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Admission trends in pediatric isolated linear skull fracture across the United States

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OBJECTIVE Pediatric isolated linear skull fractures commonly result from head trauma and rarely require surgery, yet patients are often admitted to the hospital—a costly care plan. In this study, the authors utilized a national database to investigate trends in admission for skull fractures across the United States.

METHODS Children younger than 18 years with isolated linear skull fracture, according to ICD-9 diagnosis codes in the Kids' Inpatient Database of the Healthcare and Utilization Project (HCUP), who presented between 2003 and 2016 were included. HCUP collected data in 2003, 2006, 2009, 2012, and 2016. Children with a depressed skull fracture, multiple traumatic injuries, and acute intracranial findings were excluded. Sample-level data were translated into population-level data by using an HCUP-specific discharge weight.

RESULTS Overall, 11,355 patients (64% males) were admitted to 1605 hospitals. National admissions decreased from 3053 patients in 2003 to 1203 in 2016. The mean ± SD age at admission also decreased from 6.3 ± 5.9 years to 1.2 ± 3.0 years ($p < 0.001$). The proportion of patients in the lowest quartile of median household income increased by 9%, while that in the highest income quartile decreased by 7% ($p < 0.001$). Admission was generally more common in the summer months (June, July, and August) and on weekdays (68%). The mean ± SD hospital length of stay decreased from 2.0 ± 3.1 days to 1.4 ± 1.4 days between 2003 and 2012, and then increased to 2.1 ± 6.8 days in 2016 ($p < 0.001$). When adjusted for inflation, the mean total hospital charges increased from $13,099 to $21,204 ($p < 0.001$). The greatest proportion of admissions was in the South (35%), and the lowest was in the Northeast (17%). The proportion of patients admitted to large hospitals increased (59% to 72%, $p < 0.001$), which corresponded to a decrease in patients admitted to small hospitals (16% to 9%, $p < 0.001$). Overall, the total proportion of admissions to rural hospitals decreased by 6%, and that to urban teaching centers increased by 15% ($p < 0.001$). Since 2003, no child has undergone a neurosurgical procedure or died as an inpatient.

CONCLUSIONS This study identified a general nationwide decrease in admissions for pediatric linear isolated skull fracture, but associated costs increased. Admissions became less common at smaller rural hospitals and more common at larger urban teaching hospitals. This patient population required no inpatient neurosurgical intervention after 2003.

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KEYWORDS children; skull fracture; transfer; traumatic brain injury; TBI; USA; trauma

HEAD trauma is a leading reason for presentation to the emergency department (ED) among children in the US. It accounts for more than 2000 deaths, 23,000 hospitalizations, and 800,000 ED visits annually, as well as more than $1 billion in health care expenditures.[1,2] Management of pediatric traumatic brain injury depends on injury severity, and a common indication for admission is linear skull fracture.[3]

Traditionally, children with isolated linear skull fracture are admitted to the hospital for further observation.[3] Reasons often include young age, vomiting, concern for nonaccidental trauma, and positive findings on head imaging.[4] Yet, mounting evidence in the literature indicates that children with this diagnosis are unlikely to decline clinically or require an operation or further neurosurgical follow-up care.[5–8] As such, this has called into question the need to admit or transfer the child in order to provide a higher level of care.[9–11] Repeat imaging is not routinely performed and

ABBREVIATIONS ED = emergency department; HCUP = Healthcare and Utilization Project; KID = Kids' Inpatient Database; LOS = length of stay.

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usually does not provide additional insight.[8] Inpatient admission is known to add unnecessary emotional stress to patients and caregivers and significantly increase treatment cost.[6,9,12] Thus, a more conservative approach to managing these patients has been gaining traction.

A nationwide study about admission trends over time for pediatric patients with isolated linear skull fracture in the US is lacking. This study sought to profile the incidence of linear skull fracture and the demographic characteristics of patients with this condition in the US. Specifically, we used a large national database to 1) establish trends in admission for pediatric linear skull fracture across the US, 2) determine whether hospital characteristics (type, size, location, etc.) affect admission, and 3) assess likelihood of inpatient morbidity and mortality for children with this diagnosis.

Methods

Patient Population

Children younger than 18 years with isolated linear skull fracture in the US were identified in the Kids' Inpatient Database (KID) of the Healthcare and Utilization Project (HCUP) in 2003, 2006, 2009, 2012, and 2016. KID (www.hcup-us.ahrq.gov/) is the largest publicly available pediatric US inpatient care database and publishes data every 3–4 years. It includes sample-level inpatient data from 46 states that are collected from hospital administrative billing records and provides estimates of population-level data.[13] It does not include patients discharged from the ED.

For the purposes of this study, an isolated linear skull fracture was defined as a nondisplaced skull fracture without evidence of intracranial trauma. Patients included in KID between 2003 and 2012 were identified according to ICD-9 diagnosis codes for skull fracture, and patients were excluded if they had ICD-9 codes for other traumatic injuries, depressed or displaced skull fracture, intracranial hemorrhage, or pneumocephalus. The following ICD-9 codes were included: closed fracture of skull vault without intracranial injury (800.x); closed fracture of skull base without intracranial injury (801.x); and other closed skull fracture without intracranial injury (803.x). Patients included in KID in 2016 were identified and excluded by using ICD-10 codes, in accordance with the transition of KID data from ICD-9 to ICD-10 codes in 2016.

Variables Collected

Because KID is a de-identified database, the study was considered exempt by the Vanderbilt University Institutional Review Board. Variables extracted from the database included demographic information, information about inpatient stay, and hospital characteristics. Patient demographic variables that were analyzed included sex, race, age, and median income of the patient's home zip code. Information about inpatient stay included admission month and day of the week, number of ICD-9 and ICD-10 diagnoses, number of ICD-9 and ICD-10 procedures, use of a neurosurgical procedure, concern for child abuse, length of stay (LOS), and discharge disposition. The collected hospital characteristics of interest were region, teaching status, location (rural vs urban), and size according to bed count.

A patient's socioeconomic status was estimated by using the median household income of the patient's home zip code. Household income was stratified into quartiles that were predetermined by HCUP and US Census Bureau data, which varied by year of data collection; therefore, quartile cutoff values varied.[13] For example, quartile 1, the lowest income quartile, included zip codes with median household income less than $36,000 in 2003; this limit increased to less than $43,000 in 2016.[13] Total hospital charges billed for services rendered were considered the cost associated with admission. Total hospital charges were adjusted to 2016 dollars according to the US Bureau of Labor Statistics to account for inflation over the study period.[14]

HCUP classifies hospital location according to the regions used by the US Census Bureau: West, Midwest, South, and Northeast. Hospitals within these regions are classified as urban teaching, urban nonteaching, and rural, and then further subdivided according to bed size as small, medium, and large. HCUP uses information from the American Hospital Association Annual Survey of Hospitals, core-based statistical area codes, and the US Census Bureau to determine these designations.[13] The qualifications for each subclassification varied by location and teaching status. For example, a hospital in a rural area was classified as small if it had less than 50 beds, whereas an urban nonteaching center with less than 100 beds and an urban teaching center with less than 300 beds were also considered small.[13]

Data Limitation

Per HCUP guidelines, any variable with fewer than 10 patients must be reported as $n < 10$. This is due to the purported potential for identifying information.[13]

Statistical Analysis

Sample-level data were translated into population-level data by using predetermined HCUP-reported discharge weights.[13] The software platform for statistical analysis was R version 3.6.0 (R Foundation). To assess change over time, univariable analysis was performed by using the Kruskal-Wallis test for nonnormally distributed data and 1-way ANOVA for normally distributed data. Univariable analysis of the entire study cohort was performed, as well as subgroup analysis with data stratified according to age group: infants (age < 12 months), toddlers (1–5 years), children (5–12 years), and adolescents (12–18 years). Given the large amount of data, only significant variables in the analysis of the entire study cohort were included in the subgroup analysis. Multivariable analysis was not indicated because this study was designed to statistically analyze changes within each variable over time and not the effect of a variable on a particular outcome. Statistical significance was set a priori at $p < 0.05$.

Results

Patient Demographic Characteristics

Overall, 11,355 patients (derived from 7468 records) with isolated linear skull fracture were admitted to US hospitals during the study period. The demographic characteristics of the cohort are shown in Table 1. Patients

TABLE 1. Demographic characteristics of the cohort (n = 11,355)

Variable	Value
Age, yrs	5.7 ± 5.7
Age	
Infant (0–1 yr)	3264 (29)
Toddler (1–5 yrs)	3480 (31)
Child (5–12 yrs)	2289 (20)
Adolescent (13–18 yrs)	2233 (20)
Sex	
Male	7136 (64)
Female	3991 (36)
Race	
White	5391 (59)
Hispanic	1900 (21)
African American	1111 (12)
Asian/Pacific Islander	230 (3)
Native American	78 (1)
Other	475 (5)
Admission month	
January	693 (7)
February	679 (7)
March	829 (8)
April	976 (9)
May	967 (9)
June	1047 (10)
July	1119 (11)
August	1005 (10)
September	928 (9)
October	842 (8)
November	709 (7)
December	704 (7)
Weekend admission	
Yes	3632 (32)
No	7724 (68)
Discharge disposition	
Home	11,106 (98)
Home w/ home health care	54 (1)
Inpatient rehabilitation	129 (1)
Against medical advice	18 (0)
Morgue	<10 (0)
Other	38 (0)
Died in hospital	
Yes	<10 (0)
No	11,352 (100)
No. of diagnoses	2 ± 2
No. of procedures	0 ± 1
Neurosurgical procedure	
None	11,353 (100)
Craniotomy/craniectomy, unspecified	<10 (0)
EVD insertion	0 (0)
ICP monitor insertion	0 (0)
Evidence of child abuse	
Yes	292 (3)
No	11,603 (97)
Admitting hospital size	
Small	1248 (11)
Medium	2415 (22)
Large	7315 (67)
Hospital location & teaching status	
Urban teaching	8704 (79)
Urban nonteaching	1818 (17)
Rural	455 (4)
Hospital region	
South	4013 (35)
West	3098 (27)
Midwest	2320 (20)
Northeast	1925 (17)
Median household income quartile	
1 (lowest income)	3075 (28)
2	2700 (24)
3	2748 (25)
4 (highest income)	2587 (23)
LOS, days	1.7 ± 3.0
Total hospital charges, USD	$13,660 ± 25,218

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EVD = external ventricular drain; ICP = intracranial pressure; USD = United States dollars.
Values are shown as number (percentage) or mean ± SD.

were admitted to 1605 unique hospitals across the US, and males (n = 7136 [64%]) outnumbered females by an approximately 2:1 ratio. The mean ± SD patient age was 5.7 ± 5.7 years. Over half (59%) the patients were White (n = 5391), 21% were Hispanic (n = 1900), and 12% were African American (n = 1111). Admission of White patients decreased between 2003 and 2016 (58% to 50%), with a corresponding increase in admissions of both Hispanic (20% to 25%) and African American (13% to 16%) patients (p = 0.001). The mean ± SD age at admission declined over time, from 6.3 ± 5.9 years in 2003 to 1.2 ± 3.0 years in 2016 (p < 0.001). The proportions of patients according to sex did not change in a statistically significant fashion over time (p = 0.088). When stratified according to median household income quartile, the proportion of patients in the lowest income quartile increased by 9% (25% to 34%), while the proportion of patients in the highest quartile decreased by 7% (25% to 18%) (p < 0.001).

Trends in Hospital Admission

Table 2 presents our analysis of national admission trends over time. Admissions decreased over the study period, from 3053 patients in 2003 to 1203 in 2016, and admissions usually peaked in the summer months of June, July, and August. Summer admissions constituted 28% to

32% of annual admissions and did not significantly change over the study period ($p = 0.072$). Weekday admission was more common (68%) than weekend admission (32%), and the proportion of weekday admissions increased over time (66% to 73%, $p = 0.054$).

Most patients were admitted to urban teaching hospitals (n = 8704 [79%]). The regional distribution of admissions showed that the greatest proportion of patients was admitted to hospitals in the South (n = 4013 [35%]), and the smallest proportion was admitted to Northeast centers (n = 1925 [17%]) (Fig. 1). By 2016, a larger proportion of patients was admitted to hospitals in the South, and a smaller proportion was admitted to hospitals in the Midwest and West ($p < 0.001$). Between 2003 and 2016, there was also a shift to larger hospitals. Smaller hospitals admitted fewer patients. The proportion of total admissions to smaller hospitals decreased from 16% to 9% ($p < 0.001$), which corresponded to a 13% increase in admissions to larger hospitals (59% to 72%, $p < 0.001$). Furthermore, rural hospitals experienced a 6% decrease in admissions, while urban teaching centers had a 15% increase during the study period (75% to 90%, $p < 0.001$) (Fig. 2).

Outcomes

No patients underwent neurosurgical operations in 2006, 2009, 2012, or 2016. Fewer than 10 patients underwent a neurosurgical operation in 2003. No patient underwent insertion of an external ventricular drain or intracranial pressure monitor in any study year. Fewer than 10 patients died in 2003, and no patients died in 2006, 2009, 2012, or 2016.

With respect to discharge disposition, most patients were discharged home (n = 11,106 [98%]). Of 249 patients who were not discharged home, 52% (n = 129) were transferred to an inpatient rehabilitation facility. The other patients were discharged to other care facilities, left the hospital against medical advice, or died. Of these children who were not discharged directly home, 4% (n = 10) were suspected victims of child abuse. The total cohort included 292 (3%) children with suspected or confirmed child abuse.

Health Care Charges

Overall admission-related charges increased between 2003 and 2016 (Fig. 3). The mean ± SD hospital charges increased from \$13,099 ± \$22,756 to \$21,204 ± \$62,048 between 2003 and 2016 ($p < 0.001$). The average LOS decreased from 2003 to 2012 (2.0 ± 3.1 days to 1.4 ± 1.4 days, $p < 0.001$) and then increased in 2016 (2.1 ± 6.8 days, $p < 0.001$). The number of ICD-9 and ICD-10 diagnostic codes per admitted patient increased slightly from 2003 to 2016 (2 ± 2 to 3 ± 3, $p < 0.001$), while the number of ICD-9 and ICD-10 procedural codes decreased from 2003 to 2016 (1 ± 1 to 0 ± 0, $p < 0.001$).

Subgroup Analysis

These trends were further assessed in a subgroup analysis that stratified patients according to age group (Table 3). There was a marked increase in admission of infants between 2012 and 2016, while admissions of patients in the remaining age groups decreased over the study period (Fig. 4). Across all age groups, LOS decreased until 2012 and began to increase in 2016. Trends in total hospital charges fluctuated over time, but charges were significantly greater in 2016 compared with those in 2003 across all age groups. Evidence of child abuse was more common among infants and toddlers than among older children and adolescents. Admissions of patients of all age groups increased at larger hospitals and at urban teaching hospitals. There was an associated decrease in admissions at smaller rural facilities. Of note, only the subgroup of children (age 5–12 years) showed a statistically significant increase in admission of patients from households with a lower median income, whereas other age subgroups did not demonstrate a significant difference. Race, weekend admissions, and hospital region were statistically similar across age subgroups.

Discussion

In this study of more than 11,000 children and 1605 US hospitals, the number of patients with isolated linear skull fractures who were annually admitted to a hospital decreased over time. When stratified by age, admissions decreased for all subgroups of patients, with the exception of infants whose admissions increased in recent years; this may be related to heightened awareness of nonaccidental trauma among health care providers. Admissions were consistently greater in the South, during the summer season, and on weekdays, and admissions shifted from small rural hospitals to large urban teaching centers. Interfacility transfer costs were not measured, but inflation-adjusted costs of admission increased overall (Fig. 3). Most patients were discharged home, none underwent a neurosurgical operation or procedure as an inpatient after 2003, and none died after 2003. These important trends are indicative of a changing health care landscape and highlight several themes for physicians to address.

Fewer admissions occurred in the setting of increasing diagnosis of pediatric skull fracture in the US.[6,10] This paradox may suggest that imaging sensitivities are improving[15] or more imaging studies are being performed; alternatively, more patients may be discharged home from the ED rather than admitted, which is a management strategy supported by many physicians.[6,16,17] Frequency of admission varies widely among individual institutions, with reported admission rates between 22% and 99%.[3] The national admission rate remains unclear and was not assessed in this study. Admissions shifted from rural facilities to urban teaching centers, which likely reflects the increasingly common practice of transferring children with linear skull fracture to designated pediatric trauma centers.[18,19] Historically, transfer has been encouraged for many reasons, including hospital policy, insurance network policy, and/or perceived potential for clinical decline and subsequent need for specialized neurosurgical assessment.[19] Although complications such as seizure, vomiting, and cerebral hemorrhage were previously described in this patient population,[8,19,20] the incidence of such sequelae is very low if CT has negative findings for intracranial trauma.[5,8,21–23] Furthermore, this study shows that no neurosurgical procedure affiliated with the initial admission was performed in the US in 2006, 2009, 2012, or 2016. Given the low likelihood of clinical decline, low utility of follow-up imag-

TABLE 2. Univariable analysis of variables of all children diagnosed with isolated linear skull fracture across HCUP survey years

Variable	Year of HCUP Survey					p Value*
	2003	2006	2009	2012	2016	
Total admissions	3053	2381	2595	2123	1203	—
Age, yrs	6.3 ± 5.9	5.9 ± 5.9	5.3 ± 5.6	4.9 ± 5.4	1.2 ± 3.0	**<0.001**
Age						
Infant (0–1 yr)	621 (21)	569 (24)	620 (24)	587 (28)	868 (72)	**<0.001**
Toddler (1–5 yrs)	883 (29)	702 (30)	926 (36)	740 (35)	230 (19)	
Child (5–12 yrs)	734 (24)	520 (22)	535 (21)	430 (20)	70 (5)	
Adolescent (13–18 yrs)	765 (26)	554 (24)	514 (20)	366 (17)	35 (3)	
Sex						
Male	1918 (65)	1496 (65)	1630 (64)	1372 (65)	720 (60)	0.088
Female	1015 (35)	818 (35)	924 (36)	751 (35)	483 (40)	
Race						
White	1249 (58)	1120 (62)	1328 (61)	1144 (58)	550 (50)	**0.001**
Hispanic	432 (20)	348 (19)	434 (20)	409 (21)	276 (25)	
African American	269 (13)	191 (11)	262 (12)	214 (11)	175 (16)	
Asian/Pacific Islander	50 (2)	37 (2)	47 (2)	67 (3)	29 (3)	
Native American	13 (1)	17 (1)	18 (1)	16 (1)	14 (1)	
Other	123 (6)	90 (5)	98 (5)	104 (5)	59 (5)	
Admission month						
January	187 (7)	136 (6)	134 (6)	146 (7)	91 (8)	0.072
February	165 (6)	149 (7)	145 (6)	133 (6)	87 (7)	
March	217 (8)	149 (7)	161 (7)	192 (9)	109 (9)	
April	225 (8)	220 (10)	219 (10)	208 (10)	104 (9)	
May	248 (9)	179 (9)	250 (11)	190 (9)	101 (8)	
June	243 (9)	194 (9)	244 (11)	223 (11)	145 (12)	
July	334 (12)	241 (12)	214 (9)	222 (1)	109 (9)	
August	294 (11)	188 (9)	241 (10)	197 (9)	85 (7)	
September	244 (9)	178 (9)	211 (9)	193 (9)	102 (9)	
October	246 (9)	170 (8)	179 (8)	160 (8)	87 (7)	
November	178 (7)	150 (7)	159 (7)	136 (6)	86 (7)	
December	177 (6)	152 (7)	153 (7)	123 (6)	99 (8)	
Weekend admission						
Yes	1050 (34)	772 (32)	852 (33)	633 (30)	325 (27)	**0.001**
No	2004 (66)	1610 (68)	1742 (67)	1490 (70)	878 (73)	
Discharge disposition						
Home	2971 (97)	2339 (98)	2553 (98)	2088 (98)	1155 (96)	—
Home w/ home health care	18 (1)	<10 (0)	<10 (0)	10 (0)	12 (1)	
Inpatient rehabilitation	37 (1)	22 (1)	26 (1)	18 (1)	26 (2)	
Against medical advice	<10 (0)	<10 (0)	<10 (0)	<10 (0)	0 (0)	
Morgue	<10 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
Other	17 (1)	<10 (0)	<10 (0)	<10 (0)	11 (1)	
Died in hospital						
Yes	<10 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.510
No	3050 (100)	2381 (100)	2595 (100)	2123 (100)	1203 (100)	
No. of diagnoses	2 ± 2	2 ± 2	2 ± 2	3 ± 2	3 ± 3	**<0.001**
No. of procedures	1 ± 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**<0.001**

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TABLE 2. Univariable analysis of variables of all children diagnosed with isolated linear skull fracture across HCUP survey years

Variable	Year of HCUP Survey					p Value*
	2003	2006	2009	2012	2016	
Neurosurgical procedure						
None	3051 (100)	2381 (100)	2595 (100)	2123 (100)	1203 (100)	—
Craniotomy/craniectomy, unspecified	<10 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
EVD insertion	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
ICP monitor insertion	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
Evidence of child abuse						
Yes	44 (1)	39 (2)	51 (2)	37 (2)	121 (1)	**<0.001**
No	3010 (99)	2342 (98)	2544 (98)	2086 (98)	1082 (90)	
Admitting hospital size						
Small	461 (16)	278 (12)	208 (9)	197 (10)	104 (9)	**<0.001**
Medium	744 (25)	568 (24)	470 (20)	403 (19)	231 (19)	
Large	1738 (59)	1501 (64)	1686 (71)	1523 (72)	868 (72)	
Hospital location & teaching status						
Urban teaching	2210 (75)	1813 (77)	1826 (77)	1771 (83)	1085 (90)	**<0.001**
Urban nonteaching	542 (18)	430 (18)	442 (19)	299 (14)	106 (9)	
Rural	191 (7)	103 (4)	96 (4)	53 (3)	13 (1)	
Hospital region						
South	967 (32)	855 (36)	940 (36)	765 (36)	485 (40)	**<0.001**
West	860 (28)	682 (29)	676 (26)	601 (28)	280 (23)	
Midwest	691 (23)	485 (20)	532 (21)	418 (20)	194 (16)	
Northeast	536 (18)	359 (15)	447 (17)	339 (16)	244 (20)	
Median household income quartile						
1 (lowest income)	728 (25)	642 (28)	685 (27)	618 (30)	403 (34)	**<0.001**
2	703 (24)	565 (24)	600 (24)	522 (25)	309 (26)	
3	768 (26)	563 (24)	651 (26)	500 (24)	266 (22)	
4 (highest income)	775 (25)	552 (24)	607 (24)	443 (21)	211 (18)	
LOS, days	2.0 ± 3.1	1.5 ± 1.4	1.4 ± 1.7	1.4 ± 1.4	2.1 ± 6.8	**<0.001**
Total hospital charges, USD	$13,099 ± 22,756	$11,552 ± 9696	$12,330 ± 11,163	$14,190 ± 13,532	$21,204 ± 62,048	**<0.001**

— = not applicable
Values are shown as number, number (percentage), or mean ± SD. Boldface type indicates statistical significance ($p < 0.05$).
* The Kruskal-Wallis test was used to analyze nonnormally distributed data; 1-way ANOVA was used to analyze normally distributed data.

ing, lack of neurosurgical intervention or need for regular follow-up,[19,24] and high associated health care costs,[16,19] the question is raised as to whether admission and/or transfer is routinely necessary. Interfacility transfer carries its own morbidity and costs. In this study, children (particularly those who were 5–12 years old) were increasingly from poorer families. Those who are transferred long distances are commonly admitted for social reasons, such as lack of a ride home or late time of night, which is costly.[11,25] The lack of neurosurgical sequelae in patients with isolated linear skull fracture is reassuring and should be considered when determining the need for transfer or admission.

This study supports the active yet evolving role of neurosurgeons in the management of pediatric isolated linear skull fracture. Although children are traditionally transferred for emergent neurosurgical consultation after the diagnosis of any type of skull fracture, it is becoming apparent that patients with linear skull fracture are at minimal risk for neurological complications.[26,27] In an era that is cognizant of health care overutilization, centers have begun to study various approaches for the management of these children, largely by using hospital-driven protocols. Clinical parameters that guide assessment of neurosurgical involvement include the Glasgow Coma Scale score,[26] history of nonaccidental or high-energy trauma,[28] and positive findings on head CT.[17] These protocols are facility specific, and there is no current consensus opinion. Neurosurgical consultation will continue to be warranted for select situations, such as children whose status does not return to clinical baseline[29] or concern for nonaccidental trauma requiring legal documentation;[19] however, universal emergent involvement of neurosurgeons is changing.

Cost is a major driver of the changing role of neurosurgeons. Adjusted for inflation, mean hospital charges significantly increased over the study period, and this trend mimics the increasing overall cost of US health care over

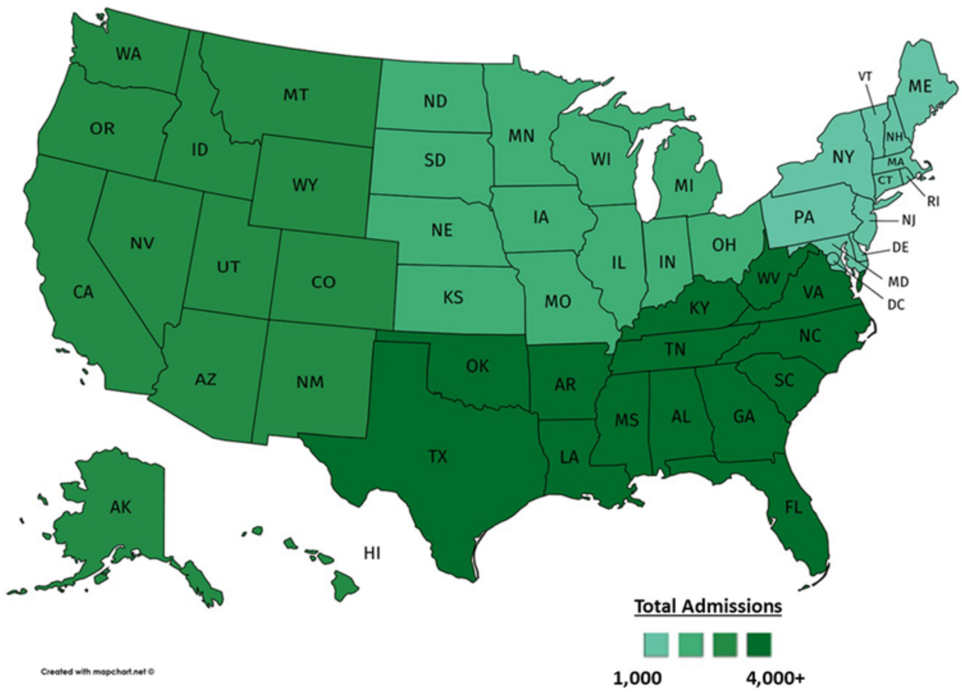

FIG. 1. Map depicting admissions for total linear skull fracture in the US. *Darker green* indicates a higher number of admissions. The South had the highest incidence of admission for linear skull fracture nationwide. Map created by using Mapchart.net. Figure is available in color online only.

a similar time.[30] Yet, when closely studied, there was a substantial decline in costs between 2003 and 2006, and charges have begun to steadily increase since then (Fig. 2). The initial decrease in cost corresponded with the initial decrease in hospital LOS, which has started to increase again. Thus, it is possible that cost and LOS are closely linked. The distribution of patients who received 23-hour observation versus inpatient admission is unclear, which is a limitation of the KID. It will be important to determine this relationship in future national studies. The cost of inpatient admission—which averages $2093 to $2653 per day according to 2018 Kaiser Family Foundation data[31]—is high, particularly if admission is deemed unnecessary. Children who may not require admission include those who can tolerate fluids without antiemetic medication[4] and those who have returned to their neurological baseline, but further study is warranted. Outpatient referral to a neurosurgeon could be considered in place of inpatient consultation, which would further streamline care in EDs and

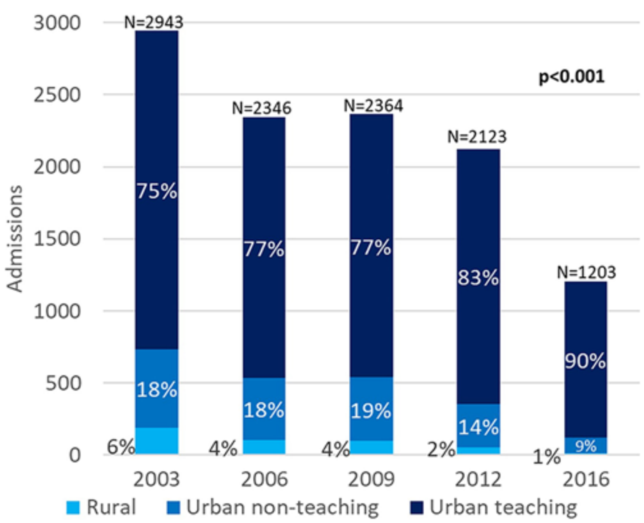

FIG. 2. Admissions stratified according to hospital type and location. Admissions decreased nationwide between 2003 and 2016. The proportion of patients admitted to urban teaching hospitals increased, while the proportion admitted to rural hospitals decreased. Figure is available in color online only.

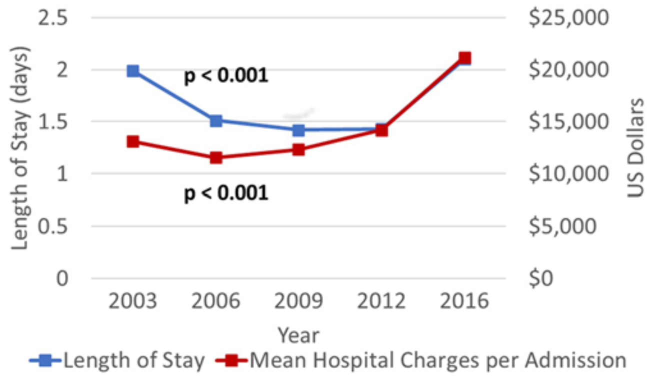

FIG. 3. Mean total hospital charges and LOS over the study period. Hospital charges initially declined but have begun to sharply increase. LOS also declined between 2003 and 2006 but has increased in recent years. Figure is available in color online only.

TABLE 3. Subgroup analysis of variables that were statistically significant on univariable analysis of the entire cohort, according to age group

Variable	2003	2006	2009	2012	2016	p Value*
Infants (age <12 mos)						
Total admissions	621	569	620	587	868	—
Race						
White	226 (50)	223 (50)	265 (52)	273 (51)	397 (51)	0.923
Hispanic	109 (24)	108 (24)	118 (23)	131 (24)	190 (24)	
African American	73 (16)	86 (9)	84 (16)	82 (15)	130 (17)	
Asian/Pacific Islander	10 (2)	11 (2)	18 (4)	16 (3)	17 (2)	
Native American	0 (0)	<10 (1)	<10 (1)	<10 (1)	<10 (1)	
Other	36 (8)	19 (4)	22 (4)	34 (6)	43 (6)	
Weekend admission						
Yes	161 (26)	170 (30)	172 (28)	135 (23)	223 (26)	0.263
No	460 (74)	399 (70)	448 (72)	452 (77)	645 (74)	
No. of diagnoses	2 ± 2	2 ± 1	2 ± 1	2 ± 2	3 ± 3	<0.001
No. of procedures	1 ± 1	0 ± 0	0 ± 0	0 ± 0	0 ± 1	—
Evidence of child abuse						
Yes	29 (5)	31 (5)	33 (5)	21 (4)	104 (12)	<0.001
No	592 (95)	538 (95)	587 (95)	566 (96)	764 (88)	
Admitting hospital size						
Small	88 (15)	47 (8)	56 (10)	50 (9)	77 (9)	0.003
Medium	152 (25)	129 (23)	116 (20)	111 (19)	159 (18)	
Large	362 (60)	391 (69)	412 (71)	425 (73)	632 (73)	
Hospital location & teaching status						
Urban teaching	478 (93)	448 (79)	456 (78)	491 (84)	783 (90)	<0.001
Urban nonteaching	95 (16)	95 (17)	105 (18)	87 (5)	75 (9)	
Rural	29 (5)	24 (4)	24 (4)	<10 (2)	10 (1)	
Hospital region						
South	193 (31)	217 (38)	243 (39)	230 (39)	342 (39)	0.051
West	142 (23)	158 (28)	140 (23)	151 (26)	187 (22)	
Midwest	133 (21)	92 (16)	111 (18)	89 (15)	142 (16)	
Northeast	153 (25)	103 (18)	127 (20)	118 (20)	197 (23)	
Median household income quartile						
1 (lowest income)	192 (32)	200 (36)	192 (32)	213 (37)	300 (35)	0.392
2	150 (25)	117 (21)	135 (22)	139 (24)	224 (26)	
3	129 (21)	127 (23)	151 (25)	122 (21)	193 (23)	
4 (highest income)	135 (22)	116 (21)	126 (21)	109 (19)	140 (16)	
LOS, days	3 ± 6	2 ± 2	1 ± 2)	1 ± 2	2 ± 8	<0.001
Total hospital charges, USD	$13,176 ± 42,361	$9046 ± 7802	$9682 ± 8798	$11,525 ± 11,497	$20,459 ± 71,567	<0.001
Toddlers (age 1–5 yrs)						
No. of patient admissions	882	702	926	740	230	—
Race						
White	342 (53)	315 (58)	460 (59)	387 (56)	107 (49)	0.415
Hispanic	151 (23)	119 (22)	172 (22)	166 (24)	58 (27)	
African American	85 (13)	57 (11)	94 (12)	71 (10)	32 (15)	
Asian/Pacific Islander	23 (4)	16 (3)	16 (2)	26 (4)	11 (5)	
Native American	0 (0)	<10 (1)	<10 (1)	<10 (1)	<10 (1)	
Other	45 (7)	25 (5)	38 (5)	36 (5)	<10 (1)	

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TABLE 3. Subgroup analysis of variables that were statistically significant on univariable analysis of the entire cohort, according to age group

Variable	2003	2006	2009	2012	2016	p Value*
			Toddlers (age 1–5 yrs)			
Weekend admission						
Yes	326 (37)	213 (30)	295 (32)	234 (32)	68 (30)	0.131
No	557 (63)	489 (70)	631 (68)	506 (68)	162 (70)	
No. of diagnoses	2 ± 1	2 ± 1	2 ± 1	2 ± 2	3 ± 2	<0.001
No. of procedures	0 ± 1	0 ± 0	0 ± 0	0 ± 0	0 ± 1	—
Evidence of child abuse						
Yes	13 (1)	<10 (1)	18 (2)	16 (2)	17 (7)	<0.001
No	869 (99)	693 (99)	908 (98)	724 (98)	213 (93)	
Admitting hospital size						
Small	133 (16)	87 (13)	80 (10)	64 (9)	21 (9)	<0.001
Medium	237 (28)	180 (26)	167 (20)	131 (18)	46 (20)	
Large	478 (56)	420 (61)	575 (70)	545 (74)	163 (71)	
Hospital location & teaching status						
Urban teaching	663 (78)	548 (80)	648 (79)	625 (84)	204 (89)	0.033
Urban nonteaching	144 (17)	116 (17)	144 (18)	101 (14)	24 (10)	
Rural	40 (5)	24 (4)	30 (4)	14 (2)	<10 (1)	
Hospital region						
South	304 (34)	272 (39)	353 (38)	279 (38)	103 (45)	0.560
West	263 (30)	197 (28)	244 (26)	206 (28)	63 (28)	
Midwest	173 (20)	146 (21)	193 (21)	152 (21)	35 (15)	
Northeast	143 (16)	87 (12)	135 (15)	103 (14)	29 (12)	
Median household income quartile						
1 (lowest income)	231 (27)	190 (28)	248 (27)	219 (30)	64 (28)	0.392
2	177 (21)	178 (26)	227 (25)	188 (26)	62 (27)	
3	220 (26)	172 (25)	222 (25)	170 (24)	57 (25)	
4 (highest income)	232 (27)	149 (22)	210 (23)	146 (20)	47 (21)	
LOS, days	2 ± 3	1 ± 1	1 ± 2	1 ± 1	2 ± 2	0.002
Total hospital charges, USD	$12,310 ± 16,836	$10,864 ± 8874	$11,996 ± 11,036	$12,690 ± 10,917	$21,332 ± 19,877	<0.001
			Children (age 5–12 yrs)			
No. of patient admissions	733	520	535	430	70	—
Race						
White	305 (64)	273 (71)	301 (67)	256 (66)	30 (45)	0.071
Hispanic	87 (18)	62 (16)	81 (18)	62 (16)	20 (29)	
African American	51 (11)	17 (5)	38 (8)	34 (9)	9 (14)	
Asian/Pacific Islander	12 (3)	<10 (1)	<10 (1)	14 (4)	<10 (2)	
Native American	<10 (1)	<10 (1)	<10 (1)	<10 (2)	<10 (4)	
Other	21 (4)	24 (6)	23 (5)	16 (4)	<10 (6)	
Weekend admission						
Yes	265 (36)	186 (36)	189 (35)	130 (30)	19 (27)	0.349
No	468 (64)	334 (64)	346 (65)	300 (70)	51 (73)	
No. of diagnoses	2 ± 2	3 ± 2	2 ± 1	3 ± 2	4 ± 3	<0.001
No. of procedures	1 ± 1	0 ± 0	0 ± 0	0 ± 0	1 ± 1	<0.001
Evidence of child abuse						
Yes	<10 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.658
No	731 (100)	520 (100)	535 (100)	430 (100)	70 (100)	

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TABLE 3. Subgroup analysis of variables that were statistically significant on univariable analysis of the entire cohort, according to age group

Variable	2003	2006	2009	2012	2016	p Value*
Children (age 5–12 yrs)						
Admitting hospital size						
Small	118 (17)	65 (13)	43 (9)	54 (13)	<10 (6)	0.017
Medium	166 (24)	124 (25)	105 (22)	82 (19)	17 (24)	
Large	410 (59)	319 (63)	340 (70)	295 (69)	49 (70)	
Hospital location & teaching status						
Urban teaching	532 (77)	408 (80)	398 (82)	365 (85)	66 (94)	0.077
Urban nonteaching	125 (18)	78 (15)	68 (14)	53 (12)	<10 (6)	
Rural	38 (6)	23 (4)	22 (5)	12 (3)	0 (0)	
Hospital region						
South	202 (28)	152 (29)	157 (29)	142 (33)	24 (34)	0.689
West	226 (31)	160 (31)	156 (29)	134 (31)	19 (28)	
Midwest	190 (26)	134 (26)	127 (24)	94 (22)	11 (15)	
Northeast	116 (16)	74 (14)	96 (18)	60 (14)	16 (23)	
Median household income quartile						
1 (lowest income)	126 (18)	115 (23)	122 (23)	105 (25)	27 (41)	0.027
2	202 (28)	116 (23)	130 (25)	111 (27)	17 (25)	
3	211 (30)	122 (25)	143 (27)	116 (28)	11 (16)	
4 (highest income)	174 (24)	142 (29)	129 (25)	86 (21)	12 (18)	
LOS, days	2 ± 2	2 ± 1	1 ± 2	1 ± 1	2 ± 1	0.003
Total hospital charges, USD	$12,850 ± 12,108	$12,876 ± 9748	$12,090 ± 11,103	$15,595 ± 13,585	$21,437 ± 16,841	<0.001
Adolescents (age 12–18 yrs)						
No. of patient admissions	765	554	514	366	35	—
Race						
White	364 (68)	307 (72)	302 (69)	228 (68)	15 (48)	0.437
Hispanic	79 (15)	57 (13)	63 (14)	50 (15)	<10 (26)	
African American	60 (11)	31 (7)	46 (11)	27 (8)	<10 (13)	
Asian/Pacific Islander	<10 (1)	<10 (2)	<10 (1)	11 (3)	0 (0)	
Native American	<10 (2)	<10 (1)	<10 (1)	0 (0)	<10 (4)	
Other	22 (4)	23 (5)	15 (3)	20 (6)	<10 (10)	
Weekend admission						
Yes	275 (36)	193 (35)	197 (38)	134 (37)	15 (42)	0.864
No	490 (64)	361 (65)	317 (62)	232 (63)	20 (58)	
No. of diagnoses	3 ± 2	3 ± 2	3 ± 2	3 ± 2	5 ± 4	0.022
No. of procedures	1 ± 1	0 ± 0	0 ± 0	0 ± 0	1 ± 2	<0.001
Evidence of child abuse						
Yes	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	—
No	765 (100)	554 (100)	514 (100)	366 (100)	35 (100)	
Admitting hospital size						
Small	114 (15)	74 (13)	29 (6)	29 (8)	<10 (4)	<0.001
Medium	172 (23)	126 (23)	82 (17)	80 (22)	<10 (26)	
Large	459 (62)	349 (64)	359 (77)	257 (70)	25 (70)	
Hospital location & teaching status						
Urban teaching	500 (67)	381 (70)	324 (69)	290 (79)	32 (92)	<0.001
Urban nonteaching	162 (22)	134 (24)	125 (27)	58 (16)	<10 (8)	
Rural	83 (11)	33 (6)	20 (4)	18 (5)	0 (0)	

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TABLE 3. Subgroup analysis of variables that were statistically significant on univariable analysis of the entire cohort, according to age group

Variable	2003	2006	2009	2012	2016	p Value*
Adolescents (age 12–18 yrs)						
Hospital region						
South	139 (30)	136 (25)	135 (27)	92 (26)	<10 (16)	0.555
West	128 (28)	135 (25)	141 (28)	102 (29)	11 (32)	
Midwest	127 (27)	148 (27)	109 (21)	85 (24)	<10 (20)	
Northeast	69 (15)	126 (23)	123 (24)	79 (22)	11 (33)	
Median household income quartile						
1 (lowest income)	166 (22)	126 (23)	123 (24)	79 (22)	11 (33)	0.843
2	166 (22)	148 (27)	109 (21)	85 (24)	<10 (20)	
3	201 (27)	136 (25)	135 (27)	92 (26)	<10 (16)	
4 (highest income)	212 (29)	135 (25)	141 (28)	102 (29)	11 (32)	
LOS, days	2 ± 2	2 ± 1	2 ± 1	2 ± 1	3 ± 6	0.002
Total hospital charges, USD	$14,054 ± 11,346	$13,347 ± 11,416	$16,362 ± 12,805	$19,830 ± 18,581	$38,813 ± 37,641	<0.001

Values are shown as number, number (percentage), or mean ± SD. Boldface type indicates statistical significance ($p < 0.05$).
* The Kruskal-Wallis test was used to analyze nonnormally distributed data; 1-way ANOVA was used to analyze normally distributed data.

outpatient clinics.[32] Research that correctly identifies the small subset of patients with isolated linear skull fracture who warrant admission and emergent neurosurgical evaluation will be critical to reducing costs and improving care.

Study Limitations

Although this study provides a national perspective about admissions for pediatric isolated linear skull fracture over time, it has several limitations. First, KID is a large de-identified data repository whose accuracy is contingent on the codes and data provided by the participating institutions. Granular data, such as bony fracture location and mechanism of injury, were not available for analysis. National generalizability is limited by these missing data, the participation of only 46 states, and the use of data-driven conversion factors to translate sample-level data into population-level data. Second, the lack of rigorous validation of the coding algorithms impacted data quality and subsequently the study design. A small subgroup of patients with codes for basilar skull fracture without intracranial injury were included, but strict criteria were applied to exclude patients with multiorgan system trauma and facial fracture and to try to identify those who may have had incorrect codes. Patients with true complex basilar skull fracture typically have severe mechanisms of injury and unique injury patterns, and we did not intend to assess these patients in this study.[33,34] Undercoding was also a likely driver of the nonzero surgical and mortality data in 2003. Third, KID does not have available follow-up data, which limits longitudinal assessment about ED revisit or delayed surgical intervention. Lastly, there were no corresponding ED discharge data to complement the admissions data assessed in this study. This study would be stronger if ED discharge data were available, which would allow comparison between these two populations and a complete multivariable analysis. Although these limitations are apparent, the results of this study emphasize the reassuring clinical status of children diagnosed with isolated linear skull fracture in the US since 2006 and can be used to support future research to correctly identify children who warrant admission.

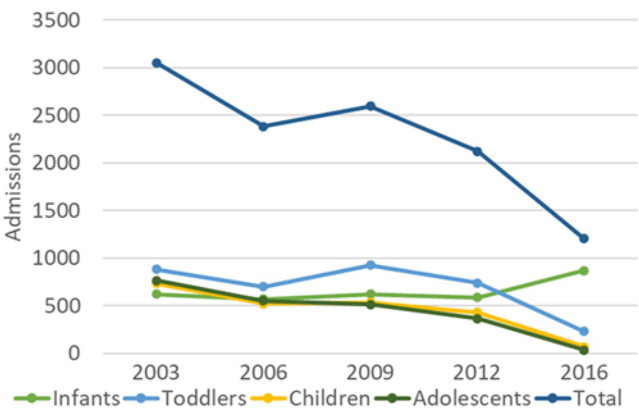

FIG. 4. Subgroup analysis of admissions according to age group. Admissions decreased in all age groups between 2003 and 2016. Notably, admissions of infants increased between 2012 and 2016, while admissions of other age subgroups continued to decline. Figure is available in color online only.

Conclusions

Between 2003 and 2016, there has been decrease in hospital admissions for pediatric isolated linear skull fracture across the US. Furthermore, there has been a decrease in hospital LOS and increase in mean total hospital charges associated with admission. Admissions were more common on weekdays than weekends and shifted from smaller rural hospitals to larger urban teaching centers. No child died or underwent a neurosurgical procedure during their initial inpatient admission in the US in 2006, 2009, 2012, or 2016. Neurosurgery has an evolving role in the care of these patients, and this study provides a platform for future discussions about indications for admission.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Reynolds, Tang, Bonfield, Shannon. Acquisition of data: Reynolds, Tang, Dallas, Shannon. Analysis and interpretation of data: Reynolds, Tang. Drafting the article: Reynolds, Tang. Critically revising the article: Reynolds, Tang, Dallas, Vance, Bonfield, Shannon. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Reynolds. Statistical analysis: Chen. Study supervision: Bonfield, Shannon.

Supplemental Information

Previous Presentations

The content of this paper was presented previously at the 48th Annual Meeting of the American Association of Neurological Surgeons/Congress of Neurological Surgeons Section on Pediatric Neurosurgery, Scottsdale, Arizona, December 5–8, 2019.

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