Secondary overtriage of pediatric neurosurgical trauma at a Level I pediatric trauma center

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OBJECTIVE The authors reviewed the transfer requests for isolated pediatric traumatic brain injuries (TBIs) at a Level I/II facility with the goal of identifying clinical and radiographic traits associated with potentially avoidable transfers that could be safely managed in a non-tertiary care setting.

METHODS The authors conducted a retrospective study of patients < 18 years of age classified as having TBI and transferred to their Level I tertiary care center over a 12-year period. The primary outcome of interest was identifying potentially avoidable transfers, defined as transfers of patients not requiring any neurosurgical intervention and discharged 1 hospital day after admission.

RESULTS Overall, 70.8% of pediatric patients with isolated TBI did not require neurosurgical intervention or monitoring, indicating an avoidable transfer. Potentially avoidable transfers were associated with outside hospital imaging that was negative (86%) or showed isolated, nondisplaced skull fractures (86%) compared to patients with cranial pathology (53.8%, $p < 0.001$) as well as age ≤ 6 years (81% [negative imaging/isolated, nondisplaced fractures] vs 54% [positive cranial pathology], $p < 0.001$). The presence of headaches, nonfocal deficits, and loss of consciousness were associated with necessary transfer ($p < 0.05$). Patients with potentially avoidable transfers underwent frequent repeat CT studies (19.1%) and admissions to the pediatric intensive care unit (55.9%) but at a lower rate than those whose transfers were necessary ($p < 0.001$). Neurosurgical interventions occurred in 11% of patients with cranial pathology, which accounted for 17.9% of necessary transfers and 5.2% of all transfers.

CONCLUSIONS In the authors' region, potentially up to 70% of interfacility transfers for pediatric brain trauma in the absence of other systemic injuries warranting surgical intervention may not require neurosurgical intervention and could be managed locally. No patients transferred with isolated, nondisplaced skull fractures or negative CT scans required neurosurgical intervention, and 86% were discharged the day after admission. In contrast, 11% of patients with CT scans indicative of cranial pathology required neurosurgical intervention. Age > 6 years, loss of consciousness, and nonfocal deficits were associated with a greater likelihood of needing a transfer. Further studies are required to clarify which patients can be managed at local institutions, but referring centers should practice overcaution given the potential risks.

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KEYWORDS head injury; pediatric; transfer; triage; trauma

LLEVEL I and II trauma centers receive patients by either direct transport or transfer to offer immediate access to centralized and comprehensive regional specialty trauma services. For designation, Level I and Level II trauma services require the same level of clinical care, with Level I trauma centers additionally required to

meet admission volume requirements, maintain a surgically directed critical care service as well as a residency program, and perform trauma research.¹ Moderately to severely injured patients treated at Level I trauma centers either through direct transport or transfer may have a 20%–38% reduction in mortality rate compared to cohorts

ABBREVIATIONS ATC = adult trauma center; ED = emergency department; GCS = Glasgow Coma Scale; ISS = Injury Severity Score; LOS = length of stay; PICU = pediatric intensive care unit; PTC = pediatric trauma center; TBI = traumatic brain injury.

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treated at nontrauma or nontertiary centers.^{27,30} For the most severe injuries, Level I centers may offer improved outcomes compared to Level II trauma centers,^{10,18} though Level II trauma centers may still offer improved outcomes relative to nontertiary trauma centers.¹⁶

Due to the superior outcomes of severely injured patients treated at higher-level trauma centers, minimally injured patients who could be managed at lower-level centers are often directly transported to higher-level centers, known as “primary overtriage.” When a minimally injured patient is initially admitted to a lower-level center, unnecessary transfer following primary survey and stabilization to a higher-level facility is known as “secondary overtriage.”²⁰ To achieve undertriage of < 1% of preventable deaths and < 5% of major traumas (as measured by Injury Severity Score [ISS]), primary overtriage of 25%–35% of patients is typically viewed as reasonable.¹ However, the impact of both primary and secondary overtriage of patients is a severe depletion of resources, including neurosurgical coverage,^{11,13} with the mean cost of interfacility overtriage ranging between \$9206 to \$12,549 per transfer.^{41,43}

Overutilization of neurosurgical coverage may be particularly acute in the pediatric transfer population. In one study, 64% of preventable transfers in the pediatric population implicated traumatic brain injury (TBI).¹⁵ Additional studies identified that one quarter to one half of unnecessary pediatric interfacility transfers utilized neurosurgical evaluation,^{15,24} and a neurological consult request represented increased odds (OR 2.61) of an unnecessary transfer.²⁴ This secondary overtriage may follow from an uncertainty with recognizing pediatric patients with TBI who do not need a higher level of care. Consequently, we reviewed the transfer requests for isolated pediatric TBI over a 12-year period at a Level I facility with the goal of identifying clinical and radiographic traits associated with potentially avoidable transfers.

Methods

We conducted an IRB-approved retrospective review of all consecutive documented requests for interhospital patient transfer due to TBI at the Kiwanis Pediatric Trauma Institute at the Floating Hospital for Children at Tufts Medical Center from January 1, 2002, to October 30, 2014. This facility is a Level I pediatric trauma center that was briefly Level II from 2008 to 2011 following the institution of volume requirements by the American College of Surgeons. These documented requests were contained within our facility’s prospectively gathered registry of adult and pediatric trauma incidents. We used our facility’s code for TBI to identify potentially relevant cases in the pediatric population (< 18 years). We then performed chart reviews to extract details regarding each transfer center event. As we function as a tertiary care center, patients were not subsequently transferred out to another hospital.

The primary outcome of interest was a “potentially avoidable transfer.” A potentially avoidable transfer was defined as a patient < 18 years of age who underwent head CT scanning prior to transfer and who was discharged the day following admission to the receiving facility without

neurosurgical intervention. A “necessary transfer” failed to meet these criteria. A “neurosurgical intervention” was defined as any invasive neurosurgical procedure, such as a craniotomy or placement of an intracranial pressure monitoring system.

We excluded patients who did not receive a head CT scan at the transferring hospital and patients whose primary reason for transfer was status epilepticus or nonaccidental traumas, because social and medical factors would likely confound the reason for extended hospital length of stay (LOS). To maintain the emphasis on head injury, we additionally excluded patients requiring nonneurological surgery. Secondary outcomes of interest included repeat CT imaging, pediatric intensive care unit (PICU) admission, and PICU admission beyond 1 day.

Charts were reviewed for patient demographics, mechanism of injury, time of arrival to outside hospital, method of transfer, outside diagnostic imaging, and outside clinical assessment, including ISS and Glasgow Coma Scale (GCS) score. We noted whether emesis, seizures, loss of consciousness, and focal or nonfocal neurological deficits were observed following injury. For verbal patients (age ≥ 2 years), we included whether amnesia or headaches were experienced. We additionally recorded neurosurgical interventions, length of hospital LOS, PICU admission, and repeat CT within 24 hours of admission. Radiological findings were subdivided into whether they revealed significant or suspected cranial pathology; isolated linear, nondisplaced skull fracture; or negative imaging (i.e., no abnormal findings). Significant cranial pathology included epidural or subdural hematomas, hemorrhage, pneumocephalus, depressed skull fractures, or a subgaleal hematoma in patients ≤ 3 months of age.

Statistical analysis was performed using IBM Statistics SPSS 24.0 (IBM Corporation). Continuous variables were analyzed with Student t-tests, while categorical variables were analyzed with a chi-square test or Fisher’s exact test as appropriate. Descriptive statistics were computed as necessary and represented as mean ± SD. A p value < 0.05 was considered significant.

Results

Retrospective review identified 1098 patients with pediatric trauma over a 12-year period who were transferred. Of these, 192 transfers met criteria for analysis as a potentially avoidable transfer (PAT) or necessary transfer (NT) for isolated head trauma. Of the 192 transfers, 136 were potentially avoidable (70.8%).

Characteristics of patients at the point of transfer are listed in Table 1. The mean age of transferred patients was 5.3 ± 5.4 years (range 1.6 weeks to 17 years). Sixty-one percent of patients (118/192) were male. The primary mechanism of transfer was by ambulance (86.5%). Almost half of the patients (87/192, 45.5%) arrived at the outside hospital between the hours of 18:00 and 23:59. At the transferring hospital, 93% (170/183) of patients were assessed as having an average GSC score of 13–15 and an ISS of 7.1 ± 5.9. Of patients’ clinical signs and symptoms (Table 2), emesis was the most common overall, occurring in 39.1% of patients, whereas headache was the most com-

TABLE 1. Characteristics of patients at point of transfer

Variable/Subvariable	Transfers			p Value
	All (n = 192)	Potentially Avoidable (n = 136)	Necessary (n = 56)	
Mean age $\pm$ SD, yrs	5.3 $\pm$ 5.4	4.3 $\pm$ 5.0	7.8 $\pm$ 5.4	<0.001
≤6	121 (63.0%)	98 (72.1%)	23 (41.1%)	<0.001
>6	71 (37.0%)	38 (27.9%)	33 (58.9%)	
Sex				0.644
Male	118 (61.5%)	85 (62.5%)	33 (58.9%)	
Female	74 (38.5%)	51 (37.5%)	23 (41.1%)	
Method of transfer				0.415
Private car	4 (2.1%)	4 (2.9%)	0 (0%)	
Ambulance	166 (86.5%)	116 (85.2%)	50 (89.3%)	
Helicopter	22 (11.5%)	16 (11.8%)	6 (10.7%)	
Arrival time at outside hospital				0.234
0:00–5:59	7 (3.7%)	7 (5.2%)	0 (0%)	
6:00–11:59	32 (16.8%)	22 (16.3%)	10 (18.2%)	
12:00–17:59	64 (33.7%)	48 (35.5%)	16 (29.1%)	
18:00–23:59	87 (45.5%)	58 (43.0%)	29 (52.7%)	
GCS score at outside hospital				0.001
13–15	170 (92.9%)	127 (98.4%)	43 (79.6%)	
9–12	5 (2.7%)	1 (0.78%)	4 (7.4%)	
3–8	8 (4.4%)	1 (0.78%)	7 (13.0%)	

Values are the number (%) of patients unless otherwise specified.

mon clinical manifestation of brain injury among the verbal cohort, at 54.3%. Focal neurological deficits, including transient deficits, occurred in 4.7% of patients, while non-focal deficits manifested in 22.9%.

Cranial pathology was identified in 47.4% (91/192) of patients, whereas isolated linear skull fractures were present in 22.4% (43/192). Imaging was negative for either fractures or intracranial pathology in 30.2% (58/192) of patients (Table 3). Thirty-four percent (65/192) of patients underwent repeat CT. The mean hospital LOS was 1.7 ± 2.8 days (range 1–34 days). One hundred twenty-two patients (63.5%) were admitted to a PICU for an average of 1.0 ± 2.7 days (range 0–34 days). Ten (5.2%) patients required neurosurgical intervention (Table 4).

Fifty-six percent of PATs were admitted to the PICU, a lower rate than NTs (82.1%, $p < 0.001$) but constituting

62.2% of total PICU admissions (76/122). NTs were admitted to the PICU for an average of 2.2 ± 4.8 days and remained in the hospital for an average of 3.4 ± 4.8 days. Ten of 56 NTs (17.9%) needed neurosurgical intervention (Table 4).

Primary Outcome

Clinical Characteristics

The mean age of patients who underwent PATs was younger than that of the NTs (4.3 ± 5.0 years vs 7.8 ± 5.4 , respectively; $p < 0.001$). Patients ≤ 6 years old comprised a greater percentage of PATs (72.1%) than NTs (41.1%) ($p < 0.001$) (OR 3.7, 95% CI 1.93–7.09) (Tables 1 and 5). A GCS score of 13–15 at the transferring hospital comprised a higher proportion of PATs than NTs (98.4% vs 79.6%,

TABLE 2. Summary of clinical signs and symptoms

Variable	Transfers			p Value
	All (n = 192)	Potentially Avoidable (n = 136)	Necessary (n = 56)	
Headache (>2 yrs)	63 (54.3%)	33 (45.8%)	30 (68.2%)	0.022
Amnesia (>2 yrs)	24 (20.2%)	13 (18.1%)	11 (25.6%)	0.352
Loss of consciousness	53 (27.6%)	26 (19.1%)	27 (48.2%)	<0.001
Emesis	75 (39.1%)	48 (35.3%)	27 (48.2%)	0.106
Seizure	11 (5.7%)	7 (5.1%)	4 (7.1%)	0.733
Focal neurological deficit	9 (4.7%)	5 (3.7%)	4 (7.1%)	0.45
Nonfocal neurological deficit	44 (22.9%)	23 (16.9%)	21 (37.5%)	0.003

Values are the number (%) of patients unless otherwise specified.

TABLE 3. Outside hospital imaging results

Variable/Subvariable	Transfers			p Value
	All (n = 192)	Potentially Avoidable (n = 136)	Necessary (n = 56)	
Outside imaging finding				<0.001
Cranial pathology	91 (47.4%)	49 (36.2%)	42 (75%)	
Isolated linear skull fracture	43 (22.4%)	37 (27.2%)	6 (10.7%)	
Negative	58 (30.2%)	50 (36.8%)	8 (14.3%)	

Values are the number (%) of patients unless otherwise specified.

respectively; $p < 0.001$). Sex, method of transfer, and time of outside hospital arrival did not differ between the cohorts (Table 1).

Loss of consciousness and nonfocal neurological deficits were more common among NTs (48.2% vs 19.1%, $p < 0.001$; 37.5% vs 16.9%, respectively; $p = 0.003$) than PATs (Table 2). Decreased odds of a PAT were associated with the absence of loss of consciousness (OR 0.25, 95% CI 0.13–0.5, $p < 0.001$) or nonfocal deficits (OR 0.34, 95% CI 0.17–0.68, $p = 0.003$) (Table 5). Among the verbal group, headaches were also more common in those with NTs (68.2% vs 45.8%, $p = 0.022$). The occurrence of seizures, emesis, or amnesia did not reliably distinguish one cohort from the other, while the sample size for focal deficits was small (Table 2).

Outside Imaging

PATs and NTs differed in their frequency of cranial pathology, isolated linear skull fractures, and negative imaging on outside hospital imaging ($p < 0.001$) (Table 3). The majority of patients with NTs had cranial pathology (75%), whereas those with PATs were more evenly distributed among negative imaging (36.8%), isolated skull fractures (27.2%), and cranial pathology (36.2%). Compared to intracranial pathology, isolated skull fractures and negative imaging more accurately predicted PATs (OR 5.3, 95% CI 2.64–10.71, $p < 0.001$), whereas isolated skull fractures

TABLE 4. Secondary outcomes: Tufts

Outcome	Transfers			p Value
	All (n = 192)	Potentially Avoidable (n = 136)	Necessary (n = 56)	
Repeat CT	65 (33.9%)	26 (19.1%)	39 (69.6%)	<0.001
Mean hospital days	1.7 ± 2.8 (1–34)		3.4 ± 4.8	
PICU admit	122 (63.5%)	76 (55.9%)	46 (82.1%)	<0.001
Mean PICU days	1.0 ± 2.7 (0–34)		2.2 ± 4.8	
Neurosurgical intervention	10 (5.2%)		10 (17.9%)	

Admit = admission.

Values are the number (%) of patients or mean ± SD (range).

TABLE 5. Selected odds ratios

Variable	PATs, OR (95% CI)	p Value
Negative for isolated skull fracture	5.3 (2.64–10.71)	<0.001
Cranial pathology	0.19 (0.09–0.38)	<0.001
≤6 yrs of age	3.7 (1.93–7.09)	<0.001
Headache (>2 yrs)	0.39 (0.18–0.86)	0.022
Loss of consciousness	0.25 (0.13–0.5)	<0.001
Nonfocal deficits	0.34 (0.17–0.68)	0.003

and negative imaging had a similar proportion of PATs (86% vs 86%, $p = 0.98$).

Secondary Outcomes

Clinical Characteristics

Secondary outcomes with respect to clinical findings are presented in Table 6. Repeat imaging was associated with patients > 6 years of age (47.9% vs 25.6%, $p = 0.003$), the presence of headache (47.6% vs 26.4%, $p = 0.022$), and nonfocal deficits (54.5% vs 27.7%, $p < 0.001$). Extended PICU stay was associated with age > 6 years (26.8% vs 5.8%, $p < 0.001$), loss of consciousness (24.5% vs 9.4%, $p = 0.009$), nonfocal deficit (29.5% vs 8.8%, $p < 0.001$), and a trend toward emesis (20% vs 9.4%, $p = 0.051$). Neurosurgical intervention tended toward association with altered mental status (11.4% vs 3.4%, $p = 0.051$).

Imaging

Secondary outcomes with respect to imaging are presented in Table 7. Subanalysis revealed that the presence of cranial pathology was associated with a higher rate of repeat advanced imaging (51.6%), PICU admission (83.5%), extended PICU stay (25.3%), and neurosurgical intervention (11.0%) than isolated skull fractures or negative imaging ($p < 0.01$). Isolated skull fractures and negative imaging did not differ among these categories, except that patients with isolated skull fractures had a higher frequency of PICU admissions (60.5% vs 34.5%, $p = 0.01$).

Discussion

In our population of children with TBI, we observed that 70.8% of interfacility transfers were potentially avoidable secondary triages, a markedly higher rate than in previous studies. In the adult or general population, secondary overtriage rates have ranged from 23.8% to 38% of patients.^{8,41,43} Although the overall secondary overtriage rate is only slightly higher among pediatric patients (age < 15 or < 18 years), ranging from 19% to 49%,^{15,17,20,25,28,31,41} analyses comparing the adult and pediatric secondary overtriage rates within the same population revealed that children are 2 to 4.5 times more likely to be transferred unnecessarily than adults.^{31,41} These transfer rates typically represent the proportion of unnecessary transfers from the vantage point of the receiving hospital; from the viewpoint of the transferring hospital, only 9.8% of adult transfers⁹ and 18% of pediatric transfers²⁴ are potentially avoidable.

Our high rate of PATs may have followed from our

TABLE 6. Secondary outcomes by age and clinical findings

Variable	Repeat CT	ICU Admit	ICU >24 Hrs	Neurosurgical Intervention
Age				
≤6 yrs	31 (25.6%), <i>p</i> = 0.003	71 (58.7%)	7 (5.8%), <i>p</i> < 0.001	4 (3.3%)
>6 yrs	34 (47.9%)	51 (71.8%)	19 (26.8%)	6 (8.5%)
Headache (>2 yrs)				
Yes	30 (47.6%), <i>p</i> = 0.022	42 (66.7%)	15 (23.8%)	3 (4.8%)
No	14 (26.4%)	32 (60.4%)	7 (13.2%)	4 (7.5%)
Amnesia (>2 yrs)				
Yes	9 (37.5%)	18 (75.0%)	6 (25.0%)	2 (8.3%)
No	34 (37.4%)	55 (60.4%)	15 (16.5%)	5 (5.5%)
Loss of consciousness				
Yes	22 (41.5%)	40 (75.5%), <i>p</i> = 0.044	13 (24.5%), <i>p</i> = 0.009	5 (9.4%)
No	43 (30.9%)	82 (59%)	13 (9.4%)	5 (3.6%)
Emesis				
Yes	25 (33.3%)	49 (65.3%)	15 (20.0%), <i>p</i> = 0.051	5 (6.7%)
No	40 (34.2%)	73 (62.4%)	11 (9.4%)	5 (4.3%)
Seizures				
Yes	3 (27.3%)	6 (54.5%)	2 (18.2%)	2 (18.2%), <i>p</i> = 0.104
No	62 (34.3%)	116 (64.1%)	24 (13.3%)	8 (4.4%)
Focal deficit				
Yes	5 (55.6%)	6 (66.7%)	3 (33.3%)	0 (0%)
No	60 (32.8%)	116 (63.4%)	23 (12.6%)	10 (5.5%)
Nonfocal deficit				
Yes	24 (54.5%), <i>p</i> < 0.001	28 (63.6%)	13 (29.5%), <i>p</i> < 0.001	5 (11.4%), <i>p</i> = 0.051
No	41 (27.7%)	94 (63.5%)	13 (8.8%)	5 (3.4%)

Values are the number (%) of patients.

definition of PAT, which was not limited by ISS score, critical care admission, or repeat imaging. Heterogeneous definitions of secondary overtriage among prior studies have limited comparison of overtriage rates. Previous analyses have defined a PAT as requiring some configuration of an ISS of < 9,²⁰ < 10,^{8,43} or without reference to ISS;^{9,15,17,25,26,31,41} discharge within 12,¹⁷ 24,^{20,25,28,31,43} 36,¹⁵ or 48^{8,9,26,41} hours; and nonreceipt of an “operation,”^{8,9,15,20,26,31,41,43} which can denote an operating room–level intervention,⁴³ any additional medical or surgical intervention,¹⁷ or select procedures.²⁸ Additional criteria, such as no critical care admission²⁰ or advanced imaging studies,¹⁵ have also been requirements of a PAT. Modest variations in criteria can drastically change results: Ciesla et al.⁸ calculated that broadening their ISS criterion from < 10 to < 16 increased the secondary overtriage, comprising their hospital’s total trauma care from 9% to 19%. This variability highlights the need for a shared definition of secondary overtriage among studies.

The pediatric patients with brain injury in our study may have been aggressively triaged because, although contested,^{32,45} a growing body of literature suggests that pediatric patients benefit from triage to pediatric trauma centers (PTCs) compared to adult trauma centers (ATCs) or ATCs with added pediatric qualifications.^{2,36,40,46} These outcome discrepancies have been attributed to the injury patterns and treatment requirements unique to young

children with whom nonpediatric physicians may be less experienced.^{21,34,36} These mortality benefits may be increased further in children ≤ 5 years of age,⁴⁰ which may explain the higher likelihood of children ≤ 6 years among avoidable transfer requests (OR 3.7, 95% CI 1.93–7.09, *p* < 0.001). In addition to the potential benefit of aggressive triage of young patients to PTCs, another contributing fac-

TABLE 7. Secondary outcomes by outside imaging result

Finding	CT (<i>p</i> < 0.001)	ICU Admit* (<i>p</i> < 0.001)	ICU > 24 Hrs (<i>p</i> < 0.001)	Neurosurgical Intervention (<i>p</i> = 0.003)
Cranial pathology (n = 91)	47 (51.6%)	76 (83.5%)	23 (25.3%)	10 (11.0%)
Isolated skull fracture (n = 43)	8 (18.6%)	26 (60.5%)	3 (4.7%)	0 (0.0%)
Negative imaging (n = 58)	10 (17.2%)	20 (34.5%)	1 (1.7%)	0 (0.0%)

Values are the number (%) of patients.

* Patients with cranial pathology were admitted to the ICU at a higher rate than those with an isolated skull fracture (*p* = 0.003) and negative imaging (*p* < 0.001), and patients with an isolated skull fracture were admitted at a higher rate than those with negative imaging (*p* = 0.01).

tor to overtriage in the pediatric population may be general physician unfamiliarity and discomfort with younger age groups. Gattu et al.¹⁷ noted that transfers from non-pediatric emergency department (ED) physicians were much more likely to be rapidly discharged than pediatric ED physicians (53.4% vs. 29.7%), consistent with Mohr et al.²⁸ As ours was a retrospective study, we were unable to assess what portion of patients came from facilities with pediatric qualifications, but the lower rate of extended LOS among patients ≤ 6 years old compared to older children suggested that observation and monitoring at a high-level pediatric facility may have been a principal motivation for transfer in this age group.

We limited our study population to instances of pediatric TBI, which may have further contributed to our high avoidable transfer rate, as the mortality benefit of transfer to PTCs derives in part from improved outcomes of pediatric head trauma cases,² which Potoka et al.³⁶ correlated to the increased intervention rates in moderate-to-severe head injuries at PTCs. Li et al.²⁵ observed that among pediatric patients received via transfer with a diagnosis code of TBI, 50% of admissions were discharged within 24 hours. In contrast, Fenton et al.¹⁵ reported that only 31.3% of head injury transfers were preventable. However, both Fenton et al.¹⁵ and Li et al.²⁵ included head injuries that co-occurred with multisystem trauma within their analyses, which may have depressed the rate preventable transfer rate. Moreover, Fenton et al.¹⁵ defined receipt of additional advanced imaging as justifying a necessary transfer, and only 61% of all transfers had received prior CT imaging, with prior receipt of head CTs more common among preventable transfers than unpreventable transfers (65% vs. 45%), indicating that some unscanned patients may have been transferred to be imaged at the receiving facility. Utilizing Fenton's criteria, nearly 20% of PATs would have been reclassified as necessary in our study. From the perspective of the referring hospital, it has been shown that head CT prior to pediatric transfer reduces the odds of unnecessary transfer (OR 0.33),²⁴ an observation consistent with studies involving adult populations (OR 0.30–0.49).^{9,26}

We limited our study population to individuals with imaging because we suspected the primary predictor of an avoidable transfer would be pretransfer CT results, and interpreting the need for transfer in light of the outside hospital CT results would best reflect clinical practice. In point of fact, we observed that 86% of both patients with isolated, nondisplaced skull fractures and patients who did not undergo imaging were discharged within 1 hospital day in contrast to 54% of patients whose imaging denoted significant cranial pathology. This meant that those without significant cranial pathology were associated with 5 times the odds of an avoidable transfer than patients with notable cranial pathology (OR 5.3, 95% CI 2.64–10.71, $p < 0.001$). Although 5.2% of transfers needed neurosurgical intervention, no such cases were counted among those with isolated, nondisplaced skull fractures or those with negative imaging. It has been previously observed that neurologically intact patients can typically be discharged without hospital admission following observation in the ED after a normal head CT scan³⁵ or one revealing only an isolated linear skull fracture.^{3,39}

A review by White et al.⁴⁷ of 438 patients transferred to a Level I facility for an isolated, linear, nondisplaced skull fracture in the absence of multisystem trauma found that all patients recovered with treatment of symptoms, and none required neurosurgical intervention, leading the authors of that paper to conclude that transfer to a higher-level trauma facility is not warranted in this population. Several studies have even suggested that isolated skull fractures may not even require hospital admission, but a complete nonaccidental trauma workup is required.^{37,38} White et al.⁴⁷ documented a perioperative seizure rate of 1.4%, lower than our rate of 5.7% among avoidable transfers, perhaps due to a misclassification of convulsions as seizures in our chart database. Of note, their rate of repeat CT scans, including those for displaced fractures, was only 6.8%, in contrast to our rate of 18.6%. Our findings lend further credence to conservatively managing this patient population without transfer in addition to patients with negative imaging, whereas more aggressive transfer of pediatric patients with a positive CT scan remains reasonable, particularly in light of 11% of patients with notable CT cranial pathology undergoing neurosurgical intervention.

We noticed a trend for possible overutilization of the PICU, to which 56% of PATs were initially admitted. This overutilization was particularly stark in the patients with isolated, nondisplaced skull fracture, of whom 60.5% were admitted to the PICU initially but only 4.7% remained after 1 day. Fenton et al.¹⁴ observed that 60% of preventable admissions to the PICU were for isolated head injury and suggested that critical care-level attention may not be necessary in many cases. Varano et al.⁴⁴ noted that 30% of patients with isolated cerebral contusions were admitted to the PICU, which was unnecessary in the presence of smaller contusions. This use of the PICU may represent the frequency of neurological checks requested by the admitting hospital team, but the need for PICU admission, as with transfer, should be contextualized within the clinical picture of the patient. Specifically, headache, loss of consciousness, and nonfocal neurological deficits were associated with necessary patient transfers, yet only loss of consciousness and nonfocal neurological deficits were associated with prolonged PICU stay. These findings are consistent with prior studies that emphasize that the pathology revealed on head CT must be interpreted within the clinical picture of the patient when determining the duration or level of hospitalization.^{3,23,44}

Certain constellations of imaging features, GCS scores, and neurological statuses had a particularly strong relationship with potentially unavoidable transfers. We noted that 29 patients were transferred with negative imaging and a GCS score of 15, with no reported seizures or loss of consciousness. Of these, 27 (93%) were discharged within 24 hours; the 2 remaining patients were discharged within 48 hours without ICU admission, surgical intervention, or repeat imaging. Among 62 patients transferred with a GCS score of 15, no reported seizures or loss of consciousness, and either negative imaging or imaging that demonstrated only a linear, nondisplaced skull fracture, 57 (90%) were discharged within 24 hours; the 5 remaining patients were discharged within 48 hours without undergoing sur-

gical intervention. In contrast, 34 patients were transferred with a positive head CT scan and either a GCS score ≤ 14 or with reported loss of consciousness. Among them, 25 (74%) were unavoidable transfers, including 7 (21%) requiring neurosurgical interventions. Although our sample size is too small to draw definitive conclusions, these observations may inform the development of a more rigorous transfer algorithm in the future while guiding clinical decision-making in the short term.

Since children are routinely scanned at outside hospitals prior to transfer, we examined the need for transfer in this subset. We do not advocate aggressive CT imaging for either the initial workup of head injury or prior to transfer. Typically, we advocate that referring institutions hold off on imaging and, if they intend to transfer a child regardless of imaging findings, allow us to evaluate the need upon the patient's arrival. Our findings are consistent with the results of Kupperman et al.,²² who proposed a detailed algorithm identifying children at low risk for clinically important TBI to obviate acquisition of head CT scans in this radiosensitive population. Clinicians must consider the entire clinical picture when evaluating TBI and not reflexively order head CT scans in the pediatric population if they do not suspect intracranial injury.

To better manage the balance between the benefits of specialized pediatric care and the systemic costs of overtriage, the use of telemedicine has been increasingly advocated in the management of pediatric emergencies.^{15,24,48} The use of telemedicine in neurosurgery has been shown in smaller studies to reduce potential transfers by 21%–44%,^{5,20,29} with the additional benefit of recommending management changes independent of transfer in 44% of patients as well.²⁹ In one study,¹² 6% of patients ≥ 10 years of age with mild head injuries observed at a peripheral hospital with neurosurgical consults available via telemedicine ultimately required transfer for operation, and the unfavorable outcome rate was similar to that in patients observed in a neurosurgical unit once adjusted for propensity score. A second study⁴ observed that 4.1% of selected head-injured patients, which included patients < 10 years of age, initially managed at a Level II facility with neurosurgical consult available via teleradiology, would undergo transfer to a Level I facility. Telemedicine may have a singularly beneficial role in the management of pediatric neurosurgical cases, where a combination of factors based on the importance of pediatric TBI,³⁴ belief in the superiority of pediatric-focused treatment centers,^{33,34} evidence of improved outcomes at centers with a high-volume of select neurosurgical cases,⁶ the benefit to neurocritically ill patients of specialized care by neurocritical care staffs,⁴² and a widening dearth of adequate neurosurgical coverage⁷ could contribute to significant overtriage of the pediatric neurosurgical population.

This study is subject to multiple limitations. First, the perspective of the study is that of the receiving hospital, and we are unable to compare our findings to the cohort of patients not transferred from the referring hospital. Consequently, we were unable to assess what percentage of patients were evaluated at the transferring facility but not transferred for avoidable neurosurgical care. As several tertiary care centers exist within the same catchment area

as ours, pediatric patients are not uniformly routed to one center for care, but we were unable to assess the number or characteristics of pediatric patients routed elsewhere. The retrospective nature of the study and the study's perspective as the receiving hospital also limited our ability to fully assess the context of the transfer and duration of hospitalization. We utilized coding to identify applicable cases, but coding alone may not capture the reason behind the referring facility's transfer and is itself vulnerable to inaccuracies. Although we excluded transfers from pediatric offices and urgent care centers, we were limited in further assessing the qualifications and capacities of the transferring hospital. We were also limited in our ability to assess the grade or accuracy of radiological pathology as reported by the referring facility, as well as the extent of pretransfer workup. Some transfers may have been "potentially avoidable" from a surgical perspective but necessary due to an appropriate need for a neurology consult or due to the pediatric ward at the transferring hospital. Assuming all cases with reported intracranial pathology, focal or nonfocal neurological deficit, headache, loss of consciousness, amnesia, seizure, or emesis were unavoidable due to factors at the transferring hospital, 22% of cases (42/192) would constitute potentially avoidable transfers, which suggests that, at a minimum, 1 out of 5 transfers is avoidable.

Future studies should follow patients longitudinally from the hospital of transfer to the receiving hospital to correlate the exact impetus for triage (e.g., discomfort managing pediatric patients, neurosurgical management, unavailable consult, lack of pediatric wards, etc.) and the subsequent care received (duration of admission, imaging and interventions performed, medications given, consults provided, and level of care). Studies should continue to examine whether the type and degree of cranial pathology revealed on outside hospital CT scans can be associated with safe nontransfer or remote management.

Conclusions

Seventy percent of interfacility transfers for pediatric brain trauma in the absence of other systemic injuries warranting surgical intervention do not require neurosurgical intervention and patients are discharged the following hospital day. No patients transferred with isolated, non-displaced skull fractures or negative CT imaging required neurosurgical intervention, and 86% were discharged the day after admission. In contrast, 11% of patients with CT scans indicative of cranial pathology required neurosurgical intervention. Clinical signs and symptoms associated with necessary transfer include headache, loss of consciousness, and nonfocal deficits. Patients 6 years of age and younger tend to be aggressively triaged. Potentially avoidable transfers have high rates of repeat imaging (19%) and PICU admission (56%), even when outside hospital imaging is negative or reveals only an isolated, nondisplaced skull fracture. We recommend more judicious transfer and management of patients, including those 6 years of age and younger, with negative imaging or isolated, nondisplaced skull fractures, particularly in the absence of neurological deficits.

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Disclosures

Dr. Hwang reports serving on the speaker's bureaus for Zimmer Biomet and NuVasive.

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Conception and design: Hwang, Mackel. Acquisition of data: Mackel, Morel, Park, Sweeney, Heller. Analysis and interpretation of data: Hwang, Mackel. Drafting the article: Hwang, Mackel. Critically revising the article: Hwang, Mackel, Winer, Rideout, Riesenburger. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Hwang. Statistical analysis: Mackel. Study supervision: Hwang.

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