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Variability in the structure and care processes for critically injured children: A multicenter survey of trauma bay and intensive care units☆

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ABSTRACT

Purpose: Evaluate national variation in structure and care processes for critically injured children.
Methods: Institutions with pediatric intensive care units (PICUs) that treat trauma patients were identified through the Virtual Pediatric Systems (n = 72). Prospective survey data were obtained from PICU and Trauma Directors (n = 69, 96% response). Inquiries related to structure and care processes in the PICU and emergency department included infrastructure, physician staffing, team composition, decision making, and protocol/checklist use.
Results: About one-third of the 69 institutions were ACS-verified Level-1 Pediatric Trauma Centers (32%); 36 (52%) were state-designated Level 1. The surgeon was the primary decision maker in the trauma bay at 88% of sites, and in the PICU at 44%. The intensivist was primary in the PICU at 30% of sites and intensivist consultation was elective at 11%. Free-standing pediatric centers used checklists more often than adult/pediatric centers for DVT prophylaxis (75% vs. 50%, p = 0.039), cervical spine clearance (75% vs. 44%, p = 0.011), and pain control (63% vs. 34%, p = 0.024). Otherwise, protocols/checklists were infrequently utilized by either center type.
Conclusion: Variability exists in structure and care processes for critically injured children. Further investigation of variation and its causal relationship to outcomes is warranted to provide optimal care.

Unintentional injury is the leading cause of fatal and nonfatal injury in children nationwide [1]. Integrated trauma systems are essential to providing quality emergency care. Despite mature adult trauma systems throughout the majority of the United States, trauma management for children remains fragmented. Ninety percent of injured children in the United States are treated in general emergency departments (EDs) at either adult or combined adult/pediatric centers rather than at trauma centers [2]. Fifty percent of EDs in the nation treat fewer than 10 pediatric patients per year [3], and only 6% of EDs in the US have the requisite supplies deemed essential for management of pediatric emergencies [4,5]. Lack of resources, organization, and centralization underlie the variability in emergency care provided to injured children throughout the nation. The Institute of Medicine's 2007 report, *Emergency Care for Children Growing Pains*, highlighted the need for coordination, regionalization, and systems of accountability to improve emergency care for injured children [6].

The distribution of pediatric injury nationwide challenges the integration of pediatric and trauma care. However, it has been shown that younger, more critically injured children derive the most benefit from treatment at verified trauma centers [7]. In addition to primary emergency and trauma services, triage and inter-facility transfer guidelines are necessary to cohort severely injured children at centers with specialized services and intensive care units (ICUs) for pediatric patients or that have designated pediatric beds. Once a child reaches the ICU, however, what constitutes optimal care remains unclear. While more

Abbreviations: ACS, American College of Surgeons; REDCap, Research Electronic Data Capture'; ICU, intensive care unit; PICU, pediatric intensive care unit; TC, trauma center; PTC, pediatric trauma center; VPS, Virtual PICU Systems, LLC; COT, Committee on Trauma; ED, emergency department.

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elucidated in adult medical and surgical critical care and trauma management [8–12], there is currently no consensus regarding unit infrastructure (open vs. closed units), physician staffing models, team composition, continuity of care, and protocol and checklist utilization in pediatric trauma management.

Additionally, the impact of latent processes of care, such as the nuances in decision making between intensivists and surgeons and the subjective "degree" of involvement by each healthcare team member, remains unknown in the setting of critically injured children. Similar questions – related to both salient and latent features of care – exist for pediatric trauma management in the emergency department.

How do we measure quality of care in this multimodal, multifaceted care environment? Quality of healthcare is often conceptualized using Donabedian's framework, highlighting structure, process, and outcome [13]. Structure includes the setting in which medical care occurs, and describes material resources and organization. Process describes provision and receipt of care. Outcome defines the impact of providing care on the health status of the patient and/or population. "This three-part approach to quality assessment is possible only because good structure increases the likelihood of good process, and good process increases the likelihood of good outcome." [13]

The objective of this study was to describe the variability in Donabedian's first two domains, the structure and processes of care, for critically injured children in a national sample that included both free-standing pediatric and combined adult/pediatric centers.

1. Materials and methods

1.1. Survey creation and dissemination

A survey was created using consensus input from experts in the fields of pediatric trauma, pediatric critical care, pediatric traumatic brain injury, and pediatric injury prevention. A pilot questionnaire was distributed to four American College of Surgeons (ACS)-verified Level 1 Pediatric Trauma Centers (PTCs) and one ACS-verified Level 2 PTC to test the validity of the survey tool. After aggregating the pilot data and soliciting feedback from respondents, questions were refined to target content of interest more effectively. Based on pilot data feedback, the questions pertaining to the trauma bay and ICU were split into two separate surveys. This division enabled a targeted query to the individual(s) who would be most knowledgeable in the structure and processes of care in each area (trauma bay vs. ICU). Trauma bay and PICU surveys are provided in Supplementary Files A and B, respectively.

Survey data were collected and managed using Research Electronic Data Capture (REDCap), a secure web-based application designed to support validated data capture, hosted at the University of Washington [14]. This study was deemed exempt from review by the University of Washington Institutional Review Board.

1.2. Sample

The survey was sent to all Virtual Pediatric Systems-affiliated institutions in the United States. Virtual Pediatric Systems, LLC ("VPS") is co-owned by two not-for-profit entities, Children's Hospital Los Angeles (CHLA) and the Children's Hospital Association's NACHRI. Since inception in 1997, VPS has grown to include over 130 active ICU units representing nearly one-million cases making it the largest pediatric collaborative for quality improvement based on detailed patient records in critical care. VPS's specialties include risk adjustment and comparative analysis, each aimed to enhance the quality of pediatric critical care [15]. All VPS-affiliated PICUs indicating in the site-specific VPS Participant Profile that their institution cared for trauma patients were considered eligible and were sent a cover letter and electronic access to the survey form(s) on May 6, 2014 ($n = 79$). Sites were contacted by phone and email between June 1 and August 4, 2014 to encourage participation. VPS site coordinators at each institution and/or the PICU Medical Director were the targeted respondents for the PICU-focused survey. The Trauma Program Manager and/or the Trauma Program Director were the targeted respondents for the trauma bay-focused survey.

1.3. Decision rules

If more than one survey was started per site, the most complete survey was chosen for analysis. If two surveys were completed, field values were blindly compared through the RedCAP software for concordance. If discrepant field values were identified, the position of the respondent was considered. The answer from the targeted respondent most immediately involved in the operations of the ICU or trauma bay was used for data analysis. If discrepant field values existed in two different surveys completed by the same individual at an institution, the most recent answer was used for analysis. This occurred rarely and appeared to be isolated to situations in which the survey respondent did not immediately know the answer to a question, consulted a colleague for input, and then started a new survey through Redcap instead of completing their original form. Surveys were considered complete if >90% of the questions were answered. Response rates were calculated based on established guidelines [16].

1.4. Definitions utilized in the survey

An academic health center was defined as an accredited, degree-granting institution of higher education that consists of a medical school (allopathic or osteopathic) or health professional school and/or is affiliated with a teaching hospital or health system [17].

Trauma center level was captured for each participating institution using both state and American College of Surgeons (ACS) definitions [18]. Hospitals self-reported their state and ACS designation; the latter was cross referenced with the most up-to-date and available data from the Committee on Trauma (COT, August 11, 2014). The ACS verifies centers for adult trauma (Levels I–III Trauma Center, TC) and pediatric trauma (Level I or II Pediatric Trauma Center, PTC). ACS also qualifies adult trauma centers that demonstrate capacity to care for the injured child. These centers must see at least 100 children under the age of 15 per year and have the following resources: trauma surgeons credentialed by the hospital for pediatric trauma management, a pediatric emergency department area, a pediatric ICU area, pediatric resuscitation equipment, and a pediatric performance improvement and patient safety (PIPS) program [18]. State certification of trauma capabilities varies by state (or county) and was captured from survey results alone.

An intensivist was defined as a physician with board certification in Medicine, Anesthesia, Surgery, or Pediatrics, and also certified in critical care medicine. Emergency Medicine physicians who completed a critical care fellowship in an ACEP accredited program were also included [19].

A "closed ICU" was defined as an "ICU where patients are cared for primarily by a critical care team," with other specialties acting as consulting services. In this case, the critical care team is the primary decision making service. Usually only the ICU team writes admission, discharge, and daily orders on the patients. ICUs that did not meet the survey's definition of 'closed' were defined as 'open.'

Unit intensity classification was defined to be consistent with Pronovost et al. [8]. High intensity units included closed ICUs, ICUs where the intensivist was considered the primary physician, and ICUs where critical care consultation was mandatory. Low intensity units included open ICUs and ICUs where there was no intensivist or consultation was elective. To target unit intensity while maintaining the granularity related to unit structure and decision making, respondents were first asked who was considered the primary physician for pediatric trauma patients admitted to the ICU. If a non-intensivist (e.g. a surgical attending without critical care board certification) was reported to be the patient's "primary" physician, the survey respondent was asked if critical care consultation was mandatory or elective. Respondents were instructed to classify consultation as mandatory if all pediatric trauma patients in their ICU had a critical care intensivist taking part in their care. Consultation was considered elective if pediatric trauma patients in the ICU did not universally have an intensivist taking part in their care.

1.5. Statistical analysis

All data were electronically exported from RedCAPto STATAv12 (Stata Corp; College Station, TX). Descriptive statistics were calculated for all variables among the entire sample, and among free-standing pediatric and combined adult-pediatric centers separately. For normally distributed data, means with standard deviation were calculated. For non-normal distributions, medians with interquartile range were determined. For comparison between groups, univariable statistics were completed using chi-square tests for heterogeneity for nominal categorical variables and one- and two-sample t-tests for proportions. The student's t-test and/or linear regression were used for continuous variables to compare means. With linear regression, robust standard errors were used to account for the mean–variance relationship in binary outcome data and provide conservative estimates of precision. A 95% confidence interval was calculated for all estimates. Data were evaluated for sites that completed one or both surveys. For the sites that completed only one of the two surveys, data were considered missing for the uncompleted survey, providing a denominator of 69 for all analyses. Missing data for individual field values were presented only if accounting for >10% of variable-specific responses.

2. Results

2.1. Response rates and regional distribution

Surveys were sent to 79 sites, of which seven responded that they do not treat trauma patients on a regular basis and were removed from the eligible survey respondent pool ($n = 72$). A total of 69 sites (96% of eligible) completed at least one survey (2 opted out, 1 did not respond). Eight sites completed only one of the two surveys, providing a 92% response proportion for the trauma bay survey (66/72) and an 89% response proportion for the ICU survey (64/72). In all, 61 sites completed both the trauma bay and ICU surveys (composite minimum response proportion 85%). All sites that completed at least one survey were included in the final analysis ($n = 69$). Included sites were located in all four US Census regions: West, 17 (25% of total sites included); Midwest, 18 (26%); Northeast, 10 (14%); and South, 24 (35%). Proportions of represented PICUs per total number of PICUs present in each region (based on 2008 AHA survey file data) were similar: West, 21%; Midwest, 14%; Northeast, 14%; and South 14% [20].

2.2. Institutional characteristics and trauma capabilities

The majority of sites (90%) were academic health centers. Thirty-four (49%) were free-standing pediatric centers and 35 were combined adult/pediatric centers (52%). The majority of sites were not ACS-verified for pediatric trauma (61%), despite their status as a free-standing pediatric (56%) or combined adult/pediatric center (66 %; Table 1). While 59% were designated by their state and/or county as having level I resources for pediatric trauma, 16% of sites had neither ACS verification nor state designation of any kind.

2.3. Trauma bay structure and processes of care

The surgeon was most frequently considered the "primary decision maker" in the trauma bay (88%; Table 2), with little variability between free-standing pediatric centers and combined adult/pediatric centers. However, the decision making process varied at a few hospitals. At two sites the 'primary decision maker' depended on the acuity of the patient, and at one site on the age of the patient (<12 years, PICU attending; >12 years, adult trauma surgeon). At one free-standing pediatric center, a 'trauma midlevel provider' (e.g. nurse practitioner, physician's assistant) was the primary decision maker for injured children in the trauma bay.

Table 1
American College of Surgeons (ACS) verification[a] and state/county certification.[b]

	ACS Verification n (%)	State/county designation n (%)
Pediatric free-standing hospitals, n = 34		
Pediatric trauma designation/verification		
I	12 (35)[c]	20 (59)
II/III	3 (9)	4 (12)
None	19 (56)	7 (21)
Unknown/Missing	n/a	3 (9)
Combined adult/pediatric hospitals, n = 35		
Pediatric trauma designation/verification		
I	10 (29)	16 (46)
II/III	2 (6)	6 (17)
None	23 (66)	9 (26)
Unknown/Missing	n/a	4 (11)
Adult trauma designation/verification		
I	18 (51)	20 (57)
I/III	4 (11)	8 (23)
None	13 (37)	3 (9)
Unknown	n/a	4 (11)

[a] ACS verification as reported by the American College of Surgeons as of August 11, 2014.
[b] Totals for relative proportions in each category may add up to 99 or 101 due to rounding of estimates. ACS-verification and state-designation are not mutually exclusive.
[c] One site reported ACS verification for adult trauma 'with pediatric capabilities.'

All sites had written trauma protocols for trauma activations and 97% had planned tiered trauma team responses depending on the severity of the injuries sustained. A senior level surgical provider (attending or fellow) was required at 99%of sites for major activations. Overall, pediatric surgical providers were required at major activations twice as often as adult surgical providers (73% vs. 35%, $p < 0.001$).

Protocols for blunt abdominal trauma in children existed at 64% of sites. The Focused Assessment with Sonography in Trauma (FAST) exam was included in the protocol at combined adult/pediatric centers more often than at free-standing pediatric centers (81% vs. 58%), but this difference was not statistically significant ($p = 0.130$). Head imaging protocols for children were more commonly utilized at free-standing pediatric centers than at combined centers (79% vs 55%; $p = 0.037$).

Surgical provider volume and qualifications varied appropriately by type of center: pediatric fellowship trained providers were prevalent at pediatric centers and adult trauma fellowship trained providers were prevalent at adult centers, however there were free-standing pediatric centers that lacked surgeons with pediatric surgery fellowship training, and there were combined adult/pediatric centers that lacked surgeons with trauma surgery fellowship training. The surgical call pool for pediatric trauma included two to 15 providers. Trauma team composition varied across sites (Fig. 1).

2.4. ICU structure for pediatric trauma patients

All sites had a medical/surgical pediatric ICU (Table 3). Sixty-three percent of combined adult/pediatric centers had adult ICUs that admitted trauma patients less than 18 years of age, some as young as eight. As expected, few (total $n = 4$) free-standing pediatric centers reported the presence of adult ICUs that care for pediatric trauma. ICU size, as reflected by number of licensed beds, varied significantly between sites (range 4–60) and the mean number of beds at pediatric free-standing centers was more than twice that at combined centers (31 vs. 15, $p < 0.001$).

Table 2
Trauma bay care processes for injured pediatric patients, %.[a]

	Total n = 69	Pediatric hospital n = 34	Combined adult/pediatric hospital n = 35	p-value
Primary decision maker				0.079
Emergency Medicine physician	6	3	9	
Surgeon[b]	88	85	91	
Other	6	12	0	
Trauma resuscitations				
Pediatric surgery attending or fellow required for all major pediatric trauma resuscitations	73	88	39	**0.020**
n/a (no pediatric surgeon available)	2	0	3	
Adult surgery attending or fellow required for all major pediatric trauma resuscitations	35	12	58	<**0.001**
n/a (no adult surgeon available)	35	64	6	
Any surgery attending or fellow required for all major pediatric trauma resuscitations	99	100	97	0.314
Protocol and checklist use				
Blunt abdominal trauma	64	73	55	0.125
Includes FAST (n = 42)	68	58	81	0.130
Includes DPL (n = 42)	15	17	12	0.662
Head imaging	67	79	55	**0.037**
Admission criteria	55	55	55	1.00
Emergency department discharge criteria	44	52	36	0.215
Surgery provider volume and qualifications for pediatric trauma patients				
Number of surgeons per center in the call pool for pediatric trauma emergencies				0.703
mean (SD)	7 (3)	8(3)	7 (3)	
median (IQR)	7 (5–10)	7 (5–9)	7 (4–10)	
range	2–15	2–15	2–14	
Number of surgeons per center with fellowship training in pediatric surgery				<**0.001**
mean (SD)	5 (4)	6 (4)	3 (2)	
median (IQR)	4 (3–6)	6 (4–8)	3 (1–4)	
range	0–15	0–15	0–10	
Number of surgeons per center with fellowship training in adult trauma surgery				**0.001**
mean (SD)	3 (3)	1 (2)	4 (4)	
median (IQR)	0 (0–5)	0 (0–1)	2 (0–6)	
range	0–12	0–7	0–12	
Proportion of call pool with fellowship training in pediatric surgery, mean (SD)	.68 (.41)	.81 (.35)	.54 (.42)	**0.008**
Proportion of call pool with fellowship training in trauma surgery, mean (SD)	.30 (.39)	.15 (.31)	.45 (.41)	**0.002**

FAST, focused assessment with sonography for trauma; DPL, diagnostic peritoneal lavage; SD, standard deviation; IQR, interquartile range.
[a] Column proportions presented unless otherwise noted. Totals for relative proportions in each category may add up to 99 or 101 due to rounding of estimates.
[b] Includes 7 sites where the pediatric surgery fellow (rather than attending) is considered the primary decision maker.

2.5. ICU processes of care for pediatric trauma patients

2.5.1. Physician staffing in the ICU

While pediatric ICUs were present at all sites, adult surgery services rather than pediatric surgery services followed injured children at 14% of hospitals (Table 4). The primary decision maker in the ICU was most frequently the surgical attending at free-standing pediatric centers (59%), but distributed evenly among intensivists (38%), surgeons (28%), and a co-management model (34%) at combined adult/pediatric centers. Overall, only 22% of sites reported having a closed unit, and among those sites with closed units, 50% reported that the surgeon was still considered the primary physician for injured children. Among sites at which the intensivist was not considered the primary physician for injured children, intensivist consultation was elective at 11%. In the surveyed ICUs managing pediatric trauma patients, 8% of ICUs where defined as low-intensity units.

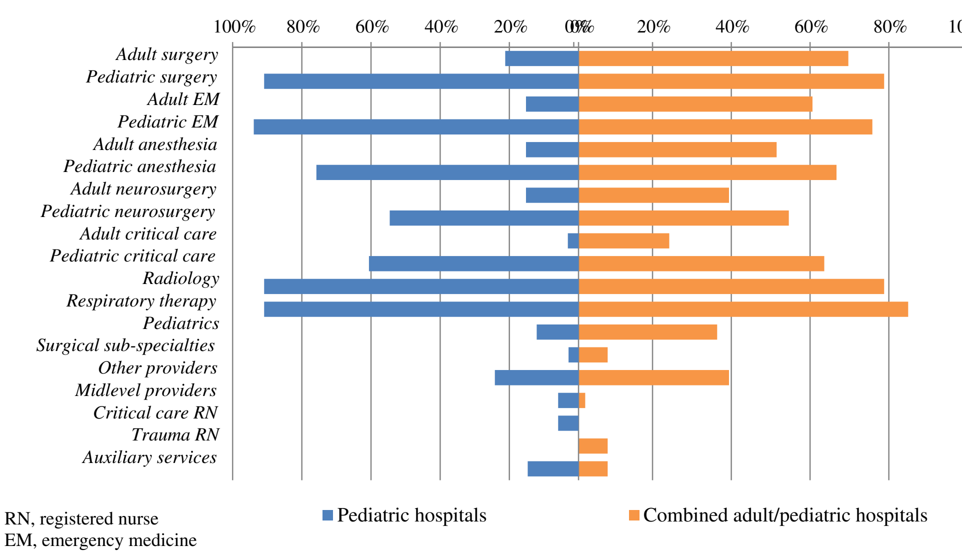

Fig. 1. Proportion of sites surveyed reporting involvement by specialty in the trauma bay.

Table 3
Characteristics of intensive care units (ICU) caring for pediatric trauma patients, %.[a]

	Total N = 69	Pediatric Hospital N = 34	Combined Adult/Pediatric Hospital N = 35	p-value
PICU types present at each center				
Medical/Surgical PICU	100	100	100	1.00
Neonatal ICU	78	82	75	.545
Cardiac PICU	16	28	3	**.006**
Medical PICU	8	9	6	.641
Surgical PICU	3	3	3	1.00
Neurological PICU	2	3	0	.313
Maximum age (y) for admission to mixed PICU				
Median (IQR)	18 (18–21)	21 (18–21)	18 (18–21)	.169
Range	0–35	0–35	17–22	
Presence of an adult ICU that cares for pediatric patients	38	13	63	<**.001**
Adult ICU types that care for pediatric patients at each center				
Surgery ICU	31	6	56	**.012**
Medical ICU	14	3	25	<**.001**
Mixed ICU	11	9	13	.689
Neurological ICU	11	3	19	**.045**
Minimum age (y) for admission to adult surgical ICUs that commonly manage pediatric trauma patients				.497
Median (IQR)	16 (14–16)	14 (12–16)	16 (15–16)	
Range	8–18	12–16	8–18	
Number of licensed ICUbeds[b]				<**.001**
Mean (SD)	23 (13)	31 (12)	15 (7)	
Median (IQR)	22 (14–30)	27 (22–36)	14 (9–22)	
Range	4–60	12–60	4–30	

PICU, pediatric intensive care unit; SD, standard deviation; IQR, interquartile range.
[a] Column proportions presented unless otherwise noted. Categories are not mutually exclusive, so percentages may add up to greater than 100%.
[b] ICU beds for the ICU in which the majority of pediatric trauma patients are managed.

The members of the daily rounding team in the ICU, represented by proportion of sites reporting each provider-type and stratified by hospital-type, are presented in Fig. 2. When asked if parents of the injured child are allowed to be present during rounds, 57% of sites reported almost always, 21% reported often, and 23% reported sometimes or rarely. There were no differences by type of center ($p = 0.341$) or type of ICU (closed vs. open, $p = 0.473$). Comparing *degree* of involvement (not involved, minimally/somewhat involved, very involved) of surgical providers, intensivist providers, general pediatric providers, and midlevel providers who are involved in the daily care of injured children, there were no statistically significant differences by ICU type (open/closed), primary provider type (intensivist, surgeon, co-management), or hospital-type (pediatric free-standing/combined adult/pediatric centers).

2.5.2. Continuity of care

Attendings staffing the ICU had a mean of 2.0 (SD 0.89; range 0–4) handoffs per 24-h period on weekends and 1.6 (SD 0.85; range 0–6) on weekdays. Nurses had a mean of 2.4 (SD 1.1; range 1–8) handoffs per 24-h period on both weekends and weekdays. Among academic programs, residents had a mean of 1.8 (SD 0.82; range 0–3) handoffs per 24-h period on weekends and 2.0 (SD 1.1; range 0–7) on weekdays. Thus, there was a mean of over six handoffs in care for patients every 24 h.

2.5.3. Protocol and checklist use

Protocols and checklists were underutilized except for a few processes of care (Table 4). Differences existed between pediatric free-standing and adult/pediatric centers, with pediatric centers more often using checklists for deep venous thrombosis (DVT) prophylaxis (75% vs. 50%, $p = 0.039$), cervical spine (C-spine) clearance (75% vs. 44%, $p = 0.011$), and pain control (63% vs. 34%, $p = 0.024$). Other protocols and checklists not included but mentioned by survey respondents included but were not limited to: central line maintenance, therapeutic hypothermia for traumatic brain injury, bronchoscopy, glucose control, peptic ulcer prevention, central line associated blood stream infection prevention, snake bite management, and burn management.

3. Discussion

3.1. Institutional characteristics and trauma resources

Compared with national distributions, our study sample over represented free-standing pediatric centers and academic medical centers [21,22]. This is likely due in part to the selection of sites a) with established PICUs, reflecting a dedication to high acuity pediatric patients, and b) that have deliberately joined the VPS collaboration, implying a dedication to research and quality improvement.

Fewer sites had ACS-verification than state or county certification for their trauma capabilities. This difference was particularly pronounced for pediatric-specific resources. Even among our sample, only 39% were ACS-verified at any level for pediatric trauma resources (irrespective of hospital type), compared to 74% state-certified centers of any level. Among combined adult/pediatric centers, 63% had ACS-verification for adult trauma compared to 88% with state-certification.

Many studies in adults have evaluated ACS-verification and state-designation, which primarily reflect Donabedian's structure of care domain, and patient outcomes. For example, the National Study on the Outcomes in Trauma (NSCOT) found lower inpatient and one-year mortality in patients treated at level 1 trauma centers compared to non-trauma centers [23]. While the NSCOT study defined "level 1 status" by ACS and/or state metrics, other studies have looked specifically at the ACS-verification status or have compared the two. Single-center studies in adults have shown improved outcomes through the ACS-verification process [24,25]. Studies using the National Trauma Databank (NTDB) have also shown improved outcomes among adults treated at ACS-verified trauma centers compared to those treated at non-trauma centers, irrespective of state-certification status [26,27]. In adults, comparisons of ACS-verified to state-designated centers of the same level have shown mixed results. Brown et al. found that for adults, ACS-verified level I centers had lower median observed vs. expected mortality ratios compared to state-certified level I centers, however only among level II centers was ACS-verification an independent predictor of survival [28]. Smith et al. reported improved survival in patients with acute respiratory distress syndrome after trauma among adults

Table 4
Intensive care unit care processes for injured pediatric patients, %.

	Total N = 69	Pediatric Hospital N = 34	Combined Adult/Pediatric Hospital N = 35	p-value
Type of surgical service that cares for pediatric trauma patients in the ICU				.281
Pediatric surgery service	86	91	81	
Adult surgery service	14	9	19	
Who is considered the primary physician for injured children in the ICU?				**.042**
Intensivist	30	22	38	
Surgery attending	44	59	28	
Depends on injuries/co-managed	27	19	34	
Intensivist consultation when the intensivist is not considered the primary physician (n = 45) is:				.090
Mandatory	89	96	80	
Elective	11	4	20	
Closed vs. Open ICU				.545
Closed	22	25	19	
Open	78	75	82	
ICU Intensity[a]				.162
High	92	97	88	
Low	8	3	13	
Protocol and Checklist use				
Mechanical Ventilation				
Spontaneous awakening trial	19	16	22	0.522
Spontaneous breathing trial	31	34	28	0.590
Lung protective ventilation	36	44	28	0.193
Weaning	34	41	28	0.292
VAP prevention	72	78	66	0.266
Sedation	55	63	47	0.209
DVT prophylaxis	63	75	50	**0.039**
Traumatic brain injury care				
Hypertonic saline	48	56	41	0.211
Mannitol	44	53	34	0.131
ICPM	59	66	53	0.309
Nutrition	38	44	31	0.302
Advanced pharmacology	39	47	31	0.200
Solid organ injury NOM	38	44	31	0.302
C-spine clearance	59	75	44	**0.011**
ECMO	22	31	13	0.070
Pain control	48	66	34	**0.024**
Trophic feeds	39	41	38	0.798
Total parenteral nutrition	34	34	34	1.000
Enteral nutrition support	44	47	41	0.614
Proton pump inhibitor	33	28	38	0.424
Urinary catheter discontinuation	63	63	63	1.000
CVC discontinuation	55	53	56	0.802

ICU, Intensive care unit; VAP, ventilator associated pneumonia; DVT, deep venous thrombosis; ICPM, intracranial pressure monitor; NOM, non-operative management; C-spine, cervical spine; ECMO, extracorporeal membrane oxygenation; CVC, central venous catheter.
[a] High Intensity requires a closed ICU, a mandatory intensivist consultation, or the intensivist must be considered the patient's primary attending physician. Low intensity includes open ICUs with no intensivist involvement or elective intensivist consultation.

admitted to ACS-verified compared to state-certified level I centers, however there was no adjusted survival advantage among all injured patients [29]. Despite the variability in findings comparing ACS-verification to state-designation, the overall consensus in adults is that care provided in level 1 trauma centers of any kind is associated with improved outcomes.

The findings in pediatric trauma are less clear [30]. As in adults, single center studies have shown improvements in outcomes in pediatric patients following ACS-verification. For example, Ehrlich et al. examined patient care indicators pre and post ACS-verification at a pediatric trauma center and found improvements in length of stay in the ED and specific charting practices [31]. On a national level, using the National Pediatric Trauma Registry, Osler and colleagues found improved survival in ACS-verified trauma centers compared to non-verified centers, however they did not find a difference when comparing pediatric trauma centers to (primarily) adult trauma centers [32].

State-based studies demonstrate similar findings. Wang et al. examined California's state-designated trauma centers (which are not required to obtain ACS-verification) and reported a decrease in mortality for pediatric trauma patients treated at state-certified trauma centers compared to non-trauma centers, but no difference in mortality between children treated at pediatric compared to adult trauma centers [33]. Pracht et al. also found a reduction in probability of mortality for pediatric patients treated at state-certified trauma centers compared to non-trauma centers in Florida [34]. In contrast to Wang and Osler, however, Pracht found a reduction in mortality associated with provision of care at pediatric trauma centers compared to primarily adult trauma centers [34]. These studies highlight the importance of trauma accreditation, be it through ACS or state-based processes, for both free-standing pediatric centers and combined adult/pediatric centers that treat injured children, and raise concern that one in six sites in this study had no trauma accreditation by any means.

3.2. Trauma bay structure and processes of care

It is well established that a variety of providers care for injured children as a function of hospital and ED structure [35]. However, there is little understanding of how the roles of emergency medicine (EM) physicians and surgeons interact in the trauma bay, and how decisions are made regarding patient evaluation and management between the two

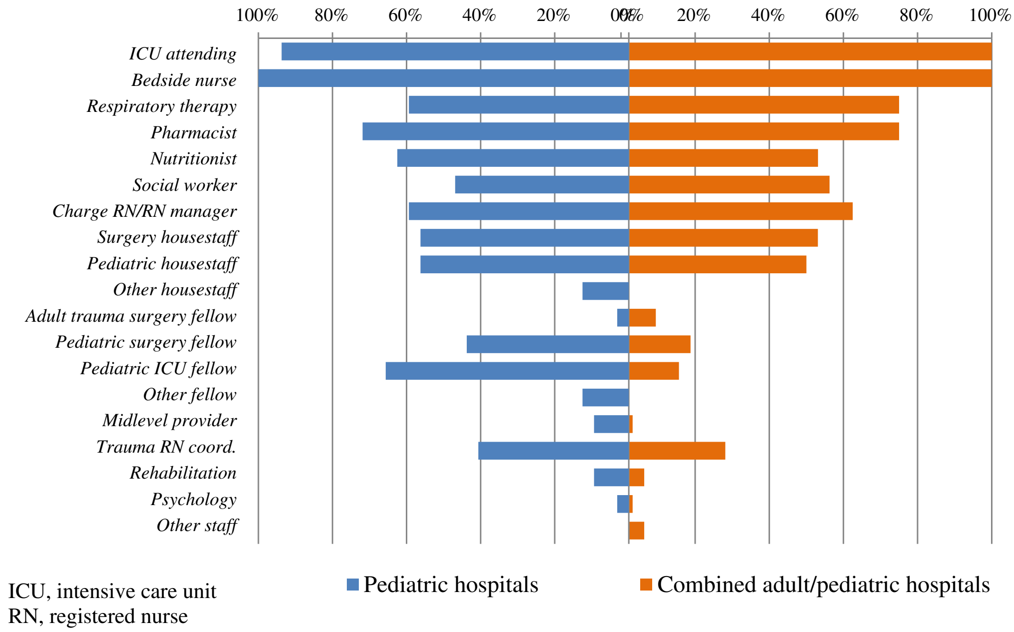

Fig. 2. Proportion of sites surveyed reporting involvement by specialty on daily rounds for pediatric trauma patients in the intensive care unit.

services. In our study, we found that the "primary decision maker" for injured children in the trauma bay was most often the surgery attending, irrespective of trauma team composition, hospital-type, and subspecialty surgical training.

Studies in adult trauma have generally found mixed results regarding the impact of in-house trauma surgeons on mortality, time to the operating room, and cost [36–39]. Studies on pediatric trauma are limited and similarly contradictory [40,41]. Despite a lack of scientific consensus, our findings indicated that most sites required attending or fellow-level surgical personnel at all trauma resuscitations, and with pediatric-specific training at three out of every four sites surveyed.

Guidelines for tiered trauma activation systems and the utilization of trauma teams are well established [18,42,43]. While tiered trauma activations were universal in our study, trauma team composition and use of management protocols varied greatly. Use of a protocol for head imaging, which has been recommended by the ACS, American Academy of Pediatrics, American College of Emergency Physicians, and Pediatric Emergency Care Applied Research Network to minimize radiation risks while optimizing care of the head injured patient, was found in only 67% of surveyed sites [43–45].

3.3. ICU structure for pediatric trauma patients

The high-intensity staffing model in pediatric intensive care units (ICU) has been shown to improve outcomes and decrease costs, and is a component of one of the four safety standards put forth by The Leapfrog Group [8,9,19]. It is reassuring that the majority of PICUs in our study were considered high-intensity despite which provider – the surgeon or the intensivist – was considered the primary physician and despite a high prevalence of centers reporting an "open" unit. Our data suggest that the surgeon was often considered the primary physician for pediatric trauma patients even in closed units where there was an intensivist as the "physician of record." In part, this dichotomy likely reflects the latent, unmeasured, and complex aspects of caring for critically injured children in which a surgeon may more often take the lead in pediatric trauma care. However it also reassuringly highlights the pervasiveness of the co-management, or team, model of care prevalent in PICUs. Irrespective of closed/open status and intensity level, in units with a primary provider specified, the other provider (surgeon or intensivist) was almost universally reported to be *very involved* in management decisions. This team approach appeared to be prevalent in both pediatric free-standing centers and combined pediatric-adult centers.

Variation exists in the broadly defined categories used to compare ICU staffing, thus hampering the development of best-practice models including specific element(s) that would positively impact outcomes. Moving forward, it will be necessary to better understand both salient and latent variation in the management of critically injury children, to inform best practices and establish quality metrics in the care of critically injured children. Our efforts to describe the variation in ICU team structure and daily round involvement is one step in this direction.

3.4. ICU care processes for pediatric trauma patients

Salient features of ICU processes of care that have been suggested to affect patient outcomes include continuity of patient care and hand-offs [46–48] and the use of protocols and checklists [49–51]. Continuity of care is an important metric of quality, but it must be weighed against the negative impact of staff burnout. We found that, on average, pediatric trauma patients managed in the ICU had more than six total handoffs between care providers in each 24 h period. Although they have been identified as points of risk, handoffs are inevitable; particularly in large units with high volume (our survey identified one unit with as many as 60 beds). Research suggests standardizing handoff practices has a positive impact on pediatric patient outcomes [46,47,52].

Protocol and checklist utilization has been shown to improve care in a variety of settings, from the operating room to the intensive care unit [49,51]. Generally, these have been associated with improved patient outcomes, reduced error, and improved resource utilization [49,53–57]. Our study, however, found that protocols and checklists were used relatively infrequently, with the exception of DVT prophylaxis and urinary catheter discontinuation, each reportedly used at more than 60% of sites. There were statistically significant differences between free-standing pediatric centers and combined adult/pediatric centers in use of protocols for DVT prophylaxis, C-spine clearance, and pain control, with free-standing pediatric centers being higher utilizers in all three care domains.

4. Limitations

Our study had many potential limitations. By design, it was limited to only centers that are part of the VPS consortium. All data were self-reported. This subjectivity may introduce bias, but this bias likely represents the "best-case scenario" at an individual institution. While experts in the field contributed to survey creation and it was field tested at a sample of centers and subsequently modified, the survey was not a previously validated and established tool. Finally, the study was most limited by a lack of outcomes data, limiting the ability to determine which infrastructures and care processes among the variation have a positive causal relationship to pediatric trauma outcomes and are likely optimal. Despite its limitations, the study also had strengths, including the high response and the uniquely described salient and latent information obtained on processes of care in both the trauma bay and PICU.

5. Conclusion

Variability exists in both structure and process involving the care for critically injured children. While acknowledging the unfinished debate regarding pediatric trauma care at PTCs vs. adult ATCs, it is clear that trauma center designation by the ACS or by the state is an important predictor of improved outcomes not only in adult trauma, but also in pediatric trauma. Despite this, our data were concerning in that one in every six sites surveyed, representing a disproportionate number of academic and free-standing pediatric hospitals, had neither ACS nor state designation of any kind. Recognizing that the vast majority of pediatric trauma patients are cared for outside of a children's hospital and/or trauma center of any kind, this survey study gives some insight into the potpourri of care that exists at even the highest level of care for the injured child.

Variation in care is not problematic as long as the care provided is optimal for each child. While it is important to implement evidence-based practices related to both structure and process of care into clinical practice, many best practices in pediatric trauma management remain undefined. To establish evidence-based practices, identification and description of specific structure and processes of care are paramount. Only then – based on the differences described – can evaluation of causal relationships to patient outcomes be examined. Herein, variability provides a platform for improvement. We have taken the first step to describe in detail the variability in salient characteristics related to structure and processes of care, and also in latent often un-measured characteristics. Clinical research must now address whether this variation is harmful or appropriate and dependent on regional resources.

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