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Pediatric solid organ injury operative interventions and outcomes at Harborview Medical Center, before and after introduction of a solid organ injury pathway for pediatrics

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Abstract

BACKGROUND—Although nonoperative management has become the standard of care for solid organ injury, variability exists in the care patients receive, and there are limited data regarding nonoperative management in patients with high grades of organ injury and substantial overall injury. We aimed to evaluate operative intervention frequency, including splenectomy, and patient outcomes before and after institution of the pediatric solid organ injury pathway at Harborview Medical Center (HMC) in 2005.

METHODS—This is a retrospective cohort study conducted at HMC for all pediatric solid organ injury patients from 2001 to 2012. Patients were identified in the Harborview Trauma Registry via DRG International Classification of Diseases—9th Rev. (ICD-9) codes for the presence of liver and spleen injuries. Demographic information, clinical characteristics, and ICD-9 procedure codes were also obtained from the trauma registry. Outcomes including splenectomy, a related abdominal surgery (exploratory laparotomy, spleen or liver repair, or splenectomy), mortality, and length of stay were compared between periods before and after 2005, adjusted for Injury Severity Score (ISS).

RESULTS—The pediatric solid organ injury population at HMC ($n = 712$) has a high frequency of high-grade injury (35% Grade IV or V) and a high level of overall injury severity (median ISS, 21). Splenectomy was rare and remained stable over time despite an increase in severity of injury

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AUTHORSHIP

L.A.D. performed the literature search, data collection, and manuscript writing and contributed to the study design, data analysis, interpretation, and critical revision. N.S.W. and M.A.K. contributed to the study design, data analysis, interpretation, and critical revision. F.P.R. and J.C. contributed to the data analysis, interpretation, and critical revision.

DISCLOSURE

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(from 2.4% to 0.8%, $p = 0.44$, among patients with isolated injury and from 4.0% to 3.3%, $p = 0.78$, among patients with nonisolated injury). Other abdominal surgeries also remained stable over time. Mortality decreased among patients with nonisolated injury (from 11.2% to 4.8%, $p = 0.01$). Length of stay decreased among patients with isolated organ injury, from a median of 4 days (interquartile range, 3–5 days) to 2 days (interquartile range, 2–3 days) ($p < 0.0005$) as well as within the lower ISS strata among patients with nonisolated organ injury (from a median of 4 days to 2 days among ISS < 12 , $p = 0.007$; from 5 days to 3 days among ISS of 12–20, $p = 0.0001$; and from 7 days to 4 days among ISS of 21–33, $p = 0.003$).

CONCLUSION—Care in the recent period (2005–2012) was associated with a stable, low frequency of splenectomy; decreased mortality for patients with nonisolated injury; and decreased hospital length of stay among most subsets of patients, suggesting improved care despite an increase in patients' severity of injury.

LEVEL OF EVIDENCE—Therapeutic study, level IV; epidemiologic study, level III.

Keywords

Solid organ injury; spleen injury; splenectomy; pediatrics; clinical pathway

The care of isolated solid organ injury to the liver and spleen has changed dramatically during the past several decades, as nonoperative management has become the standard of care. Review of this experience has led to the publication of benchmarks of a splenectomy frequency of no more than 3% in children with isolated splenic injuries and of 5% to 11% in all children with splenic injury.¹ This goal seems to be achievable in a variety of care settings^{2–4} without subjecting patients to increased risk of transfusion, urgent surgery, late complications, or mortality.^{4–12} In nonoperatively managed patients, subsequent efforts aimed to decrease resource use showed that most may be successfully managed with relatively short intensive care unit (ICU) stays, relatively short hospital stays, limited laboratory draws, and limited repeat imaging tests.^{5–7,13–16}

A number of issues impact whether this approach to care is consistently provided to patients; variability exists in the nonoperative care that patients actually receive.¹⁷ Management algorithms (also called pathways or clinical practice guidelines) are increasingly used to address variability in clinical care. Many management algorithms for solid organ injury have been published and studied, some based on American Pediatric Surgical Association guidelines and some based on other criteria.^{5–7,13–16} However, there are limited data available on outcomes associated with the application of these guidelines to severely injured patients with high grades of solid organ injury, as patients with Grade V injuries were excluded from many studies on pediatric solid organ injury pathway care^{6,7,13,14,16} and are present only in low numbers in others.^{5,15}

Harborview Medical Center (HMC) developed an institution-specific management pathway in 2005 to standardize care for pediatric patients with isolated solid organ injury (hepatic and splenic injuries). This pathway is based on existing published pathways^{5,6} and emphasizes hemodynamic status as the primary factor in decision making, while aiming to minimize laboratory draws, nil per os and bed rest periods, ICU observation, and hospital

days for hemodynamically stable patients (Fig. 1). Given that HMC cares for a high proportion of trauma patients with multiple injuries and with high grades of splenic and hepatic injury, who are represented in low numbers in similar studies, we aimed (1) to compare the proportion of patients (with both isolated and nonisolated injury) undergoing operative interventions before and after the pathway was introduced in 2005 and (2) to compare outcomes including length of stay and mortality between these two periods.

PATIENTS AND METHODS

We conducted a review of the records of all pediatric patients (<18 years of age) admitted to HMC with solid organ injury (hepatic or splenic injury) from 2001 to 2012. The University of Washington Institutional Review Board approved this study, and the need for informed consent was waived. Solid organ injury was defined as having an DRG International Classification of Diseases—9th Rev. (ICD-9) code describing a hepatic or splenic injury (864.00–864.05, 864.09–864.15, 864.19, 865.00–865.04, 865.09–865.14, and 865.19). Patients meeting this definition were identified by querying the Harborview Trauma Registry. Two patients had separate admissions; both were included. No records were subsequently excluded.

From the trauma registry, demographic and injury-related information were obtained, including age, sex, Injury Severity Score (ISS), emergency department vital signs, emergency department disposition, hospital length of stay, mortality, discharge ICD-9 codes, organ injury Abbreviated Injury Scale (AIS) codes, and ICD-9 procedure codes, dates, and times. AIS codes were only available in the registry for the years 2005 to 2012. Additional clinical data were obtained from the clinical chart, accessed and reported by the AMALGA informatics group. Patients were classified as being “hemodynamically unstable” if their vital signs in the emergency department (according to the trauma registry) were outside the age-specific ranges delineated in the pathway (Table 1). Injuries were classified as high-grade if they were Grade IV or Grade V by either ICD-9 criteria¹⁸ or AIS scoring. ISS was further categorized into quartiles for stratified comparisons (ISS < 12; ISS, 12–20; ISS, 21–33; ISS > 33).

No standard definition of isolated organ injury based on ICD-9 coding was identified in the literature. Patients were classified as having isolated organ injury if no ICD-9 codes were present identifying either multiple solid organ injuries or any additional severe injuries, including cerebral edema (ICD-9 codes 348–350), traumatic brain injury (ICD-9 codes 850–852 and 854–855), myocardial contusion or depression, or pulmonary vascular injury (ICD-9 codes 410–429), cerebral infarct (ICD-9 codes 433–444), pneumothorax/hemothorax or penetrating thoracic trauma (ICD-9 codes 511–518, 860–863, 875–876, and 901–903), peritonitis or penetrating abdominal trauma (ICD-9 codes 567–568 and 868.1–868.19), intracranial hemorrhage or cerebral laceration (ICD-9 codes 800.1–802, 852–854, and 803–805), spinal cord injury (ICD-9 codes 806–807), and pelvic fracture or long bone fracture (ICD-9 codes 808–809, 821–822, and 812–813).

The primary operative outcome of interest was receipt of splenectomy (ICD-9 procedure code 41.5). An additional operative outcome of interest was defined as one or more of the

following abdominal surgeries: spleen surgery (ICD-9 codes 41.5, 41.93, and 41.95), liver surgery (50.2, 50.22, 50.3, 50.6, 50.61, and 50.69), or exploratory laparotomy (54.11, 54.1, and 54.19), given that many patients who receive splenectomy do so after an exploratory laparotomy is performed for other indications (peritonitis, ongoing bleeding, or hemodynamic instability).

Statistical Analysis

Within categories of isolated and nonisolated injury, the population was described for the prepathway period (2001–2004) and the postpathway period (2005–2012) using descriptive statistics for age, sex, ISS, splenic and hepatic injuries, proportion of high-grade injuries, and presence of hemodynamic instability. These variables were compared for clinically relevant differences between periods and for possible associations with the outcome of interest to determine potential confounders.

We evaluated the proportion of isolated and nonisolated spleen injury patients receiving splenectomy by period and of isolated and nonisolated solid organ injury patients receiving an abdominal surgery of interest by period. In the descriptive analysis, ISS was the only item associated with both period and splenectomy. To address confounding by ISS over time, we calculated a directly adjusted relative risk to estimate surgical and mortality proportions adjusted for ISS strata. Surgical and mortality outcomes, adjusted for ISS strata, were then compared using the Mantel-Haenszel χ^2 test. Median hospital length of stay was compared between periods within the isolated and nonisolated injury populations and within ISS strata using a two-sample Wilcoxon rank-sum test. STATA SE 12 was used for all analyses.

RESULTS

We identified 712 patients who met inclusion criteria. This included 236 from the prepathway period (2001–2004) and 476 from the postpathway period (2005–2012). Descriptive statistics of the population studied are presented in Table 2. Age and sex were similar between periods. ISS was higher in the postpathway period for patients with both isolated and nonisolated injury. A substantial proportion of patients were severely injured, with more than half of the cohort having an ISS of 21 or higher. A substantial proportion of both isolated and nonisolated organ injury patients had high-grade injury (Grade IV or V, 35.3% and 36.5%, respectively).

The proportion of patients qualifying as hemodynamically unstable, based on emergency department vital signs and per the pathway guidelines, was extremely low, including among patients ultimately requiring operative intervention. Three of 27 patients (11.1%) who received splenectomy and 8 of (11.8%) 68 patients who underwent abdominal surgery qualified as being hemodynamically unstable. However, those who were hemodynamically unstable had a median ISS of 52 (interquartile range [IQR], 34–66) and a mortality of 50.0%. Among those with hemodynamic instability who survived ($n = 11$), median length of stay was 20.5 days (IQR, 9–34 days), 54.5% required an abdominal surgery, and 33% of those with spleen injury required splenectomy.

Outcomes evaluated are reported in Table 3. Spleen-injured patients requiring splenectomy had a much higher median ISS than those who did not receive splenectomy (36 vs. 20). The association of ISS with splenectomy as well as with period raised concern for confounding; therefore, outcomes were compared further within ISS strata, and an ISS-adjusted estimate was used to evaluate the trend over time. The proportion of spleen-injured patients undergoing splenectomy and the proportion of patients undergoing abdominal operative intervention did not change over time. However, mortality among patients with nonisolated injury decreased over time from 11.2% to 4.8% ($p = 0.01$). Median length of stay also decreased after 2005 among patients with isolated solid organ injury (4 days vs. 2 days, $p < 0.0005$) and decreased among patients with nonisolated solid organ injury within the three lower ISS quartiles (4 days vs. 2 days, $p = 0.007$; 5 days vs. 3 days, $p = 0.0001$; and 7 days vs. 4 days, $p = 0.003$, respectively).

DISCUSSION

Following the introduction of the HMC Pediatric Solid Organ Injury Pathway in 2005, mortality decreased among patients with nonisolated injury, and length of stay decreased for most subsets of patients. However, splenectomy and abdominal operative intervention (including splenectomy, liver surgery, and exploratory laparotomy) did not change over time. Despite the high overall severity of injury and high proportion of Grade IV and V solid organ injury in this population, HMC achieves a length of stay comparable with that recommended by American Pediatric Surgical Association guidelines¹⁶ and achieved by pathway care in other institutions.⁷ While we are unable to conclude that pathway care is responsible for these outcomes, as we were unable to evaluate pathway adherence, HMC has demonstrated improvement in the care it provides for these patients over time despite caring for more severely injured patients. This study also suggests that there are areas, including length of stay among patients with ISS greater than 33, which may warrant additional efforts to improve care.

This pathway also aims to classify patients' hemodynamic status based on age-specific vital sign parameters to help guide resuscitation and operative decision making. Very few patients met pathway criteria for hemodynamic instability, limiting the clinical utility of this parameter as defined in the pathway. The patients who did meet these criteria had serious injuries and poor outcomes, so the current definition may help alert providers to patients who are likely to be seriously ill. Alternatively, this component of the pathway may warrant revision to improve its sensitivity for identifying patients who may benefit from aggressive resuscitation.

The proportion of patients with Grade IV and V injury among those with isolated injury (35.3%, after 2005) in the HMC population is high; other pathways reported include no more than 13% Grade IV and V injuries, with a mean organ injury grade of between 2.3 and 2.8.^{5-7,13,14,16} Despite the high grades of organ injury and substantial overall injury in the HMC solid organ injury population, the overall splenectomy frequency of 4.0% among all pediatric splenic injury patients at HMC from 2005 to 2012 falls below published benchmarks of 5% to 11% in a nonisolated injury population.^{1,19} This suggests that there

may be opportunity for further reducing splenectomy frequency, particularly among severely injured patients.

This study was unable to evaluate the pathway's influence on clinician behavior, as we were unable to reliably assess preoperative intravenous fluid and blood product use. Clinical records were reviewed in detail for blood product use among all patients undergoing splenectomy in the recent period, for which robust data were available (10 patients, 2008–2012) (see Table, Supplemental Digital Content 1, <http://links.lww.com/TA/A604>). Among these patients, 7 of 10 received blood products before splenectomy. The 3 of 10 patients who received no blood products were all admitted to the pediatric ICU before splenectomy, suggesting a possible opportunity to improve preoperative blood product resuscitation efforts outside of the emergency department setting.

Strengths of this study include a large study population, including high numbers of severely injured patients and patients with Grade IV and V solid organ injury, in light of limited published data regarding these patients. While basing our patient selection on ICD-9 codes from an established trauma registry may have led to potentially missed cases, this number was likely low. We compared AIS codes and ICD-9 codes for liver and spleen injury for the years 2005 to 2012. Only 7 (1.7%) of 415 patients were missing an ICD-9 code for spleen injury, and 6 (1.6%) of 366 patients were missing an ICD-9 code for liver injury. We may also have underestimated the proportion of patients having isolated injury by using a ICD-9 code-based definition, which may have included some minor injuries; we were restricted by the limited availability of AIS scores in the trauma registry to the 2005 to 2012 period. HMC is a regional referral center; we were unable to reliably adjust for length of time elapsed since injury, which may have changed during the period in the study.

In summary, this review shows that, despite a high overall severity of injury and a high proportion of high-grade injury, HMC has demonstrated improvement in the care it provides for pediatric solid organ injury patients over time, by achieving a decline in mortality among patients with nonisolated injury, and a decreased median length of stay in several subgroups of patients, after introduction of the pediatric solid organ injury pathway in 2005.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
HMC solid organ injury pathway for pediatrics. Hemodynamic status based on age-specific vital sign classification; see Table 1.

Table 1

Harborview Medical Center Solid Organ Injury Pathway for Pediatrics: Triggers for Hemodynamic Instability.

Age	Maximum Pulse (bpm)*	Minimum SBP (mmHg)	Respirations (/min)
0-12 months	<160	60	30-60
1-5 years	<130	70	24-40
6-11 years	<110	80	18-34
12-17 years	<100	90	12-30

* With pain and anxiety treated.

Abbreviations: bpm = beats per minute. SBP = systolic blood pressure.

Table 2

Demographics and injury description for 712 pediatric solid organ injury patients at Harborview Medical Center, 2001-2012

	Isolated solid organ injury		Non-isolated solid organ injury	
	Pre-pathway (2001-2004) N=84	Post-pathway (2005-2012) N=144	Pre-pathway (2001-2004) N=152	Post-pathway (2005-2012) N=332
Age, years ($\pm$ SD)	10.8 ($\pm$ 4.5)	10.5 ($\pm$ 4.5)	12.4 ($\pm$ 4.9)	12.1 ($\pm$ 4.9)
% Male	76%	77%	59%	66%
Median ISS (IQR)	9 (5-16)	10 (9-17)	24.5 (14-34)	29.5 (21-41)
High-grade solid organ injury (grade IV-V) ^a	-	35.3%	-	36.5%
Liver injuries	27 (32.1%)	62 (43.1%)	80 (55.3%)	191 (59.3%)
<i>Grade I-III</i>	--	13 (21.0%)	--	42 (22.0%)
<i>Grade IV-V</i>	--	16 (25.8%)	--	55 (28.8%)
<i>Unspecified</i>	--	33 (53.2%)	--	94 (49.2%)
Spleen injuries	57 (67.9%)	82 (56.9%)	91 (60.5%)	192 (57.8%)
<i>Grade I-III</i>	--	40 (48.8%)	--	111 (57.3%)
<i>Grade IV-V</i>	--	31 (37.8%)	--	55 (28.6%)
<i>Unspecified</i>	--	6 (7.3%)	--	19 (9.9%)
Hemodynamically unstable ^b	1/84 (1.2%)	0/143 (0%)	5/150 (3.3%)	16/330 (4.9%)

SD = standard deviation. ISS = injury severity score. IQR = interquartile range.

^a Specific injury grades were only well-defined for years in which individual AIS scores were coded in the Harborview trauma registry, 2005-2012.

^b Excluding 5 patients (0.7%) missing hemodynamic data.

Table 3

Outcomes for 712 pediatric solid organ injury patients at Harborview Medical Center, 2001-2012

	Isolated solid organ injury		Non-isolated solid organ injury	
	Pre-pathway (2001-2004) N=84	Post-pathway (2005-2012) N=144	Pre-pathway (2001-2004) N=152	Post-pathway (2005-2012) N=332
Splenectomy ^a	2.4%	2.1%	4.0%	4.8%
ISS-adjusted ^b	-	0.77%	$p = 0.44$	$p = 0.78$
ISS <12	1/52 (1.9%)	0/83	0/23	0/17
ISS 12-20	1/28 (3.6%)	0/46	0/38	1/61 (1.6%)
ISS 21-33	0/3	3/14 (21.4%)	4/51 (7.8%)	1/110 (0.91%)
ISS >33	0/1	0/1	2/40 (5.0%)	14/144 (9.7%)
Abdominal operation ^c	4.8%	4.9%	11.2%	12.4%
ISS-adjusted ^b	-	3.2%	$p = 0.66$	$p = 0.82$
ISS <12	2/52 (3.9%)	1/83 (1.2%)	3/23 (13.0%)	0/17
ISS 12-20	2/28 (7.14%)	2/46 (4.4%)	3/38 (7.9%)	3/61 (4.9%)
ISS 21-33	0/3	4/14 (28.6%)	6/51 (11.8%)	10/110 (9.1%)
ISS >33	0/1	0/1	5/40 (12.5%)	28/144 (19.4%)
Mortality	0.0%	0.0%	11.2%	7.5%
ISS-adjusted ^b	-	-	$p = 0.01$	
ISS <12	-	-	0/23	0/17
ISS 12-20	-	-	3/38 (7.9%)	0/61
ISS 21-33	-	-	5/51 (9.8%)	2/110 (1.8%)
ISS >33	-	-	9/40 (22.5%)	23/144 (16.0%)
Length of stay ^d	4 (3-5)	2 (2-3)	$p < 0.0005$	$p = 0.08$
ISS <12	4(3-4)	2(1-2)	$p < 0.0005$	$p = 0.007$
ISS 12-20	4(3-5)	3(2-3)	$p = 0.005$	$p = 0.0001$
ISS 21-33	4(2-6)	3(2-5)	$p = 0.95$	$p = 0.003$
ISS >33	3	48	$p = 0.32$	$p = 0.63$

ISS = injury severity score.

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^b Among patients with a spleen injury.

^b Estimate adjusted for ISS using direct adjustment over the ISS quartiles shown. P values based on Mantel-Haenszel chi-square test between time periods.

^c Combined outcome including at least one of: liver repair, spleen repair or splenectomy, or exploratory laparotomy.

^d Reported in days (IQR). Two-sample Wilcoxon rank-sum test applied for the entire sample, and within each ISS quartile.