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Medical errors in hospitalized pediatric trauma patients with chronic health conditions

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Abstract

Objective: This study compares medical errors in pediatric trauma patients with and without chronic conditions.

Methods: The 2009 Kids' Inpatient Database, which included 123,303 trauma discharges, was analyzed. Medical errors were identified by International Classification of Diseases, Ninth Revision, Clinical Modification diagnosis codes. The medical error rates per 100 discharges and per 1000 hospital days were calculated and compared between inpatients with and without chronic conditions.

Results: Pediatric trauma patients with chronic conditions experienced a higher medical error rate compared with patients without chronic conditions: 4.04 (95% confidence interval: 3.75–4.33) versus 1.07 (95% confidence interval: 0.98–1.16) per 100 discharges. The rate of medical error differed by type of chronic condition. After controlling for confounding factors, the presence of a chronic condition increased the adjusted odds ratio of medical error by 37% if one chronic condition existed (adjusted odds ratio: 1.37, 95% confidence interval: 1.21–1.5), and 69% if more than one chronic condition existed (adjusted odds ratio: 1.69, 95% confidence interval: 1.48–1.53). In the adjusted model, length of stay had the strongest association with medical error, but the adjusted odds ratio for chronic conditions and medical error remained significantly elevated even when accounting for the length of stay, suggesting that medical complexity has a role in medical error. Higher adjusted odds ratios were seen in other subgroups.

Conclusion: Chronic conditions are associated with significantly higher rate of medical errors in pediatric trauma patients. Future research should evaluate interventions or guidelines for reducing the risk of medical errors in pediatric trauma patients with chronic conditions.

Keywords

Medical errors, pediatric, trauma, chronic conditions, children

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Introduction

A 2000 Institute of Medicine report indicated that medical errors are estimated to result in about between 44,000 and 98,000 preventable deaths and 1000,000 excess injuries each year in US hospitals.[1] Medical errors, though also common in adults, potentially have more serious consequences in children.

Pre-existing chronic conditions increase the complexity of medical care for pediatric patients, and a number of studies indicate that the proportion of children with chronic conditions is increasing.[2–5] A recent study estimates that 43% of US children (32 million) currently have at least 1 of the 20 chronic health conditions assessed; this estimate increases to 54.1% when overweight, obesity, or being at risk for developmental delays are included.[6] It would not be surprising to see increasing numbers of pediatric trauma patients

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with chronic conditions. Traumatic injuries are the leading cause of death among children, and each year nonfatal injuries impact millions of children of all ages.[7]

Our previous study showed that chronic conditions are associated with an increased rate of medical errors among pediatric inpatients, 5.3 per 100 discharges in children with chronic conditions and 1.3 in children without chronic conditions,[8] but the effect of chronic conditions on medical error in pediatric trauma patients has not been reported. Our recent study considered outcomes in hospitalized pediatric trauma patients; we found that compared with pediatric trauma patients without chronic conditions, those with chronic conditions had a longer average stay in the hospital, higher charges, and higher mortality.[9] It is important to examine the association between chronic conditions and medical errors among pediatric trauma patients because this subset of patients may be more likely to experience medical errors given these longer lengths of stay.[8] They may also require more complex care and have worse outcomes compared with pediatric trauma patients without chronic conditions.[9–11]

This study aims to compare the rates of medical error in pediatric trauma patients with and without chronic conditions and to identify potential associated factors for medical errors in these patients. Understanding the relationship between chronic conditions and medical errors in pediatric trauma patients can help determine whether this subset of patients is a special group who might have higher proportions of medical errors.

Methods

Data source

This study used the 2009 Kids' Inpatient Database (KID). Sponsored by the Agency for Healthcare Research and Quality, the KID is a national dataset that is a part of the Healthcare Cost and Utilization Project (HCUP). It examines US children's usage of hospital services, outcomes, and expenditure information. Containing more than 100 clinical and non-clinical variables, the KID is a sample of pediatric discharges from community, non-rehabilitation hospitals in states that have agreed to participate in the HCUP.

At the time this study was performed, the 2009 KID was the most recently available dataset, and the 2009 sample has 3.4 million pediatric discharges from 4121 hospitals in 44 states. Included in the stratification variables are hospital geographic region (Northeast, Midwest, West, and South), hospital control (public, voluntary, and proprietary), hospital location (urban or rural), hospital teaching status (teaching or non-teaching), hospital bed size (small, medium, and large), and hospital type (children hospital, non-children hospital, and children's unit in general hospital). The sample is weighted to produce information about a national estimate of more than 7.3 million discharges.

Study ethical approval

Our study was reviewed by the Institutional Review Board at Nationwide Children's Hospital, and the study was exempted from the need for Institutional Review Board (IRB) approval. The KID datasets exclude data elements that could directly or indirectly identify individuals, hospitals, or states. In our final result tables, any table cell with a sample size less than 10 was suppressed to further protect the privacy of patients.

Definition of pediatric discharges and trauma

The definition of pediatric discharges in the 2009 KID is all discharges of patients 20 years of age or younger at the time of admission. We used the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) principal diagnosis code to determine whether or not the patient was a trauma patient. Using the National Trauma Data Standard Patient Inclusion Criteria, a trauma patient was defined as one who sustained a traumatic injury and had ICD-9-CM diagnosis codes 800–959, excluding late effects injury (905–909), superficial injuries (910–924), and foreign bodies (930–939).[12]

Definition of chronic condition

A chronic condition in KID was defined as a condition that lasts 12 months or longer and meets one or both of the following conditions: (1) the condition limited self-care, independent living, and social interactions or (2) the condition caused individuals to require continuous intervention with medical products, services, and special equipment. The identification of chronic conditions is based on ICD-9-CM diagnosis codes. In addition to the principal diagnosis code, the 2009 KID provides up to 24 secondary ICD-9-CM codes for each patient. For each ICD-9-CM diagnosis code in the KID, a "Chronic Condition Indicator" is provided to categorize the diagnosis as chronic or not chronic. For our trauma patients, we searched all secondary codes to determine whether or not the patient had a chronic condition, and to determine the number of chronic conditions. We excluded 262 discharges with injury/poisoning secondary diagnosis codes categorized as chronic, because we could not determine whether these diagnoses were pre-existing or the reason for the current hospitalization and the result of multiple disabling injuries.

Definition of medical errors

Using the approach of similar studies by Slonim et al.[10] and by Ahuja et al.,[8] medical errors were identified using several specific ICD-9-CM codes for hospital-reported iatrogenic medical errors. Our study included ICD-9-CM codes 996–999 (complications of surgical and medical care) and code 995.2 (unspecified adverse effect of drug medicinal and

Table 1. Types of medical errors in US pediatric trauma patients with and without chronic conditions, KID 2009.

		With chronic conditions				Without chronic conditions			
		No. of medical errors[a]	National estimate	Rate[b]	95% CI	No. of medical errors[a]	National estimate	Rate[b]	95% CI
	All inpatients discharge with medical complications	1667	2436	4.04	(3.75–4.33)	885	1284	1.07	(0.98–1.16)
996	Complications peculiar to certain specified procedures	364	532	0.88	(0.77–1.00)	179	261	0.22	(0.18–0.26)
997	Complications affecting specified body system	806	1173	1.95	(1.75–2.14)	341	495	0.41	(0.36–0.47)
998	Other complications of procedures not elsewhere classified	558	818	1.36	(1.22–1.50)	354	513	0.43	(0.38–0.48)
999	Complications of medical care not elsewhere classified	136	198	0.33	(0.27–0.39)	61	87	0.07	(0.05–0.09)
995.2	Unspecified adverse effect of drug medicinal and biological substance	<10				<10			

KID: Kids' Inpatient Database; CI: confidence interval.
[a]Patients can be represented in more than one of the categories of medical errors.
[b]Rate: number of medical errors per 100 discharges.

biological substance). For each KID discharge, we searched through all 24 secondary diagnosis codes. A discharge with a hospital-reported medical error was defined as any discharge that had at least one of the ICD-9-CM codes mentioned previously.

Determination of injury severity

We used the New Injury Severity Score (NISS) to measure the severity of the initial injuries. The NISS has been shown to be more predictive of outcomes than the Injury Severity Score, particularly for moderate to severe injuries.[13] The NISS uses ICD-9-CM codes to assign a severity score ranging from 1 to 75, with 75 being the most severe. The NISS is computed as a sum of the squares of the three most severe injuries.

Statistical analyses

We used SAS 9.3 (SAS Institute, Cary, NC) to account for the multi-stage sampling of the 2009 KID dataset. The data were weighted and adjusted accordingly to represent all pediatric trauma hospitalizations in the United States based on information provided by the 2009 KID. The following KID variables were included in the analyses: age, gender, race, median household income, patient residence, injury intent, NISS, health insurance status, length of stay (LOS), discharge status, and hospital characteristics (type, location, teaching status, size, and region).

The rates of medical error per 100 pediatric trauma discharges were calculated for patients with and without chronic conditions by type of chronic condition and by patient and hospital stay characteristics. The 95% confidence intervals (95% CIs) for the rates of medical errors were compared between pediatric patients with and without chronic conditions to see whether the difference between the two groups was statistically significant. Odds ratios (ORs) and 95% CIs were calculated by fitting univariate and multivariable logistic regression models with medical error as response variable and the number of chronic conditions, age group, gender, race, income, residence, insurance coverage, injury intent, NISS, LOS, and hospital characteristics as independent variables.

The rates of medical errors per 100 discharges and per 1000 hospital days were plotted against the total number of chronic conditions associated with each discharge record. The rate of medical errors per 1000 hospital days takes into account patients' hospital exposure times.

Results

We included 123,303 pediatric trauma patients from among the 3.41 million discharges in the 2009 KID sample (after excluding 262 cases with injury as the chronic condition). There were 2552 discharges with medical errors in the sample producing a national estimate of 3720 US pediatric trauma patient discharges with medical errors (Table 1). The national estimate of pediatric trauma discharges with medical errors that also had medical conditions is 2436. Overall, pediatric trauma patients with chronic conditions had a significantly higher rate of medical errors than those without chronic conditions, 4.04 per 100 discharges (95% CI: 3.75–4.33) versus 1.07 per 100 discharges (95% CI: 0.98–1.16).

Table 2. Medical errors in US pediatric trauma patients by type of chronic condition, KID 2009.

	National estimate, N of discharges	National estimate medical errors[a]	Rate[b]	95% CI
Without chronic conditions	119,491	1284	1.07	(0.98–1.16)
With chronic conditions	60,307	2436	4.04	(3.75–4.33)
Mental disorders	30,069	954	3.17	(2.87–3.47)
Diseases of the respiratory system	12,672	332	2.62	(2.25–3.00)
Diseases of the nervous system and sensory organs	12,429	753	6.06	(5.46–6.66)
Endocrine, nutritional, metabolic diseases and immunity disorders	7363	690	9.37	(8.26–10.49)
Diseases of the circulatory system	6114	606	9.91	(8.82–11.01)
Diseases of blood and blood-forming organs	4755	517	10.88	(9.62–12.14)
Congenital anomalies	2929	113	3.87	(2.95–4.78)
Diseases of the digestive system	2335	152	6.49	(5.30–7.68)
Diseases of the musculoskeletal system	1909	143	7.48	(5.93–9.02)
Other[c]	4153	475	11.45	(10.05–12.85)

KID: Kids' Inpatient Database; CI: confidence interval.
[a]Patients can be represented in more than one of the categories of chronic conditions.
[b]Rate: number of medical errors per 100 discharges.
[c]Other includes factors influencing health status and contact with health services, diseases of genitourinary system, diseases of the skin, and subcutaneous tissue; symptoms, signs, and ill-defined conditions; neoplasms; infectious and parasitic disease, complications of pregnancy, childbirth, puerperium, and certain conditions originating in the perinatal period; and so on.

Table 2 shows the rates of medical errors by type of chronic conditions. The rate of medical error is highest for chronic conditions grouped in the "Other" category (11.45 per 100 discharges); these conditions each represent <1% of the total reported chronic conditions (data not shown). The next highest medical error rates are seen in the categories of diseases of blood and blood-forming organs (10.88 per 100 discharges), diseases of the circulatory system (9.91 per 100 discharges), and endocrine, nutritional, metabolic diseases, and immunity disorders (9.37 per 100 discharges).

For all of the patient discharge variables shown in Table 3, patients with chronic conditions had higher rates of medical errors compared with their counterparts without chronic conditions.

The number of chronic conditions, age, gender, injury intent, LOS, hospital urban/rural location, and hospital region remained significant variables in the multivariable model (Table 4). The odds of experiencing medical errors also significantly increased with increasing numbers of chronic conditions. The association between medical errors and LOS was the strongest factor even after controlling for confounding variables, with a stay of 15+ days having OR = 67.78 (95% CI: 55.86–82.25).

The rate of medical errors increased with increasing number of chronic conditions in 2009 KID trauma patients (Figure 1). The rates of medical errors per 100 discharges and per 1000 hospital days were highest for patients with five or more chronic conditions. While the rate per 1000 hospital days remained fairly consistent with more than two chronic conditions, the rate per 100 discharges continued to steadily increase up to five or more chronic conditions.

Discussion

Our results provide evidence that pediatric trauma patients with chronic conditions experienced a higher medical error rate compared with patients without chronic conditions: 4.04 versus 1.07 per 100 discharges. After controlling for potential confounding factors, the presence of a chronic condition increased the odds of medical error by 37% if one chronic condition existed and 69% if more than one chronic condition existed. Additionally, higher adjusted odds ratios (AORs) were seen for males, for older pediatric age groups, for those with intentional injury, for those with longer lengths of stay, and for rural hospitals and for those hospitals in the West. In the adjusted model, LOS had the strongest relationship with medical error, but the AOR for chronic conditions and medical error remained significantly elevated even when accounting for the LOS, suggesting that medical complexity has a role in medical error. The rates of medical errors differed by type of chronic condition. Moreover, we found that the rates of medical error per 100 discharges and per 1000 hospital days increased with increasing numbers of chronic conditions. However, the medical error rate per 1000 hospital stay days seems to indicate that the average number of medical errors remains fairly consistent with the presence of more than two chronic conditions, indicating the stronger association of LOS with medical error.

Our previous study in a general pediatric inpatient population established that medical errors are associated with chronic conditions,[8] and this holds true in this study specifically looking at pediatric trauma patients. Other authors have suggested that children might be more at risk in emergent situations.[14,15] This was not seen in this study of pediatric trauma patients; they did not have higher rates of medical

Table 3. Medical error rates by patient characteristics in US pediatric trauma patients, KID 2009.

	With chronic conditions				Without chronic conditions			
	N of medical errors	National estimate	Rate[a]	95% CI	N of medical errors	National estimate	Rate[a]	95% CI
Age group (years)								
0–5	202	303	3.62	(3.06–4.19)	144	212	0.64	(0.52–0.76)
6–12	202	304	3.08	(2.60–3.55)	142	211	0.70	(0.59–0.82)
13–18	746	1083	4.28	(3.91–4.66)	397	572	1.42	(1.26–1.57)
19–20	517	746	4.45	(4.00–4.90)	202	290	1.80	(1.52–2.08)
Gender								
Male	1250	1821	4.21	(3.89–4.53)	654	947	1.21	(1.10–1.32)
Female	417	614	3.69	(3.25–4.12)	229	334	0.90	(0.78–1.03)
Race								
White	729	1067	3.66	(3.30–4.02)	375	542	1.00	(0.89–1.11)
Black	334	489	5.03	(4.42–5.64)	164	239	1.49	(1.19–1.80)
Hispanic	260	373	4.33	(3.68–4.99)	152	216	1.09	(0.91–1.27)
Other[b]	344	506	3.95	(3.41–4.50)	194	286	0.97	(0.81–1.13)
Median household income[c]								
Low income	568	833	4.49	(4.03–4.95)	279	408	1.18	(1.02–1.34)
Not low income	1045	1525	3.81	(3.49–4.13)	573	829	1.01	(0.92–1.11)
Missing	54	78	4.55	(3.26–5.84)	33	47	1.50	(0.86–2.14)
Patients residence								
Large metropolitan area	869	1262	4.00	(3.65–4.35)	440	629	0.97	(0.85–1.09)
Small metropolitan area	450	663	3.98	(3.55–4.42)	247	361	1.14	(1.00–1.29)
Micropolitan area	170	251	4.01	(3.34–4.67)	86	129	1.09	(0.86–1.31)
Non-urban area	123	183	4.25	(3.48–5.02)	77	115	1.40	(1.08–1.72)
Missing	55	77	4.91	(3.51–6.32)	35	50	1.58	(0.97–2.20)
Insurance								
Public	655	960	4.71	(4.22–5.19)	313	456	1.12	(0.98–1.27)
Private	746	1089	3.78	(3.45–4.10)	413	599	0.97	(0.87–1.07)
Self-pay	125	180	2.87	(2.33–3.40)	79	114	1.19	(0.92–1.46)
Other[d]	141	206	4.30	(3.61–4.99)	80	115	1.51	(1.16–1.85)
Injury intent								
Unintentional	976	1426	3.21	(2.93–3.48)	548	797	0.80	(0.72–0.89)
Intentional[e]	299	428	4.66	(4.07–5.25)	142	203	2.23	(1.78–2.68)
Other[f]	392	581	8.75	(7.44–10.06)	195	285	2.49	(1.99–2.99)
New Injury Severity Score								
1–8	255	375	1.57	(1.35–1.79)	260	381	0.60	(0.52–0.68)
9–15	348	512	3.02	(2.69–3.35)	218	317	1.03	(0.89–1.17)
16–24	426	622	6.21	(5.57–6.85)	168	241	2.13	(1.80–2.47)
25–34	403	587	11.33	(10.02–12.65)	124	180	4.89	(3.94–5.85)
35+	225	326	8.25	(6.71–9.78)	103	148	1.53	(1.06–2.01)
Discharge status								
Lived	1616	2361	4.04	(3.74–4.34)	873	1267	1.06	(0.97–1.15)
Deceased	50	73	3.95	(2.89–5.01)	10	14	3.97	(1.53–6.40)
Length of stay (days)								
0–2	130	192	0.64	(0.52–0.76)	139	204	0.25	(0.21–0.29)
3–7	316	461	2.39	(2.11–2.67)	285	415	1.36	(1.19–1.54)
8–14	339	493	8.57	(7.63–9.51)	223	321	6.36	(5.43–7.29)
15+	881	1288	24.87	(22.80–26.94)	238	344	17.14	(14.88–19.39)
Total charge[g]								
<12,219	69	101	0.79	(0.58–0.99)	58	86	0.21	(0.15–0.28)
12,219–21,925	52	76	0.63	(0.45–0.81)	63	93	0.29	(0.21–0.36)
21,925–41,045	152	224	1.56	(1.30–1.82)	179	261	0.97	(0.82–1.12)
>41,045	1394	2034	9.68	(8.93–10.42)	585	844	4.35	(3.87–4.84)

KID: Kids' Inpatient Database; CI: confidence interval.

[a]Rate: number of medical errors per 100 discharges.

[b]Includes cases with missing information.

[c]Median household income for patient's ZIP Code: low income: 0th–25th percentile; not low income: 26th–100th percentile (based on current year).

[d]Includes cases with no charge and missing information.

[e]Includes cases that were coded as self-inflicted and assault.

[f]Includes cases with undetermined causes and missing information.

[g]Cut points based on the 25th, 50th, and 75th percentiles of total charge of all patients.

Table 4. Univariate and multivariable models of medical errors and selected discharge characteristics, KID 2009.

	Univariate model		Multivariable model	
	OR	95% CI	OR	95% CI
No. of chronic conditions				
0 (Ref)	1.00		1.00	
1	2.37	(2.12–2.65)	1.37	(1.21–1.55)
2+	6.10	(5.44–6.83)	1.69	(1.48–1.93)
Age group (years)				
0–5 (Ref)	1.00		1.00	
6–12	1.04	(0.90–1.20)	1.32	(1.11–1.57)
13–18	2.05	(1.79–2.36)	1.54	(1.32–1.80)
19–20	2.59	(2.23–3.00)	1.42	(1.20–1.68)
Gender				
Male	1.29	(1.18–1.42)	1.21	(1.09–1.35)
Female (Ref)	1.00		1.00	
Race				
White (Ref)	1.00		1.00	
Black	1.48	(1.29–1.70)	1.15	(0.98–1.36)
Hispanic	1.08	(0.93–1.24)	0.99	(0.85–1.16)
Other[a]	0.97	(0.83–1.14)	1.01	(0.85–1.19)
Medium household income[b]				
Low income (Ref)	1.00		1.00	
Not low income	0.83	(0.75–0.91)	1.00	(0.89–1.12)
Missing	1.11	(0.83–1.47)	0.83	(0.61–1.13)
Patients residence				
Large metropolitan area (Ref)	1.00		1.00	
Small metropolitan area	1.08	(0.97–1.21)	1.04	(0.92–1.17)
Micropolitan area	1.07	(0.91–1.25)	0.91	(0.74–1.11)
Non-urban area	1.22	(1.03–1.44)	1.10	(0.90–1.33)
Missing	1.38	(0.98–1.94)	1.91	(1.43–2.55)
Insurance				
Public (Ref)	1.00		1.00	
Private	0.80	(0.73–0.88)	0.94	(0.84–1.05)
Self-pay	0.79	(0.68–0.93)	0.92	(0.78–1.09)
Other[c]	1.12	(0.94–1.32)	0.98	(0.81–1.18)
Intent				
Unintentional (Ref)	1.00		1.00	
Intentional[d]	2.27	(2.00–2.58)	1.55	(1.35–1.79)
Other[e]	3.19	(2.70–3.78)	2.61	(2.25–3.04)
New Injury Severity Score				
1–8 (Ref)			1.00	
9–15	2.03	(1.79–2.29)	0.96	(0.84–1.10)
16–24	4.84	(4.27–5.49)	1.01	(0.87–1.17)
25–34	10.89	(9.35–12.68)	1.02	(0.85–1.23)
35+	4.14	(3.35–5.12)	0.85	(0.69–1.05)
Length of stay (days)				
0–2 (Ref)	1.00		1.00	
3–7	5.05	(4.34–5.89)	4.74	(4.00–5.63)
8–14	22.96	(19.58–26.93)	20.05	(16.50–24.35)
15+	82.79	(70.86–96.73)	67.78	(55.86–82.25)
Hospital type				
Not identified as children's hospital (Ref)	1.00		1.00	
Identified as children's hospital	0.66	(0.52–0.84)	0.83	(0.62–1.10)
Children's unit in a general hospital	1.17	(1.00–1.36)	0.97	(0.82–1.15)

Table 4. (Continued)

	Univariate model		Multivariable model	
	OR	95% CI	OR	95% CI
Hospital location				
Rural	0.71	(0.57–0.89)	1.60	(1.22–2.09)
Urban (Ref)	1.00		1.00	
Hospital teaching status				
Non-teaching (Ref)	1.00		1.00	
Teaching	1.48	(1.26–1.73)	1.00	(0.86–1.18)
Hospital bed size				
Small (Ref)	1.00		1.00	
Medium	1.27	(0.92–1.74)	1.03	(0.75–1.40)
Large	1.52	(1.14–2.03)	1.09	(0.81–1.47)
Missing	1.74	(1.22–2.49)		
Hospital region				
Northeast (Ref)	1.00		1.00	
Midwest	1.28	(1.05–1.55)	1.04	(0.85–1.28)
South	1.40	(1.15–1.70)	1.10	(0.91–1.34)
West	1.26	(1.03–1.54)	1.32	(1.08–1.62)

Ref: reference group; KID: Kids' Inpatient Database; CI: confidence interval; OR: odds ratio.
[a]Includes cases with missing information.
[b]Median household income for patient's ZIP code: low income: 0th–25th percentile; not low income: 26th–100th percentile.
[c]Includes cases with no charge and missing information.
[d]Includes cases that were coded as self-inflicted and assault.
[e]Includes cases with undetermined causes and missing information.

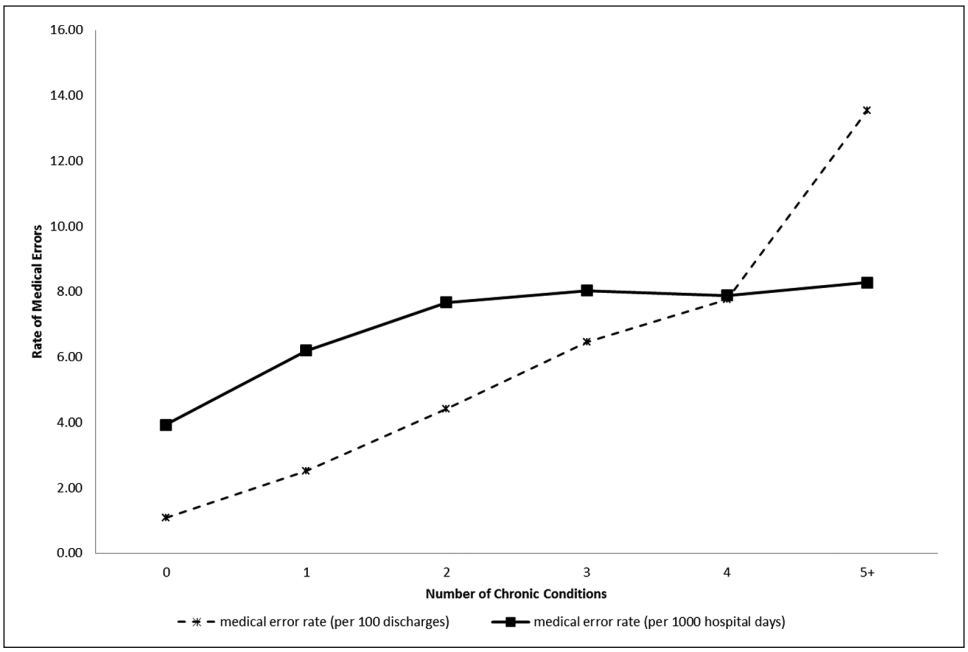

Figure 1. Rate of medical error in pediatric trauma patients, KID 2009.
KID: Kids' Inpatient Database.

errors than that seen in the previous study of all pediatric inpatients. Earlier work, using 2006 KID data, found that the medical error rate among all pediatric inpatients was 5.3 per 100 discharges[8] as compared with the medical error rate of 4.04 per 100 discharges rate seen in this study limited to pediatric trauma patients. It is important to point out that these two studies utilize different years of KID data, and we did not directly compare trauma patients to other pediatric

patients using the same dataset. It is also important to note that the KID sample includes only those trauma patients who were hospitalized. In both studies, the AORs of medical error increased with increasing numbers of chronic conditions and the AORs were of a similar magnitude. Pediatric trauma patients differed from all pediatric inpatients in that they had a lower rate of errors categorized as "Complications Peculiar to Certain Specified Procedures." Included in this category are mechanical complications and infections related to devices, implants, and grafts, including transplanted organs and reattached body parts. In pediatric trauma patients in this study, the medical error rate in this category was 0.88 per 100 discharges. In the study which included all pediatric inpatients, the error rate in this category was 3.0 per 100 discharges.[8]

Consistent with past studies,[8,10,16] our study also found that male patients were at significantly higher odds of experiencing medical errors compared with their female counterparts, even when controlling for confounding factors. Prior studies have suggested that immune responses to trauma are gender dimorphic and that sex steroids may influence maintenance of immune functions following injury.[17–19]

Implications

This study highlights two of the five concepts necessary to address medical errors: transparency and care integration.[20] Transparency is perhaps the most important in attribute in creating a culture of safety in healthcare.[20–22] Leape et al.[20] list chronic disease care and complex acute care as areas where integrated care has the potential to impact patient safety. Future research should consider care integration approaches and medical error prevention for pediatric trauma care for patients with chronic conditions.

Study limitations

Limitations of our study need to be considered when interpreting our study results. First, voluntary reporting of medical errors may only detect a portion of medical errors in hospitals. A survey of pediatric physicians and nurses suggests that medical errors are significantly underreported, particularly by physicians.[23] Second, the conditions have a range of severity and chronicity, and ICD-9-CM coding often does not capture this range of characteristics. Third, the Chronic Condition Indicator in the KID dataset labels conditions as chronic or nonchronic based only on the ICD-9-CM code; therefore, some non-injury diagnoses may be the result of the traumatic injury rather than being pre-existing conditions. Fourth, ICD-9-CM codes may underestimate the problem of medical errors because coding practices can vary among medical records coders. At present, however, ICD-9-CM codes are the best available tool for examining medical errors in large administrative databases.[16] Finally, it is not possible to determine the direction of causality between medical errors and LOS using the KID, which is a cross-sectional dataset. In previous studies, medical errors[8] and LOS[2,24] have each been shown to have a statistically significant association with the presence of chronic conditions. Possibly, the higher degree of care required by patients with chronic conditions and their increased likelihood for encountering medical errors may contribute to the difference seen in LOS between patients with and without chronic conditions.[11] Conversely, longer LOS can be seen in children with chronic conditions, which increases the exposure time for medical errors.

Conclusion

This is the first study to show significant associations between chronic conditions and medical errors in pediatric trauma patients using a nationally representative database. Our results show that the presence of chronic conditions was associated with more than triple the rate of medical errors in pediatric trauma patients with chronic conditions. Future research should develop and evaluate interventions or critical care guidelines for reducing risk of iatrogenic medical errors in pediatric trauma patients with chronic conditions.

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Declaration of conflicting interests

The authors have no conflicts of interests relevant to this article to disclose.

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References

1. Kohn L, Corigan JM and Donadldson MS. *To err is human: building a safer health system*. Washington, DC: National Academies Press, 2000.
2. Edwards JD, Houtrow AJ, Vasilevskis EE, et al. Chronic conditions among children admitted to U.S. pediatric intensive care units: their prevalence and impact on risk for mortality and prolonged length of stay. *Crit Care Med* 2012; 40(7): 2196–2203.

3. Perrin JM, Bloom SR and Gortmaker SL. The increase of childhood chronic conditions in the United States. *JAMA* 2007; 297(24): 2755–2759.
4. Burns KH, Casey PH, Lyle RE, et al. Increasing prevalence of medically complex children in US hospitals. *Pediatrics* 2010; 126(4): 638–646.
5. Van Cleave J, Gortmaker SL and Perrin JM. Dynamics of obesity and chronic health conditions among children and youth. *JAMA* 2010; 303(7): 623–630.
6. Bethell CD, Kogan MD, Strickland BB, et al. A national and state profile of leading health problems and health care quality for US children: key insurance disparities and across-state variations. *Acad Pediatr* 2011; 11(Suppl. 3): S22–S33.
7. National Center for Injury Prevention and Control. *CDC injury fact book*. Atlanta, GA: Centers for Disease Control and Prevention, 2006.
8. Ahuja N, Zhao W and Xiang H. Medical errors in US pediatric inpatients with chronic conditions. *Pediatrics* 2012; 130(4): e786–e793.
9. Miller CM, Shi J, Wheeler KK, et al. Chronic conditions and outcomes of pediatric trauma patients. *J Trauma Acute Care Surg* 2013; 75(2): 250–257.
10. Slonim AD, LaFleur BJ, Ahmed W, et al. Hospital-reported medical errors in children. *Pediatrics* 2003; 111(3): 617–621.
11. Wardle TD. Co-morbid factors in trauma patients. *Br Med Bull* 1999; 55(4): 744–756.
12. National Trauma Data Bank. National Trauma Data Standard Data Dictionary, http://www.ntdsdictionary.org/dataElements/documents/NTDS2012_xsd_Final_102011.pdf (accessed 16 August 2012).
13. Lavoie A, Moore L, LeSage N, et al. The Injury Severity Score or the New Injury Severity Score for predicting intensive care unit admission and hospital length of stay? *Injury* 2005; 36(4): 477–483.
14. Sacchetti A, Sacchetti C, Carraccio C, et al. The potential for errors in children with special health care needs. *Acad Emerg Med* 2000; 7(11): 1330–1333.
15. Carraccio CL, Dettmer KS, duPont ML, et al. Family member knowledge of children's medical problems: the need for universal application of an emergency data set. *Pediatrics* 1998; 102(2 Pt 1): 367–370.
16. Miller MR, Elixhauser A and Zhan C. Patient safety events during pediatric hospitalizations. *Pediatrics* 2003; 111(6 Pt 1): 1358–1366.
17. Choudhry MA, Bland KI and Chaudry IH. Trauma and immune response-effect of gender differences. *Injury* 2007; 38(12): 1382–1391.
18. Hsieh YC, Frink M, Choudhry MA, et al. Metabolic modulators following trauma sepsis: sex hormones. *Crit Care Med* 2007; 35(Suppl. 9): S621–S629.
19. Haider AH, Crompton JG, Chang DC, et al. Evidence of hormonal basis for improved survival among females with trauma-associated shock: an analysis of the National Trauma Data Bank. *J Trauma* 2010; 69(3): 537–540.
20. Leape L, Berwick D, Clancy C, et al. Transforming healthcare: a safety imperative. *Qual Saf Health Care* 2009; 18(6): 424–428.
21. Leape LL. Error in medicine. *JAMA* 1994; 272(23): 1851–1857.
22. Leape LL and Berwick DM. Five years after To Err Is Human: what have we learned? *JAMA* 2005; 293(19): 2384–2390.
23. Taylor JA, Brownstein D, Christakis DA, et al. Use of incident reports by physicians and nurses to document medical errors in pediatric patients. *Pediatrics* 2004; 114(3): 729–735.
24. Silber JH, Gleeson SP and Zhao H. The influence of chronic disease on resource utilization in common acute pediatric conditions. Financial concerns for children's hospitals. *Arch Pediatr Adolesc Med* 1999; 153(2): 169–179.