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ORIGINAL ARTICLE

Variation in Pediatric Traumatic Brain Injury Outcomes in the United States

Nathaniel H. Greene, MD,[a,b] Mary A. Kernic, PhD, MPH,[b,c] Monica S. Vavilala, MD,[a,b,d] Frederick P. Rivara, MD, MPH[b,c,d]

From the [a]Department of Anesthesiology and Pain Medicine, School of Medicine, University of Washington, Seattle, WA; [b]Harborview Injury Prevention and Research Center, University of Washington, Seattle, WA; [c]Department of Epidemiology, School of Public Health, University of Washington, Seattle, WA; and [d]Department of Pediatrics, School of Medicine, University of Washington, Seattle, WA.
Current affiliation for Greene, Duke University School of Medicine, Durham, NC.

Abstract

Objective: To ascertain the degree of variation, by state of hospitalization, in outcomes associated with traumatic brain injury (TBI) in a pediatric population.

Design: A retrospective cohort study of pediatric patients admitted to a hospital with a TBI.

Setting: Hospitals from states in the United States that voluntarily participate in the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project.

Participants: Pediatric (age ≤19y) patients hospitalized for TBI (N=71,476) in the United States during 2001, 2004, 2007, and 2010.

Interventions: None.

Main Outcome Measures: Primary outcome was proportion of patients discharged to rehabilitation after an acute care hospitalization among alive discharges. The secondary outcome was inpatient mortality.

Results: The relative risk of discharge to inpatient rehabilitation varied by as much as 3-fold among the states, and the relative risk of inpatient mortality varied by as much as nearly 2-fold. In the United States, approximately 1981 patients could be discharged to inpatient rehabilitation care if the observed variation in outcomes was eliminated.

Conclusions: There was significant variation between states in both rehabilitation discharge and inpatient mortality after adjusting for variables known to affect each outcome. Future efforts should be focused on identifying the cause of this state-to-state variation, its relationship to patient outcome, and standardizing treatment across the United States.

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Traumatic brain injury (TBI) is the leading cause of injury-related death and disability in children and young adults in the United States and worldwide.[1] The medical literature has consistently reported significant and persistent deficits in cognition, language, and motor function among children who sustain moderate to severe TBIs.[2] While most children with TBI who are seen in the emergency department have mild TBI, the majority of those admitted as inpatients have moderate to severe injuries.[2] Various factors have been identified, such as insurance status, race, and sex, that influence admission rates for pediatric patients who are seen in the emergency department with TBI.[2] These factors may also influence discharge disposition, which may in turn affect long-term outcomes associated with pediatric TBI.

After initial stabilization and acute management of a TBI, utilization of rehabilitation care can result in more favorable long-term outcomes.[3] Optimal long-term outcomes could be hindered if children with TBI do not receive rehabilitation, either because of a lack of access or because of a lack of recognition of need by clinicians. A recent survey[4] of health care utilization demonstrated that 83% of pediatric patients hospitalized with TBI demonstrated a need for further care after discharge. Since pediatric TBI is a complex condition with a high amount of need, the approach to this need can be highly variable. Several recent studies suggest regional

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variation in practice patterns in the management of diseases such as splenic injury,[5] intussusception,[6] and urinary lithiasis.[7]

We therefore hypothesized that there would be significant state-to-state variation in discharge disposition and associated outcomes in pediatric patients hospitalized with TBI in the United States.

Methods

Overview of study design

This retrospective cohort study was conducted to examine differences in outcomes of pediatric patients with TBI by the state in which care was received. The Healthcare Cost and Utilization Project State Inpatient Database (SID) was used to identify all pediatric TBI hospitalizations in reporting states and subsequent outcomes. Discharge to inpatient rehabilitation among inpatients who were discharged alive served as the primary outcome of interest. A secondary outcome was inpatient mortality. State-specific relative risk estimates were generated using multivariable models to best describe the effect each state had on both our primary and secondary outcomes. These relative risk estimates were then used to quantify absolute risk differences for the rehabilitation outcome to estimate the actual number of patients affected in each state. This study was focused not on ascertaining why the observed differences between states exist, but rather looking for significant variation between states. Human subjects' approval was not required for analysis of these publically available datasets without identifiable information.

Data sources

The SID is a set of hospital databases from data organizations in participating states and contains the universe of the state inpatient discharge abstracts translated into a uniform format to facilitate multistate comparisons and analyses. The SID contains a core set of clinical and nonclinical information on all patients, regardless of payer, including persons covered by Medicare, Medicaid, private insurance, and the uninsured. A subset of the SID was used for this analysis: 13 states from 2001 (Colorado, Florida, Iowa, Maine, Maryland, Massachusetts, New Jersey, New York, North Carolina, Oregon, Utah, Washington, West Virginia), 18 states from 2004 (Arizona, Colorado, Florida, Iowa, Kentucky, Maryland, Massachusetts, Nevada, New Jersey, New York, North Carolina, Oregon, Rhode Island, Utah, Vermont, Washington, West Virginia, Wisconsin), 16 states from 2007 (Arkansas, Arizona, California, Colorado, Florida, Iowa, Kentucky, Maryland, Nevada, New Jersey, North Carolina, Oregon, Utah, Vermont, Washington, West Virginia), and 19 states from 2010 (Arkansas, Arizona, California, Colorado, Florida, Iowa, Kentucky, Maryland, Mississippi, North Carolina, New Jersey, Nevada, New York, Oregon, Utah, Vermont, Washington, Wisconsin, West Virginia). These states were chosen because of the availability of data to the investigators. Of note, this database treats rehabilitation units of the same hospital building as different hospitals and thus even captures discharge to a rehabilitation unit within the same hospital.

List of abbreviations:

CDC **Centers for Disease Control and Prevention**
ICD-9 ***International Classification of Diseases, Ninth Revision***
SID **State Inpatient Database**
TBI **traumatic brain injury**

Sampling methods

We identified all pediatric patients (age ≤19y) hospitalized with TBI (modified Centers for Disease Control and Prevention [CDC] definition of TBI using *International Classification of Diseases, Ninth Revision* [ICD-9] diagnosis codes: 800.0–801.9, 800.00–801.99, 803.0–804.9, 803.00–804.99, 850.0–854.1, and 850.00–854.19; excluded 950.1–950.3, 995.55, and 959.01) in participating states during the selected years. The CDC definition was made more restrictive by the investigators to ensure that patients included had a legitimate TBI (eg, 959.01 could refer to a simple scalp laceration). All available discharge codes were sorted into 7 mutually exclusive discharge groups: home, skilled nursing facility, inpatient rehabilitation, transfer to another acute care hospital, psychiatric hospital, hospice, and death. We excluded patients with a discharge disposition indicating "transfer to another acute care hospital" to avoid double counting. Patients discharged to hospice were counted with deaths. Of note, patients discharged home with outpatient rehabilitation were not distinguishable from those discharged home in the dataset and thus were counted as being discharged to home. Four states did not provide data on discharge to rehabilitation; California did not have such a code in their dataset, and Maine, Rhode Island, and Vermont had such a code, but it either never appeared in their data or appeared for only 1 patient. We excluded patients for whom any of the following variables were missing: age (18 patients) and insurance status (241 patients). All other variables were fully observed.

Independent variables of interest

In addition to our main independent variable of interest (state), we were also interested in the independent contributions of age (0–4y, 5–9y, 10–14y, 15–19y), insurance status (government, private, uninsured), and severity of TBI stratified by Abbreviated Injury Scale score (minor, moderate, serious, severe, critical, unsurvivable).[4,8-11] Severity of TBI was categorized using the ICD Programs for Injury Categorization implemented with Stata statistical software[a] that extracts Abbreviated Injury Scale scores from ICD-9-Clinical Modification codes.[5,12,13]

Multivariable regression analyses

The 2 outcomes of interest, discharge to inpatient rehabilitation (out of total live discharges) and discharge mortality rates (out of all discharges), were examined in multiple regression analyses. Independent variables were treated as categorical variables and included state of hospitalization, insurance status, age, and TBI severity. Multivariable Poisson regression with robust SE estimates and clustering by hospital was used for both outcomes, given the nonrare occurrence of our outcomes of interest. Although Poisson regression is typically used for count outcomes, robust Poisson regression is an alternative to logistic regression for nonrare outcomes (>10%) overall[14] or among subgroups of interest.[15] States with the highest number of patients were selected as referent states to optimize SE calculations. "Risk" estimates are statistical terms that refer to (1) the chance of being discharged to rehabilitation and (2) the chance of dying after hospitalization. Risk does not carry a value (positive or negative) connotation. Note that California, Rhode Island, Maine, and Vermont were excluded from the rehabilitation regression because of the lack of a relevant code in the California data, and either 0 or only 1 documented discharge to inpatient rehabilitation in the other 3

states. Additionally, separate models were compared for both outcomes, 1 using and 1 omitting the "state of hospitalization" variable, using a likelihood ratio test to formally evaluate the contribution of the variable to each respective model. Effect modification between state and insurance status in both models was assessed by examining the significance of interaction terms when added to each outcome model. All analyses were performed using Stata Intercooled 12.[a]

Determination of population impact of rehabilitation variation by state and national estimate

Since state-specific relative risks were calculated using Florida as the referent state for inpatient rehabilitation, the inverse of relative risk estimates for inpatient rehabilitation was taken to reflect the risk of not being discharged to rehabilitation. These estimates were then multiplied by the number of children observed to be discharged to inpatient rehabilitation, and the number of children in excess of the observed number was reported as excess children who could have been discharged to rehabilitation. A final national estimate was made using similar methods to estimate the number of children who would be sent to rehabilitation if all other 49 states performed as well as the referent state.

Results

Patient characteristics

There were 71,476 pediatric patients hospitalized with a TBI in the states and years examined (table 1). In general, patients were boys (67.5%), most commonly 15 to 19 years of age (44.4%), had moderate TBI (38.1%), had private insurance (57.6%), and were sent directly home from the hospital (90.7%).

Unadjusted outcomes

For the entire cohort, there were significant differences by state in the proportion of discharges to inpatient rehabilitation among live patients and in inpatient mortality (table 2). When states with no reported rehabilitation discharges were excluded, the proportion of discharges to inpatient rehabilitation varied from 2.3% in New York to 10.5% in Kentucky. Likewise, inpatient mortality varied from 2.2% in New Jersey to 6.0% in Arkansas. The proportion of discharges to inpatient rehabilitation varied by insurance status, from 1.5% in uninsured patients to 4.4% in private insurance patients. Inpatient mortality also varied by insurance status, from 5.2% in uninsured patients to 3.3% in private insurance patients. Discharge to inpatient rehabilitation varied by age group, from 1.3% in the 0- to 4-year group to 6.3% in the 15- to 19-year group. Inpatient mortality rate also varied by age group, from 2.4% in the 5- to 9-year group to 4.6% in the 15- to 19-year group.

Multivariable Poisson regression: relative risk of inpatient rehabilitation discharge and mortality

The multivariable Poisson regression examining discharge to rehabilitation showed a pediatric patient in Kentucky was approximately 3.6 times more likely to receive inpatient rehabilitation after a hospitalization with TBI than an otherwise similar patient in Florida (fig 1; see table 2). Additionally, a pediatric patient without insurance was .32 times as likely to be discharged to inpatient rehabilitation as one with government-based insurance (eg, Medicaid), and adolescents aged 15 to 19 years were 5.3 times more likely to get rehabilitation care than an otherwise similar patient aged 0 to 4 years. Testing the significance of the categorical state variable using the likelihood ratio test led to a chi-square statistic of 391.36, which corresponds to a P value of $<.001$ assuming 17 degrees of freedom.

The multivariable Poisson regression examining inpatient mortality showed pediatric patients with TBI in Florida, North Carolina, and Vermont were more than 33% more likely to die during a hospitalization than an otherwise similar patient in California (fig 2; see table 2). These were also the only states to reach statistical significance when comparing states with California. Additionally, a pediatric patient without insurance was approximately 45% more likely to die in the hospital than an otherwise similar patient with private insurance. Testing the significance of the categorical state variable using the likelihood ratio test led to a chi-square statistic of 50.70, which corresponds to a P value of $<.001$ assuming 21 degrees of freedom.

To examine the presence of effect modification between state and insurance status on study outcomes, we excluded states in which any of the insurance types yielded a zero cell. For these exploratory analyses, we excluded 4 states from the rehabilitation model (Iowa, Mississippi, Nevada, Oregon) and 0 states from the mortality model when testing for the presence of effect modification. Tests for effect modification in these subgroups yielded a P value of $<.001$ for both the rehabilitation and mortality models. Two states (Colorado, Utah) were most likely responsible for the presence of effect modification in the rehabilitation model, since there was no adjusted difference in patients without insurance

Table 1 Characteristics of children aged 0 to 19 years hospitalized with TBI in select states of the U.S., years 2001, 2004, 2007, and 2010 (N=71,476)

Characteristic	Number	%
Female	23,237	32.5
Age group (y)		
0–4	17,959	25.1
5–9	8718	12.2
10–14	13,076	18.3
15–19	31,723	44.4
Severity of TBI		
Minor	7044	9.9
Moderate	27,226	38.1
Serious	24,905	34.8
Severe	11,150	15.6
Critical	1121	1.6
Unsurvivable	30	0.04
Insurance		
Government	24,511	34.3
Private	41,197	57.6
Uninsured	5768	8.1
Disposition		
Home	64,799	90.7
SNF	1324	1.9
Inpatient rehabilitation	2658	3.7
Psychiatric	72	0.1
Hospice	18	0.03
Died	2605	3.6

Abbreviations: SNF, skilled nursing facility; U.S., United States.

Table 2 Adjusted outcomes of pediatric patients with TBI hospitalized in the U.S. in select states in 2001, 2004, 2007, and 2010

		Rehabilitation*			Mortality		
State	N	Crude %	RR	95% CI	Crude %	RR	95% CI
Arkansas	668	5.4	1.92	0.68–5.37	6.0	1.47	0.94–2.31
Arizona	5092	5.2	2.19	1.31–3.66	2.8	0.94	0.74–1.20
California†	9948	ND	ND	ND	3.2	Referent	Referent
Colorado	3424	3.8	1.35	0.77–2.38	4.2	1.06	0.85–1.33
Florida	10,693	2.5	Referent	Referent	4.8	1.34	1.10–1.64
Iowa	1599	4.9	1.82	1.07–3.10	4.1	1.35	0.91–2.01
Kentucky	1711	10.5	3.59	2.01–6.43	4.6	1.21	0.85–1.72
Massachusetts	2398	6.0	2.35	1.33–4.16	3.4	1.09	0.82–1.46
Maryland	3843	6.9	2.50	1.51–4.15	3.5	1.21	0.93–1.56
Maine†	177	0.0	ND	ND	5.7	1.17	0.55–2.50
Mississippi	235	6.0	2.19	0.87–5.50	4.1	1.40	0.93–2.10
Nevada	1399	5.9	2.16	1.31–3.56	4.2	1.03	0.63–1.68
New Jersey	5688	4.0	2.04	1.26–3.31	2.2	0.99	0.78–1.24
New York	9087	2.3	1.12	0.74–1.71	2.4	0.98	0.76–1.26
North Carolina	4137	9.3	3.07	2.07–4.56	5.8	1.35	1.11–1.65
Oregon	2461	3.8	1.44	0.99–2.10	3.5	1.04	0.87–1.24
Rhode Island†	165	0.0	ND	ND	6.7	1.19	0.93–1.52
Utah	2579	3.6	1.44	0.71–2.93	3.5	1.16	0.92–1.46
Vermont†	167	0.6	ND	ND	5.4	1.40	1.05–1.87
Washington	2943	5.1	1.76	1.13–2.75	4.2	1.16	0.91–1.46
Wisconsin	1479	6.4	2.26	1.21–4.21	3.2	0.91	0.72–1.15
West Virginia	1573	3.5	1.33	0.85–2.09	4.5	1.33	0.95–1.87
Severity of TBI							
Minor	7044	0.8	Referent	Referent	0.1	Referent	Referent
Moderate	27,226	1.3	1.68	1.21–2.35	0.3	3.21	1.42–7.26
Serious	24,905	6.0	7.54	5.49–10.35	4.6	51.83	23.37–114.95
Severe	11,150	6.7	9.18	6.64–12.71	5.8	65.28	29.43–144.81
Critical/unsurvivable	1151	26.7	26.90	18.77–38.56	66.5	695.37	314.4–1537.97
Type of Insurance							
Government	24,511	3.5	Referent	Referent	3.9	Referent	Referent
Private	41,197	4.4	1.01	0.91–1.11	3.3	0.91	0.84–0.99
Uninsured	5768	1.5	0.32	0.24–0.44	5.2	1.32	1.16–1.50
Age Group (y)							
0–4	17,959	1.3	Referent	Referent	3.5	Referent	Referent
5–9	8718	1.9	1.50	1.28–1.75	2.4	0.80	0.69–0.93
10–14	13,076	2.9	2.48	2.11–2.92	2.4	0.83	0.73–0.94
15–19	31,723	6.3	5.29	4.10–6.82	4.6	1.25	1.13–1.37

Abbreviations: CI, confidence interval; ND, no data; RR, relative risk; U.S., United States.

* Rehabilitation % uses only alive patients for denominator.

† California had no possible code for discharge to rehabilitation; Maine, Rhode Island, and Vermont had possible codes for discharge to rehabilitation, but 0 entries or 1 entry.

(Utah), or there was a difference in the opposite direction (Colorado). The rest of the states that were examined exhibited similar patterns to the overall regression value in the rehabilitation model (fig 3). There seemed to be variable interactions between insurance status and mortality within each state (fig 4).

State and national estimates of population impact

Table 3 presents the additional number of children with TBI in each state who would potentially be sent to inpatient rehabilitation annually if states performed at the same adjusted rate as North Carolina, the state with the highest adjusted proportion of patients discharged to inpatient rehabilitation.

Since our population sample did not cover all 50 states, we extrapolated our results to estimate the number of children who would potentially be sent to inpatient rehabilitation after a TBI hospitalization based on weighting our population to the population in the United States. This yielded an estimate of 1981 additional children who would potentially be sent to rehabilitation in the United States annually.

Discussion

There was significant regional variation in both rehabilitation hospitalization and inpatient mortality of pediatric patients hospitalized for TBI. This variation was only partially attenuated after adjusting for other factors known to affect these outcomes. These differences translate to a substantial number of children with TBI who could potentially receive rehabilitation care annually in the United States.

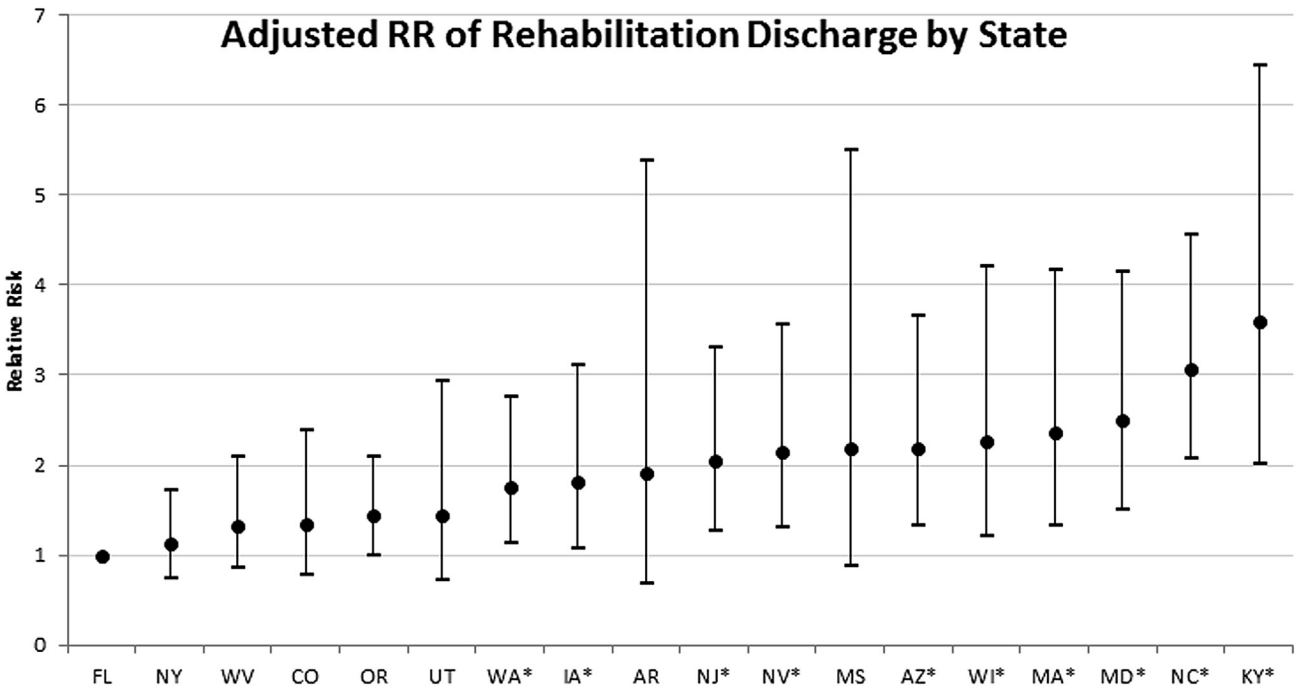

Fig 1 Adjusted relative risk of rehabilitation discharge by state. Multivariate Poisson regression estimates with robust 95% confidence interval estimates. *$P<.05$. Abbreviations: AR, Arkansas; AZ, Arizona; CO, Colorado; FL, Florida; IA, Iowa; KY, Kentucky; MA, Massachusetts; MD, Maryland; MS, Mississippi; NC, North Carolina; NJ, New Jersey; NV, Nevada; NY, New York; OR, Oregon; RR, relative risk; UT, Utah; WA, Washington; WI, Wisconsin; WV, West Virginia.

Our study is the first to demonstrate significant variation in pediatric TBI outcomes by state and one of the largest studies to examine TBI outcomes by age, insurance status, and severity of TBI. This study also helps to confirm what has been observed in previous studies: that there are significant variations in outcomes of patients by insurance status. While it may make intuitive sense that uninsured patients would be less likely (68%) to receive rehabilitation care after a hospitalization, there was also

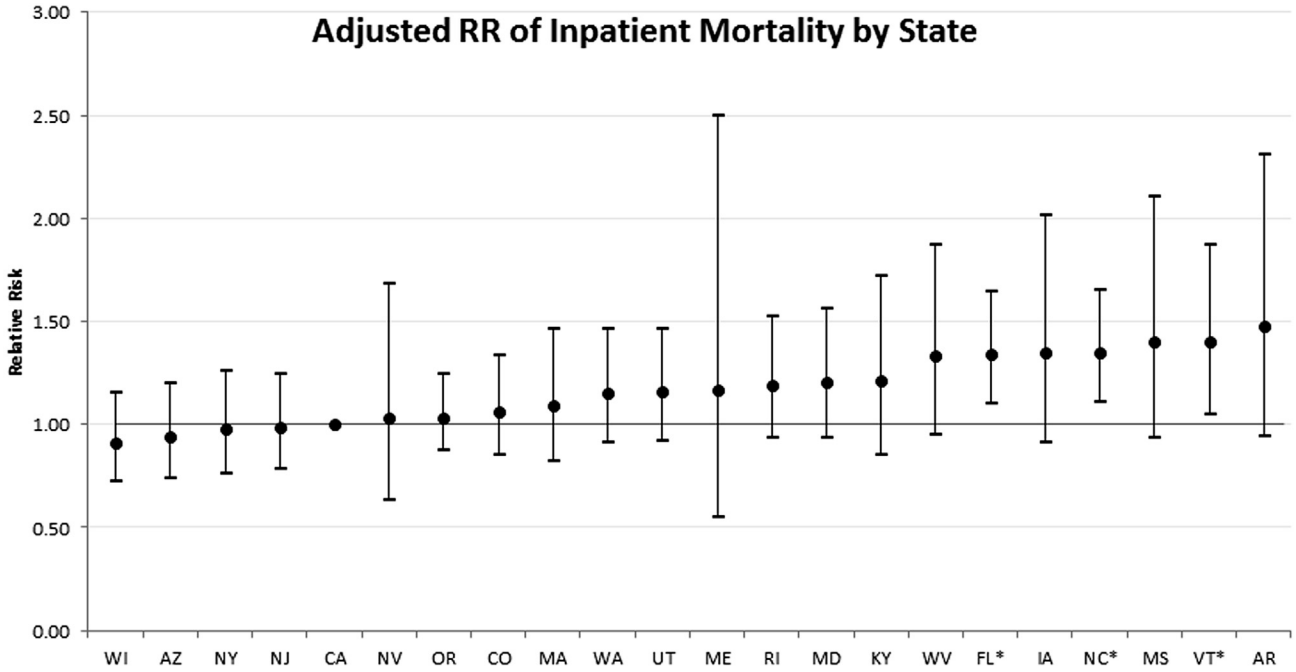

Fig 2 Adjusted relative risk of inpatient mortality by state. Multivariate Poisson regression estimates with robust 95% confidence interval estimates. *$P<.05$. Abbreviations: AR, Arkansas; AZ, Arizona; CA, California; CO, Colorado; FL, Florida; IA, Iowa; KY, Kentucky; MA, Massachusetts; MD, Maryland; ME, Maine; MS, Mississippi; NC, North Carolina; NJ, New Jersey; NV, Nevada; NY, New York; OR, Oregon; RI, Rhode Island; RR, relative risk; UT, Utah; VT, Vermont; WA, Washington; WI, Wisconsin; WV, West Virginia.

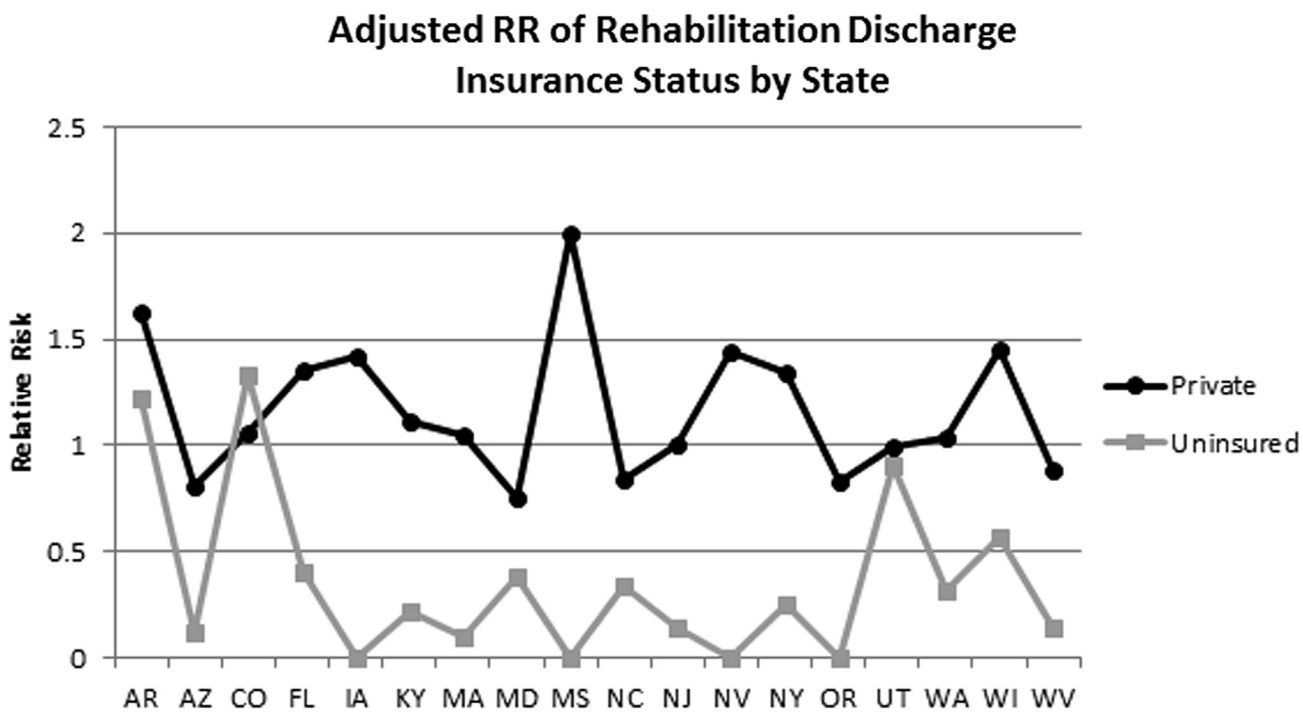

Fig 3 Adjusted relative risk estimates for rehabilitation multivariable regression model when assessing for the presence of effect modification between insurance status and state. Government insurance is referent value; black line, private insurance; gray line, uninsured. Abbreviations: AR, Arkansas; AZ, Arizona; CO, Colorado; FL, Florida; IA, Iowa; KY, Kentucky; MA, Massachusetts; MD, Maryland; MS, Mississippi; NC, North Carolina; NJ, New Jersey; NV, Nevada; NY, New York; OR, Oregon; RR, relative risk; UT, Utah; WA, Washington; WI, Wisconsin; WV, West Virginia.

substantially higher mortality (45%) in uninsured patients than in private insurance patients. While this result may be subject to residual confounding or a reflection of the role socioeconomic status has on child health, the magnitude of the effect nevertheless suggests there still may be other potential causes of this difference that occur after admission to the hospital.

Particularly interesting estimates were yielded in the calculation of the impact on populations by state for rehabilitation. A significant

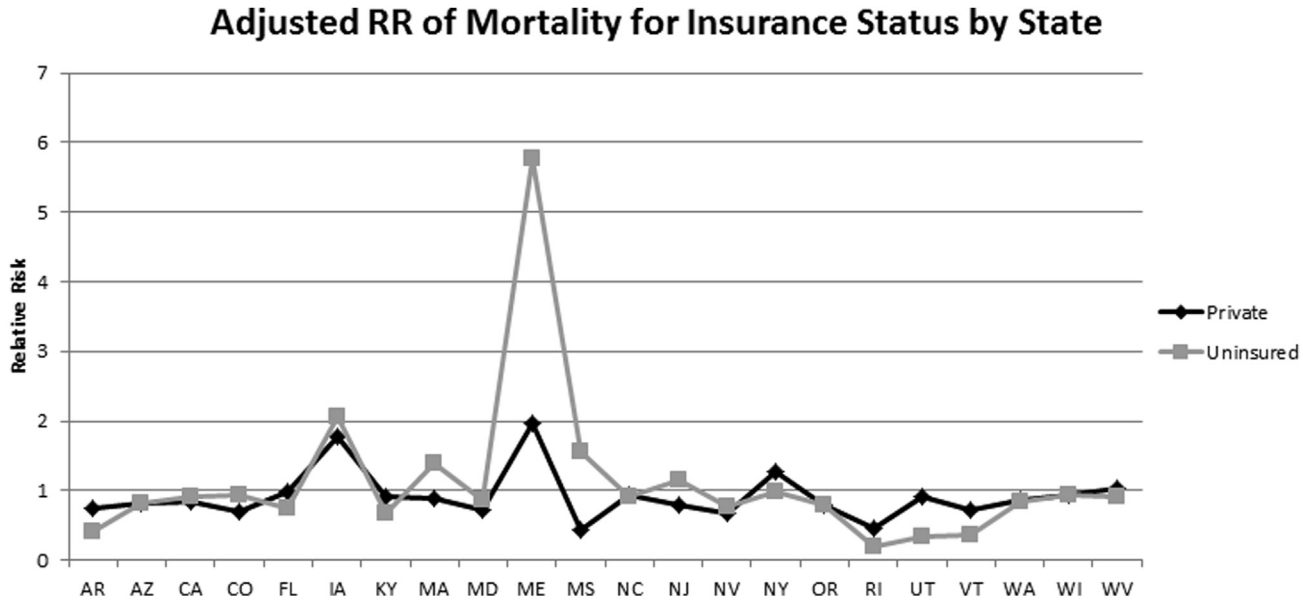

Fig 4 Adjusted relative risk estimates for mortality multivariable regression model when assessing for the presence of effect modification between insurance status and state. Government insurance is referent value; black line, private insurance; gray line, uninsured. Abbreviations: AR, Arkansas; AZ, Arizona; CA, California; CO, Colorado; FL, Florida; IA, Iowa; KY, Kentucky; MA, Massachusetts; MD, Maryland; ME, Maine; MS, Mississippi; NC, North Carolina; NJ, New Jersey; NV, Nevada; NY, New York; OR, Oregon; RI, Rhode Island; RR, relative risk; UT, Utah; VT, Vermont; WA, Washington; WI, Wisconsin; WV, West Virginia.

Table 3 Estimated absolute risk projections if states performed at highest observed level

State	Annual Patients With TBI (N)	Risk of No Rehabilitation Discharge (North Carolina)*	Number of Children to Rehabilitation Annually	Additional Children to Rehabilitation Annually
Arkansas	334	1.87	17	15
Arizona	1697	1.64	86	55
California†	4974	ND	ND	ND
Colorado	856	2.65	31	51
Florida	2673	3.59	64	165
Iowa	400	1.97	19	18
Kentucky	570	1.00	57	0
Massachusetts	799	1.53	46	24
Maryland	961	1.44	64	28
Maine†	177	ND	ND	ND
Mississippi	245	1.64	14	9
Nevada	466	1.67	26	18
New Jersey	1422	1.76	55	42
New York	3029	3.20	68	150
North Carolina	1034	Referent	91	Referent
Oregon	615	2.50	23	34
Rhode Island†	165	ND	ND	ND
Utah	645	2.49	22	33
Vermont†	56	ND	ND	ND
Washington	736	2.04	36	37
Wisconsin	740	1.59	46	27
West Virginia	393	2.70	13	22
Total	22,988			728
National estimate‡	45,757			1981

Abbreviation: ND, no data.

* Transformed from original regression.

† No rehabilitation data available or no rehabilitation discharges.

‡ United States estimate extrapolated data to entire United States population.

number of patients every year are affected by this variation, which we have shown is not just due to chance. While at first glance it may seem that particular states are not providing rehabilitation care to this patient population, it should be noted that this study is not capturing outpatient rehabilitation in any way. Thus, the observed variations in practice may be the mode of rehabilitation care. A similar calculation was not made with the variations observed in mortality because the reasons are not yet clear why these variations in mortality exist, and is a matter of further investigation.

Study limitations

The limitations of our study should be considered when interpreting these results. The sample of states analyzed represents approximately half the United States population of children aged 0 to 19 years, thus potentially limiting generalizability. Four states in the analysis (California, Maine, Rhode Island, Vermont) did not provide sufficient data on rehabilitation discharges. We did not have information on treatment variation, nor could we address issues of access bias, since the availability of emergency care may have an effect on out-of-hospital death, thereby affecting the overall injury severity of patients who are seen at the emergency department. There may also be variation between states on practices for location of declaration of death (eg, at the scene of an accident or after transport to an emergency department). While location of declaration of death is technically available via the CDC Wide-Ranging Online Data for Epidemiologic Research database, much of this information is missing. Lastly, while we did not adjust for the severity of other injuries, we assumed that the severity of nonhead injuries is similar between states and thus an unlikely source of bias.

Conclusions

Future work should be done to examine differences in health policy that may exist between states and what can be done at a higher level to decrease these variations in outcome by state. States at both ends of the spectrum should be analyzed closely to identify different types and functioning of trauma care systems, as there are many steps in the care of each pediatric patient with TBI from when the initial injury occurs to being discharged from the hospital. Of note, the points in care examined with this analysis start with admission to a hospital and end with discharge from the acute care hospital. Strong evidence-based guidelines are needed to guide treatment of pediatric TBI, and these guidelines then need to be implemented uniformly in every state, to best treat these patients in the future.

Supplier

a. StataCorp LP, 4905 Lakeway Dr, College Station, TX 77845.

Keywords

Healthcare disparities; Patient outcome assessment; Rehabilitation; Traumatic brain injury

Corresponding Author

Nathaniel H. Greene, MD, Duke University Hospital, DUMC Box 3094, Durham, NC 27710. *E-mail address:* nathaniel.greene@duke.edu.

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