.0)	317 (89.8)	63 (85.1)	.45
Penetrating	17 (4.0)	13 (3.7)	4 (5.4)	
Missing[d]	30 (7.0)	23 (6.5)	7 (9.5)	
Mechanism of injury				
Child physical abuse	45 (10.5)	37 (10.5)	8 (10.8)	<.001
Penetrating	11 (2.6)	7 (2.0)	4 (5.4)	
Fall	125 (29.3)	117 (33.1)	8 (10.8)	
Motor vehicle collision occupant	77 (18.0)	52 (14.7)	25 (33.8)	
Pedestrian	30 (7.0)	20 (5.7)	10 (13.5)	
Transport, other or motorcycle	20 (4.7)	17 (4.8)	3 (4.1)	
Pedal cyclist	23 (5.4)	23 (6.5)	0	
Struck by or against	31 (7.3)	27 (7.6)	4 (5.4)	
Other	15 (3.5)	13 (3.7)	2 (2.7)	
Missing[d]	50 (11.7)	40 (11.3)	10 (13.5)	
Initial systolic blood pressure[e]				
Normal	379 (88.8)	315 (89.2)	64 (86.5)	.75
Not normal	15 (3.5)	12 (3.4)	3 (4.1)	
Missing[d]	33 (7.7)	26 (7.4)	7 (9.5)	
Initial heart rate[e]				
Normal	277 (64.9)	235 (66.6)	42 (56.8)	.25
Not normal	132 (30.9)	106 (30.0)	26 (35.1)	
Missing[d]	18 (4.2)	12 (3.4)	6 (8.1)	
Initial GCS score[f]				
>12	338 (79.2)	303 (85.8)	35 (47.3)	<.001
9-12	10 (2.3)	8 (2.3)	2 (2.7)	
<9	42 (9.8)	17 (4.8)	25 (33.8)	
Missing[d]	37 (8.7)	25 (7.1)	12 (16.2)	
ICU admission				
No	242 (56.7)	223 (63.2)	19 (25.7)	<.001
Yes	174 (40.8)	123 (34.8)	51 (68.9)	
Missing[d]	11 (2.6)	7 (2.0)	4 (5.4)	
ICU length of stay if admitted to ICU, median (IQR), d	4.0 (2.0-7.0)	3.0 (2.0-5.0)	9.0 (4.0-18.0)	<.001
Total hospital length of stay, median (IQR), d	3.0 (2.0-8.0)	3.0 (1.0-6.0)	13.0 (4.0-22.0)	<.001

(continued)

Table 2. Associations of New Domain Morbidity With Injury Characteristics and Outcomes (continued)

Characteristic	Patients[a] Overall (N = 427)	No new domain morbidity (n = 353)	New domain morbidity (n = 74)	P value[b]
Disposition at discharge				
Home with parent or guardian	367 (85.9)	332 (94.1)	35 (47.3)	<.001
Foster care	6 (1.4)	5 (1.4)	1 (1.4)	
Inpatient rehabilitation facility	45 (10.5)	10 (2.8)	35 (47.3)	
Long-term care or skilled nursing facility	1 (0.2)	0	1 (1.4)	
Acute care hospital	3 (0.7)	2 (0.6)	1 (1.4)	
Other	3 (0.7)	3 (0.8)	0	
Missing[d]	2 (0.5)	1 (0.3)	1 (1.4)	

Abbreviations: AIS, Abbreviated Injury Scale; GCS, Glasgow Coma Scale; ICU, intensive care unit; IQR, interquartile range.

[a] Data are presented as number (percentage) of patients unless otherwise indicated. Percentages may not add to 100% because of rounding.

[b] Determined using the χ^2 test or Wilcoxon rank sum test.

[c] AIS scores range from 1 to 6, with higher scores indicating more severe injury. A score of 3 or more indicates serious, severe, or critical injury.

[d] Not included in the χ^2 or Wilcoxon tests.

[e] Normal was defined as a *z* score of −1.96 to 1.96; not normal was defined as a *z* score less than −1.96 or greater than 1.96.

[f] A GSC score greater than 12 indicates minor traumatic brain injury; 9 to 12, moderate; and less than 9, severe.

Table 3. Level of Impairment and Outcomes Among Children and Adolescents With Body Regions With at Least 1 Serious Injury[a]

Outcome	Multiple body regions: Severe head injury	Multiple body regions: Nonsevere head injury	Multiple body regions: Not including head injury	Isolated: Severe head injury	Isolated: Spinal injury	Isolated: Extremity injury	Isolated: Thoracic injury	Isolated: Abdominal injury	Isolated: Nonsevere head injury
Sampled cohort (N = 427)									
Total patients, No. (%)[b]	24 (5.6)	13 (3.0)	36 (8.4)	23 (5.4)	21 (4.9)	115 (26.9)	30 (7.0)	81 (19.0)	84 (19.7)
Admitted to ICU, No. (%)	24 (100)	12 (92.3)	21 (58.3)	17 (73.9)	10 (47.6)	6 (5.2)	14 (46.7)	26 (32.1)	44 (52.4)
ICU LOS, median (IQR), d	12.0 (6.5-24.5)	3.5 (2.5-7.5)	4.0 (2.0-11.0)	6.0 (3.0-11.0)	4.5 (3.0-8.0)	4.0 (3.0-18.0)	3.5 (2.0-8.0)	2.0 (2.0-4.0)	2.0 (2.0-3.0)
Total LOS, median (IQR), d	20.0 (13.0-33.0)	8.0 (5.0-21.0)	7.5 (4.0-13.5)	9.0 (6.0-20.0)	3.0 (1.0-10.0)	2.0 (1.0-4.0)	3.5 (2.0-7.0)	3.0 (2.0-7.0)	2.5 (1.0-5.0)
Abnormal FSS score at baseline, No. (%)[c]	1 (4.2)	0	0	1 (4.3)	0	7 (6.1)	0	1 (1.2)	3 (3.6)
Abnormal FSS score at discharge, No. (%)[c]	22 (91.7)	6 (46.2)	11 (30.6)	12 (52.2)	6 (28.6)	30 (26.1)	5 (16.7)	5 (6.2)	6 (7.1)
New domain morbidity, No. (%)	20 (83.3)	4 (30.8)	10 (27.8)	7 (30.4)	6 (28.6)	19 (16.5)	4 (13.3)	3 (3.7)	1 (1.2)
POPC scale score >2 at discharge, No. (%)[d]	18 (75.0)	4 (30.8)	13 (36.1)	6 (26.1)	4 (19.0)	32 (27.8)	5 (16.7)	11 (13.6)	6 (7.1)
PCPC scale score >2 at discharge, No. (%)[d]	12 (50.0)	1 (7.7)	2 (5.6)	5 (21.7)	0	3 (2.6)	0	1 (1.2)	3 (3.6)
Trauma registry data (N = 5195)									
Total patients. No. (%)	175 (3.4)	110 (2.1)	158 (3.0)	369 (7.1)	144 (2.8)	1828 (35.2)	259 (5.0)	414 (8.0)	1738 (33.5)
Projected patients with new domain morbidity, No. (%)	146 (19.5)	34 (4.5)	44 (5.9)	112 (15.0)	41 (5.5)	302 (40.3)	34 (4.5)	15 (2.0)	21 (2.8)

Abbreviations: FSS, Functional Status Scale; ICU, intensive care unit; IQR, interquartile range; LOS, length of stay; PCPC, Pediatric Cerebral Performance Category; POPC, Pediatric Overall Performance Category.

[a] Serious injury was defined as an Abbreviated Injury Scale score of 3 or greater.

[b] Values in this row are the denominators used in percentage calculations for the rows below.

[c] Abnormal FSS score was defined as greater than 7 on a scale of 1 to 30, with less than 8 considered normal; 8 or 9, mild; and greater than 9, moderate or greater impairment.

[d] Scores range from 1 to 5, with scores greater than 2 indicating more than mild impairment.

lated spinal (5 of 7 [71.4%]), extremity (18 of 19 [94.7%]), or abdominal (2 of 3 [66.7%]) injuries had most new motor deficits. Those with isolated thoracic injuries had new morbidity in the motor and feeding domain (2 of 4 [50%] and 2 of 4 [50%], respectively). Morbidities among those with isolated nonsevere head injuries were limited to the sensory domain (1 of 1 [100%]).

The registry at the sites during the study period contained records for 20 612 children and adolescents, of whom 5195 (25.2%) had at least 1 serious or greater injury. On the basis of the prevalence of injuries in each category among the sampled patients (Table 3), we estimated that 749 of 5195 patients (14.4%) would have discharge functional impairment. The most common injury categories among those with a serious injury were isolated extremity injury (1828 patients [35.2%]) followed by isolated nonsevere head injury (1738 [33.5%]) (Table 3). Patients with extremity injuries (302 of 749 [40.3%]) followed by those with multiple injured body re-

Figure. Distribution of the Domains of New Morbidity in Each Injury Category

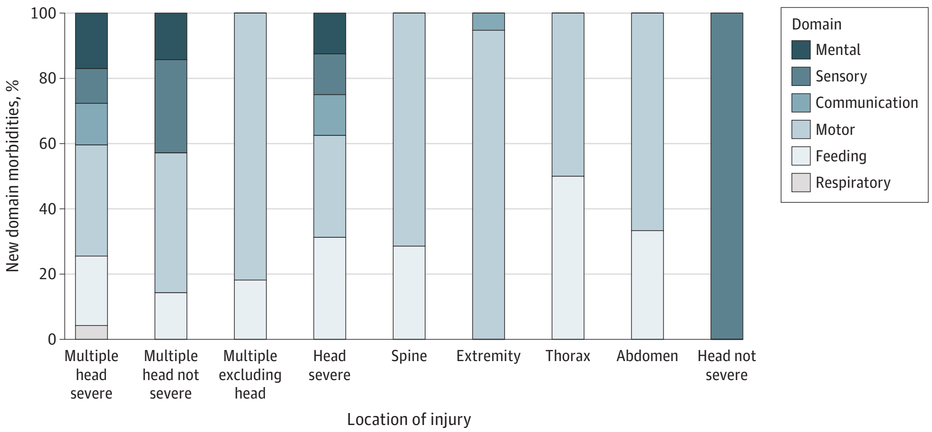

Table 4. Comparisons Between the Odds of New Domain Morbidity Among Injury Categories Using Multivariable Logistic Regression

Comparison category	Reference category, odds ratio (95% CI)							
	Multiple injuries including nonsevere head injury	Multiple injuries excluding head injury	Severe head injury	Spinal injury	Extremity injury	Thoracic injury	Abdominal injury	Nonsevere head injury
Multiple injuries including severe head injury	14.95 (5.53-40.41)	26.92 (11.45-63.27)	27.54 (12.40-61.13)	17.28 (7.09-42.14)	57.30 (28.21-116.40)	66.04 (27.13-160.70)	278.3 (103.00-752.10)	1503 (598.20-3775.00)
Multiple injuries including nonsevere head injury		1.80 (0.73-4.47)[a]	1.84 (0.80-4.24)[a]	1.16 (0.45-2.96)[a]	3.83 (1.78-8.25)	4.42 (1.72-11.35)	18.61 (6.59-52.55)	100.5 (38.05-265.40)
Multiple injuries excluding head injury			1.02 (0.52-1.99)[a]	0.64 (0.29-1.42)[a]	2.13 (1.21-3.76)	2.45 (1.13-5.33)	10.34 (4.21-25.39)	55.82 (24.83-125.50)
Severe head injury				0.63 (0.31-1.29)[a]	2.08 (1.36-3.19)	2.40 (1.20-4.81)	10.11 (4.42-23.10)	54.57 (26.26-111.60)
Spinal injury					3.32 (1.81-6.06)	3.82 (1.70-8.60)	16.10 (6.48-40.03)	86.95 (36.84-205.2)
Extremity injury						1.15 (0.63-2.11)[a]	4.86 (2.33-10.10)	26.22 (13.93-49.35)
Thoracic injury							4.21 (1.70-10.45)	22.75 (9.87-52.46)
Abdominal injury								5.40 (2.11-13.84)

[a] No significant difference between comparison and reference categories.

gions including a severe head injury (146 of 749 [19.5%]) accounted for the largest proportions of those estimated to have new domain morbidity. Patients with severe head injuries in isolation or with another injured body region accounted for 544 of 5195 patients (10.5%) with a serious injury in the registry but 258 of 749 cases (34.4%) of new domain morbidity.

Multivariate analysis showed an association between new domain morbidity and injury category (eAppendix 2 in the Supplement). For example, compared with nonsevere isolated head injury, the OR for severe isolated head injury was 54.57 (95% CI, 26.68-111.60; $P < .001$) and the OR for injuries to multiple body regions including severe head injury was 1503 (95% CI, 598.20-3775.00; $P < .001$). We first used isolated mild or moderate head injury as the reference group because these injuries were associated with the lowest domain morbidity (Table 2). By varying the reference injury category used in this regression, we found ORs that represented comparisons among all possible injury categories (**Table 4**). Using these ORs, we ranked the risk for new domain morbidity among the 9 categories (highest to lowest risk): multiple injured body regions including a severe head injury; other types of multiple injured body region patterns (excluding head, head not severe), isolated severe head injuries, and isolated spinal injuries; isolated extremity injuries and isolated thoracic injuries; isolated abdominal injuries; and isolated mild or moderate head injuries.

Discussion

The need for assessing nonmortality outcomes after injury is well recognized.[6,23] Although substantial resources are allocated for maintaining trauma registries, resources for obtaining postdischarge evaluations have been limited.[23] One approach for addressing these resource challenges is to perform postdischarge evaluations only for patients with a high risk of impairment. In this study, we used FSS scores to identify categories of injured children and adolescents at high risk for functional impairment who should be targeted for these assessments.

Few studies have described categories of injuries associated with risk for functional impairment in a general population of injured children and adolescents. Previous studies[3,10,11] have had small samples, have limited their assessments to those with the most severe injuries, or have excluded individuals in specific age groups. Functional impairment was observed in all domains using the Functional Independence Measure system in a cohort of 162 children with at least 1 serious injury.[10] The functional status of 149 seriously injured children was evaluated using this system, the King's Outcome Scale for Childhood Head Injury, and the modified Glasgow Outcome Scale. One month after discharge, impairment was observed in the 4 body regions evaluated, but infants were excluded from some assessments.[3] In an analysis of 553 injured children treated in an ICU, new FSS domain morbidity was observed in 17% of patients.[11] Our study addressed some of the limitations of these studies. We evaluated a larger sample of children, including those hospitalized outside the ICU, and oversampled those with uncommon injuries. We estimated that new domain morbidity occurred in 17.3% of seriously injured children treated at the participating sites. We observed similar findings using the POPC scale, a measure also used for functional status assessment in large-scale studies.[19] The impairment using new FSS domain morbidity exceeded by approximately 4-fold the reported mortality after severe injury in children,[2] supporting the FSS as a more granular and potentially more robust measure of quality.

We estimated impairment within each injury category at the participating sites using the proportions of new domain morbidity in the sampled population. Isolated extremity injury was the most frequently reported category and accounted for an estimated 40.3% of new domain morbidities. Children hospitalized for extremity injuries are a population at high risk for functional impairment.[3,10,11] Recent studies have identified the need to implement validated functional outcome assessments for pediatric orthopedic injuries.[24,25] Although children and adolescents with severe head injuries accounted for 11.0% of patients with a serious injury, those with severe head injuries accounted for 36.5% of those estimated to have impairment at the time of discharge. We also observed an association between the number of injured body regions and functional outcome.[11,26] Children and adolescents with multiple injured body regions including severe head injury had the highest proportion of functional impairment, a finding observed in adult trauma patients.[27] Almost half (49.5%) of children and adolescents with multiple injured body regions with or without a head injury also had discharge impairment.

Injuries in some body regions were associated with low percentages of impairment, including isolated mild or moderate head injuries and isolated thoracic or abdominal injuries. Although we used the FSS scale, a range of other measures can be used to assess impairment in children with a traumatic brain injury.[28] Although a population of interest from a resource perspective,[29] children and adolescents with isolated abdominal injuries had infrequent functional impairment at discharge. Consistent with previous findings, isolated thoracic injuries in the sample in the present study were associated with a low frequency of impairment at discharge.[3] Our results highlight the need to define specific injuries in the abdominal and thoracic regions that are associated with risk for disability.

Limitations

This study has several limitations. First, we used the FSS to define functional status rather than more extensive functional assessments such as the Vineland Adaptive Behavior Scale III. Although it has advantages for large-scale studies, FSS may not be sufficiently granular to detect additional aspects of function at hospital discharge. Second, patients within each category used in this study had different injury profiles based on the organs injured and the occurrence of multiple injuries within the same body region. Third, we did not consider physiological differences not represented by initial vital signs and GCS. The integration of trauma registries and clinical data sets has been proposed for managing this limitation.[30] Fourth, we observed wide 95% CIs for several ORs in the multivariate model when comparing injury categories. Although potentially arising from comparison of categories with small sample sizes or infrequent new domain morbidity, it is also possible that the wide 95% CIs reflect high variability in the observed associations. Fifth, we did not consider the causation of new domain morbidity. New discharge impairment may be associated with a combination of primary injury and complications related to management.

Conclusions

In this cohort study, most injured children and adolescents returned to baseline functional status, as assessed using the FSS, by hospital discharge. These findings suggest that functional status assessments can be limited to cohorts of injured children and adolescents at the highest risk for impairment.

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