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Charges associated with preventable trauma transfers after application of pediatric brain injury guidelines (kBIG)

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ABSTRACT

Introduction: Preventable pediatric trauma transfers impose substantial economic burdens on healthcare systems by overutilization of specialized facilities and resources. The brain injury guidelines for kids (kBIG) safely standardize care and reduce unnecessary transfer and interventions for children with traumatic brain injuries (TBI). This study examines how kBIG impacts hospital and transfer charges for low-risk pediatric TBI patients transferred to a level 1 trauma center.
Methods: A retrospective cohort of pediatric blunt trauma patients with TBI at a level 1 pediatric trauma center from 2018 to 2024 was identified. After chart review and kBIG application, hospital and transfer charges for patients with low-risk, isolated head injuries (kBIG 0 and 1, AIS other body area ≤ 1) were analyzed.
Results: Of 1894 patients, 204 kBIG 0 (11 %) and 203 kBIG 1 (11 %) were transferred. Total hospital charges were estimated $6.6 M over the 6-year study period. Among these patients, 12 % of kBIG 0 and 18 % of kBIG 1 underwent repeat head CT, while 44 % of kBIG 0 and 67 % of kBIG 1 received neurosurgical consultation. There were 11 % of kBIG 0 and 12 % of kBIG 1 who were transferred by aircraft (transfer charges ~$2.2 M) with the remaining patients transported by ground (transfer charges ~$1.7 M). In total, the 6-year hospital and transfer charges were approximately $10.7 M, corresponding to $1.8 M annually.
Conclusion: The financial burden and overutilization of resources associated with pediatric low-risk TBI are significant. Implementing the kBIG to reduce these burdens on the families while maintaining patient safety.
Level of Evidence: III.
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1. Introduction

Preventable transfers occur in approximately 25–40 % trauma patients transferred to level 1 pediatric trauma centers [1–3]. Previous studies have shown that the majority of these preventable transfers are mild traumatic brain injuries (TBI) [2], and frequently comprise patients who are stable, do not require any emergent interventions, and can be safely managed at the referring facilities [1,2,4]. Given the complexity within each state's healthcare system and resources, estimates for pediatric transfers vary widely. However, there is strong evidence to suggest that regardless of location, TBI-related transfer charges are high. Prior studies report that transfer charges per pediatric TBI-transfer range from approximately $1500 for ambulance transport to over $15,000 for rural air transfers [2–4]. In addition to the economic burden, these transfers impose a significant strain on trauma centers, attributed to the overutilization of specialized trauma resources. Additionally, families are often forced to navigate complex healthcare system transfers sometimes hundreds of miles from their homes or sites of injury [2,5].

To address this problem, we recently developed the brain injury guidelines for kids (kBIG), a set of pediatric-specific TBI management guidelines based on patient exam, history, and initial

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head CT findings. These guidelines were designed to safely standardize care and reduce unnecessary transfer, admission, imaging, and consultation in children with TBI (Fig. 1) [6]. Specifically, patients are classified as kBIG 0 when they have a normal neurologic examination with an isolated, nondisplaced skull fracture and no intracranial hemorrhage. Patients are classified as kBIG 1 when they have a normal neurologic examination but demonstrate a small, low-risk intracranial hemorrhage ($\leq$4 mm subdural or intraparenchymal hemorrhage, or $\leq$3 sulci subarachnoid hemorrhage) without mass effect. According to these guidelines, both kBIG 0 and kBIG 1 patients do not qualify for a transfer or admission to the level 1 pediatric trauma hospital. Instead, they recommend that these patients be discharged from the referring facility's emergency room with appropriate return precautions and follow-up. Early validation work has shown that kBIG is safe and effective for guiding clinical decision in pediatric patients with blunt TBI. It is expected that reducing transfers based on these guidelines will significantly reduce resource utilization on the patient, facility, and system levels. However, the specific effect on economics is unknown.

In this study, we aim to evaluate the potential economic impact of implementing kBIG on the patient, hospital, and system. Our objective is to quantify the potential savings that could be realized by avoiding unnecessary transfers, admissions, CT utilization, and neurosurgical consultation through implementation of the kBIG. We hypothesized that implementing kBIG would reduce unnecessary transfers and hospital resource utilization without affecting patient outcomes.

2. Methods

2.1. Cohort identification

After IRB approval (IRB # 00176573), this study was conducted at a single level 1 pediatric trauma center. A retrospective cohort of 1894 pediatric patients with blunt head injury from 2018 to 2024 was identified. Patient demographics, clinical characteristics, imaging findings, and outcomes were extracted from the electronic medical record. After chart review, we applied the kBIG criteria to the cohort, assigning each patient a kBIG score 0–3 based on their clinical presentation and CT findings. Isolated kBIG 0 and kBIG 1 patients were then identified through AIS score exclusion of any patient with an AIS score in another body system of $\geq$2.

2.2. Charge assumptions

Hospital charges were obtained for kBIG 0 and kBIG 1 patients using proprietary hospital-level charge data. These charges included all recorded charges associated with the patient's inpatient hospital stay.

Charges for CT scans were assessed using national averages, with the base case estimated using hospital-level charge data. Neurosurgical consultation charges were standardized using standard hospital charge data, based on the average reimbursement across the three available billing tiers for new patient consultations. The base case scenario assumptions utilized average billing tiers and charges for CT charges as well as the middle-tier

Variables	kBIG 0	kBIG 1	kBIG 2	kBIG 3
Mechanism of injury	Blunt TBI excluding NAT	Blunt TBI excluding NAT	Blunt TBI excluding NAT	Blunt TBI including NAT
Initial ED GCS	15	15	13–14	≤ 12
Intoxication	No	No	Yes	Yes/No
Anticoagulation/antiplatelet	No	No	No	Yes
Skull fracture	Nondisplaced/ mildly displaced	Nondisplaced/ mildly displaced	Nondisplaced/ mildly displaced	Displaced (with or without bleed)
Epidural hematoma	No	No	< 8 mm	≥ 8 mm
Subdural hematoma	No	≤ 4 mm	5-7 mm	≥ 8 mm
Intraparenchymal hematoma	No	≤ 4 mm	5-7 mm	≥ 8 mm, multiple locations
Subarachnoid hemorrhage	No	≤ 3 sulci	> 3 sulci, single hemisphere	> 3 sulci, bi-hemispheric
Intraventricular hemorrhage	No	No	No	Yes
Therapeutic Plan				
Hospitalization	No	No	Yes	Yes
rCTH	No	No	No	Per neurosurgery request
Neurosurgery Consultation	No	No	No	Yes

TBI: traumatic brain injury; NAT: non-accidental trauma; ED: emergency department; GCS: Glasgow coma scale; rCTH: repeat computed tomography of head.

Fig. 1. Brain Injury Guidelines for Kids (kBIG). TBI: traumatic brain injury; NAT: non-accidental trauma; ED: emergency department; GCS: Glasgow coma scale; rCTH: repeat computed tomography of head.

cost of ambulance transport charges. The high and low sensitivity scenario assumptions (see Supplementary Appendix Table S1) used the high and low end of the billing tiers and ambulance fees respectively.

Transportation charges were evaluated separately using both mechanism of transfer and distance traveled for transfer. Transfer mechanism (ambulance, fixed wing, or rotary wing) was extracted from the trauma registry. Distance transported was calculated using Google Maps to determine the fastest driving distance assuming highway driving from the referring facility to the level 1 pediatric trauma center. Transportation charges were estimated using the State of Utah's public charge rates for each transport modality (2024 published charges were used for ambulance transfers and 2022 charges for air transfers, adjusted with inflation to 2024 rates) [7,8]. Total charge of transfer was calculated as: *Transfer charge = fixed charge for modality + (modality charge* per *mile x miles transported)*. Finally, total charge per patient was then calculated as: *Total charges = transportation charge + hospital charges.* All charges were then adjusted for inflation to 2024 dollars. A summary of the charge calculation assumptions is shown in Table 1.

2.3. Statistical analysis

Descriptive statistics and all calculations were used to summarize baseline characteristics using Microsoft Excel (version 16.97). Basic comparisons of the kBIG0 and kBIG1 demographics were performed. Continuous variables were summarized as medians with interquartile ranges (IQR) and compared between groups using the Wilcoxon rank-sum test. Categorical variables were summarized as frequencies and percentages and compared using the chi-square test. A two-sided p-value <0.05 was considered statistically significant. All analyses were performed using Stata version 18 (StataCorp, College Station, TX).

3. Results

A total of 1894 patients met the inclusion criteria for our study cohort (Table 2). We identified 318 patients as kBIG 0 and 271 (85.2 %) of these patients had isolated head trauma. Of these isolated kBIG 0 patients, 204 (75.3 %) were transferred. In addition, we identified 336 as kBIG 1, of whom 287 (85.4 %) had isolated head trauma. Of these isolated kBIG 1 patients, 203 (70.7 %) were transferred. The majority of the cohort were male (61 %), and nearly 30 % were on public healthcare insurance (Medicaid).

Among the transferred patients (n = 407), 33 (12 %) of kBIG 0 and 51 (18 %) of kBIG 1 patients received repeat head CT (rCTH), while 120 (44 %) kBIG 0 and 192 (67 %) kBIG 1 patients received a neurosurgical consult. There was a significant difference between the isolated kBIG 0 and 1 patients in terms of rCTH ($p < 0.05$), neurosurgical consultation ($p < 0.001$), and length of hospital stay (LOS, $p < 0.001$). The rCTH charges totaled $67,171 in the base case scenario, ranging from $42 K in the low case to $168 K in the high case scenario. Neurosurgical consultation services were calculated to incur $125 K in charges corresponding to 312 h of billed consultation time. Hospital charges were available for all transferred isolated kBIG 0 and kBIG 1 patients (N = 407) and totaled $6.6 M over the 6-year study period (Fig. 2).

Table 1
Hospital and transfer assumptions for charge calculations.

	Metric	Assumption	Source
Hospital Charges	Per-patient total hospital charges	Varied per patient based on inpatient stay total charges	Primary Children's Hospital Billing Department Proprietary Charge Data
	Computed tomography head without contrast	Base case: $800/scan	CMS, Primary Children's Hospital Billing Department Proprietary Charge Data
	Neurosurgical consultation fee for new patient	$400/patient	CMS and Primary Children's Hospital Neurosurgical Services Proprietary Charge Data
Neurosurgical resources	Neurosurgical consultation hours	1 h per patient	Primary Children's Hospital Neurosurgical Services
Miles transported	Miles transported	Miles from referring facility to level 1 trauma center via fastest driving route	Google Maps
Average Daily Wage	State of Utah average daily wage	$256.80	State of Utah Labor Commission Division [9]
Transfer Charges	**Base rate**		State of Utah published EMS charge report [7,8]
	Ambulance	$1552.68	
	Rotary Wing	$18,867.75	
	Fixed Wing	$13,603.82	
	Charge Per Mile Transport		
	Ambulance	$42.24	
	Rotary Wing	$251.47	
	Fixed Wing	$91.29	

Table 2
Demographic characteristics of transferred isolated kBIG 0 and kBIG 1 patients.

	All N = 1894 (%)	Isolated kBIG 0 N = 271 (%)	Isolated kBIG 1 N = 287 (%)	p-value
Male Sex	(61 %)	(59 %)	(58 %)	0.70[a]
Age, year	5.5 (0.9, 12.4)	3.5 (0.9, 7.6)	5.9 (0.8, 12.3)	0.06[b]
ISS	10 (9, 17)	9 (5, 10)	9 (9, 10)	0.38[b]
Transferred	1388 (73 %)	204 (75 %)	203 (71 %)	0.19[a]
Government Payor (Medicaid)	502 (27 %)	78 (29 %)	65 (23 %)	0.10[a]
rCTH	780 (41 %)	33 (12 %)	51 (18 %)	**<0.05[a]**
Progression on rCTH	182 (10 %)	0 (0 %)	0 (0 %)	1.0[c]
Neurosurgical consultation	1676 (88 %)	120 (44 %)	192 (67 %)	**<0.001[a]**
OR neurosurgery	277 (15 %)	0 (0 %)	0 (0 %)	1.0[c]
LOS, day	2 (1, 4)	1 (1, 1)	1 (1, 2)	**<0.001[b]**

Categorical data are presented as frequency (%) and continuous data as median (IQR). Data were compared between isolated kBIG 0 and isolated kBIG 1 using [a]chi-square test [b]Wilcoxon ran-sum test, and [c]Fisher's exact test. ISS: injury severity score; rCTH: repeat computed tomography of head; OR: operating room; LOS: length of hospital stay.

A total of 308 patients were transferred by ambulance, which amounted to $1.7 M in charges. If ambulances required the highest level of transport provider, in the high case scenario the total transfer charges would have equaled $1.9 M with $1.6 M in the base case scenario. The average distance of transfer was 78 miles by ambulance, 339 miles by fixed wing, and 135 miles by helicopter. Aircraft transfer including both fixed and rotary wing accounted for 12 % of kBIG 0 and kBIG 1 patients, resulting in $2.2 M in transfer charges. Overall, transfer charges totaled $3.9 M, or approximately $9600 per patient in the base case scenario. Total charge including hospital and transfer charges equated to $10.7 M, or $26,300 per patient.

Lastly, median LOS was found to be one day (IQR 1-1) for transferred isolated kBIG0 patients and one day (IQR 1–2) for transferred isolated kBIG1 patients. Using the range of these LOS data, this accounts for 558 days (IQR 558–845) of unnecessary hospitalization. Based on the assumption of one parent out of work for the day of hospitalization and a Utah state daily wage average of $256.80[10], this would account for a median of $143,294 wages lost due to unnecessary hospitalization.

4. Discussion

The purpose of this study was to examine the potential impact of implementing the novel pediatric brain injury guidelines (kBIG) across state-wide healthcare systems. We found that, despite their low-risk clinical status, isolated kBIG 0 and kBIG 1 patients transferred to a level I pediatric trauma center incurred nearly $11 million in total charges over the 6-year study period, equivalent to $25,000 per patient. Half of these patients received a neurosurgical consultation, nearly 20 % underwent repeat head CT, and more than 10 % were transported by aircraft, despite having no other injuries. These findings suggest a substantial and unnecessary use of healthcare resources on clinically stable, low-risk patients. Implementation of the kBIG offers a significant opportunity to improve targeted resource utilization in the care of these low-risk TBI patients, in conjunction with coordinated post-discharge follow-up care for concussion symptom management along with telehealth provider interaction for assurance and assistance. In this study, we take a novel approach to this problem by quantifying potential cost savings to the institutions implementing the KBIG, rather than the cost incurred by each individual patient.

Our findings underscore a significant opportunity for savings and resource optimization in pediatric trauma systems. None of the children in the present study required neurosurgical intervention or any advanced imaging beyond their initial workup, supporting the notion that many of these transfers were unnecessary [6]. Despite the low-risk nature of their injuries, 12 % of kBIG 0 and 18 % of kBIG 1 patients received a repeat head CT scan, exposing these children to unnecessary radiation and the risk of future associated malignancies [10–13]. Neurosurgical consultation was performed in 44 % of all kBIG 0 and 67 % of kBIG 1 patients, amounting to over 300 consultation hours spent on low-risk patients who could be safely managed solely by trauma providers without neurosurgical input [6,14–17]. The median length of stay for both the kBIG 0 and 1 patients was also 1 day, highlighting the fact that the vast majority of these low-risk patients are sent home quickly from the hospital. This mirrors prior findings that mild pediatric TBI accounts for the bulk of preventable transfers and that clinical observation and discharge from the referring facility, rather than transfer, is safe and resource-effective for these patients [2,6].

Transfer of pediatric trauma patients has been well documented to incur high costs to the healthcare system, with most prior studies focusing on the individual cost per patient to either the receiving facility or the healthcare system [1–4,18]. White et al.

		N	Base Case Charges	Total
	Total Isolated kBIG 0 Isolated kBIG 1	1,894 271 287	--	--
Hospital Charges	**Transferred** kBIG 0 kBIG 1	75% (204/271) 71% (203/287)	$2.88M $3.70M	$6.57M
	Repeat CTH kBIG 0 kBIG 1	12% (33/271) 18% (51/287)	$26,400 $40,800	$67,200
	NSGY Consultation kBIG 0 kBIG 1	44% (120/271) 67% (192/287)	$48,000 $76,800	$124,800
Transport Charges	**Air Transport (Helicopter+ Fixed wing)** kBIG 0 kBIG 1	11% (23/204) 12% (25/203)	$1.12M $1.08M	$2.20M
	Ambulance Transport kBIG 0 kBIG 1	71% (144/204) 81% (164/203)	$0.89M $0.83M	$1.72M
	Total			**$10.68M**

Fig. 2. Total charges for isolated kBIG 0 and 1 patients.

[18] evaluated the charges for children transferred with linear isolated skull fractures and found that it was roughly $5000 per patient for transfer charges in 2005. In 2024 US dollars based on the Consumer Price Index, this value would be nearly 100 % higher, which is very similar to our estimated per-patient transfer charge of $9600.

It is important to acknowledge that the financial impact reported in this study likely underestimates the true economic burden of these unnecessary transfers. Our analysis does not account for indirect costs such as travel and lodging expenses, or the psychosocial toll of transfers. Additionally, we likely underestimated transfer costs by assuming a moderate-level ambulance transport requiring EMT-Advanced support, rather than paramedic-level transportation services which would increase the overall cost. We also did not address opportunity costs incurred by both the referring and receiving facilities. The Level I trauma center might have to allocate resources to these lower-acuity cases at the expense of higher-acuity patients, while the referring hospitals might lose the ability to perform both continuity of care and the man-hours dedicated to the coordination of transport services. Similarly, the neurosurgical service at the level 1 trauma center spent over 300 h consulting patients which should not be needed according to the kBIG. Those hours could have been spent on more highly specialized clinical work and were not accounted for in this model. Lastly, approximately 30 % of the patients in our study were on Medicaid. Thus, the charges associated with these patients were directly passed on to the state's public health insurance system, rather than private payors. However, this is lower than the national average which estimates that 50 % of children nationally receive public insurance through Medicaid and/or Children's Health Insurance Program (CHIP) [19]. We might not have only underestimated the costs on the individual level, but likely the costs on the national systems level.

There are several limitations to this study. As this study was a retrospective review there are inherent limitations including our reliance on administrative and registry data which may be subject to coding inconsistencies and missing clinical detail. Transfer decisions are not addressed in this study, and despite the state of Utah's extensive telemedicine transfer network through the Utah Pediatric Trauma Network (UPTN), there are decision factors for rural and out-of-state providers that we did not take into account in this study, such as pediatric bed availability for observation. To this point, transfer decisions are also often influenced by providers' comfort level, limited observation beds, and lack of rehab/follow-up resources at critical access hospitals, not just cost, and we were not able to model these factors in our analysis. We did not account for the potential need for pediatric rehabilitation and follow-up services, such as return-to-sports counseling which may not be directly available at non-pediatric institutions. However, through the UPTN, we have robust telehealth services that can allow for follow-up care that is comparable to the pediatric-level service. Additionally, we did not have access to cost or reimbursement data for the study patients and had to rely on charge estimates for transport and hospital stay. While we acknowledge that this may limit the generalizability of our work, the current data serve as a starting point for evaluating the cost of implementation of the kBIG on a societal level, providing valuable inputs to a future cost effectiveness model. Finally, as our primary goal was to determine the potential benefits of avoiding unnecessary transfers, clinical outcomes were not the focus of the present study. In fact, there are ongoing prospective evaluations of the kBIG that will provide further data on patient safety. The implementation of the kBIG within our state-wide UPTN is expected to be both cost-effective and feasible, and a cost-effectiveness analysis of this implementation is already in process. A rigorous economic evaluation should focus on comparing the cost savings from reducing unnecessary transfers with the minimal costs of kBIG implementation, including staff training and necessary system integrations. Given the existing infrastructure through the UPTN, this integration should represent a low-cost, high-value investment in improving the efficiency and quality of pediatric trauma care. This warrants the next phase of research to validate our findings across multiple centers via the UPTN and other multi-institutional collaborations.

5. Conclusion

In conclusion, we found that implementation of the kBIG could have avoided approximately $11 million in charges by reducing unnecessary transfers, imaging, and neurosurgical consultations for isolated kBIG 0 and kBIG 1 patients. This approximates $1.7 million per year in unnecessary charges and likely underestimates the true economic benefit of guideline adoption. Beyond financial savings, targeted use of resources helps improve patient safety and allow clinicians to devote more time to patients who truly need their specialized expertise. The kBIG is currently being implemented at our institution and across the state of Utah, and future studies will evaluate the impact of this initiative on resource utilization and patient outcomes.

Conflict of interest

The authors declare no competing financial interests or personal relationships that could have influenced the work reported in this manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpedsurg.2025.162763.

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