Management of children with solid organ injuries after blunt torso trauma

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BACKGROUND: Management of children with intra-abdominal solid organ injuries has evolved markedly. We describe the current management of children with intra-abdominal solid organ injuries after blunt trauma in a large multicenter network.

METHODS: We performed a planned secondary analysis of a prospective, multicenter observational study of children (<18 years) with blunt torso trauma. We included children with spleen, liver, or kidney injuries identified by computed tomography, laparotomy/laparoscopy, or autopsy. Outcomes included disposition and interventions (blood transfusion for intra-abdominal hemorrhage, angiography, laparotomy/laparoscopy). We performed subanalyses of children with isolated injuries.

RESULTS: A total of 12,044 children were enrolled; 605 (5.0%) had intra-abdominal solid organ injuries. The mean (SD) age was 10.7 (5.1) years, and injured organs included spleen 299 (49.4%), liver 282 (46.6%), and kidney 147 (24.3%). Intraperitoneal fluid was identified on computed tomography in 461 (76%; 95% confidence interval [CI], 73–80%), and isolated solid organ injuries were present in 418 (69%; 95% CI, 65–73%). Treatment included therapeutic laparotomy in 17 (4.1%), angiographic embolization in 6 (1.4%), and blood transfusion in 46 (11%) patients. Laparotomy rates for isolated injury were 11 (5.4%) of 205 (95% CI, 2.7–9.4%) at non-freestanding children's hospitals and 6 (2.8%) of 213 (95% CI, 1.0–6.0%) at freestanding children's hospitals (difference, 2.6%; 95% CI, −7.1% to 12.2%). Dispositions of the 212 children with isolated Grade I or II organ injuries were home in 6 (3%), emergency department observation in 9 (4%), ward in 114 (54%), intensive care unit in 73 (34%), operating suite in 7 (3%), and transferred in 3 (1%) patients. Intensive care unit admission for isolated Grade I or II injuries varied by center from 9% to 73%.

CONCLUSION: Most children with solid organ injuries are managed with observation. Blood transfusion, while uncommon, is the most frequent therapeutic intervention; angiographic embolization and laparotomy are uncommon. Emergency department disposition of children with isolated Grade I to II solid organ injuries is highly variable and often differs from published guidelines. (*J Trauma Acute Care Surg*. 2015;79: 206–214. Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Prognostic/epidemiologic study, level III; therapeutic study, level IV.

KEY WORDS: Pediatric trauma; abdominal organ injury; children's hospitals.

The management of intra-abdominal solid organ injuries has evolved steadily during the last three decades.[1] A better understanding of the natural history of children with spleen, liver, and kidney injuries now allows for less aggressive and more selective operative intervention. Nonoperative management of solid organ injuries has its roots in pediatric trauma care, and many of the principles developed in the management of children with solid organ injuries have carried over into the treatment of adults.[2–8]

We sought to characterize the current management of children with intra-abdominal solid organ injuries using data from a large, multi-institutional, prospectively conducted study in the Pediatric Emergency Care Applied Research Network (PECARN).[9] We specifically analyzed children with isolated spleen, liver, and kidney injuries to minimize the effects on diagnosis and treatment of multiple intra-abdominal injuries in the same patient. We hypothesized that most children with spleen, liver, and kidney injuries, especially lower grades of injury, are currently being successfully managed without major therapeutic interventions but that considerable variability in management still exists.

PATIENTS AND METHODS

This study was a planned secondary analysis of a prospective, observational study conducted in the PECARN. The study was approved by the institutional review boards of all 20 participating sites. Six of the sites were non-freestanding children's hospitals, and 14 were freestanding children's hospitals. A detailed description of the study methods has been previously published.[10] Methods specific to the current subanalysis are presented in the following sections.

Children younger than 18 years with blunt torso (thorax and abdomen) trauma evaluated in the emergency department (ED) of any of the participating PECARN centers from May 2007 to January 2010 were eligible for the study. The current study included those patients who were eligible for the primary study and were ultimately diagnosed with intra-abdominal solid organ injuries. Patients were included in the original study if they experienced blunt trauma and had any of the following after a traumatic mechanism: decreased level of consciousness (except not isolated head injury), paralysis, multiple nonadjacent long bone fractures, high-speed motor vehicle crash (≥40 mph), car

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versus pedestrian or bike at 5 mph or faster, fall from 20 feet or higher, torso crush injury, physical assault involving the abdomen, or physician concern for abdominal injury resulting in abdominal computed tomography (CT) scanning, abdominal ultrasound, laboratory screening for abdominal injury, or chest/pelvic radiography. Patients were excluded if they met any of the following criteria: injury occurring greater than 24 hours before presentation, penetrating trauma, preexisting neurologic disorders impeding reliable examination, known pregnancy, or transfer from another hospital with previous abdominal CT or diagnostic peritoneal lavage.

Children were considered to have intra-abdominal solid organ injuries if they had an injury to the spleen, liver, or kidneys identified by radiography, diagnostic peritoneal lavage, surgery, or autopsy. Children were considered to have any intra-abdominal injury if they had an abdominal wall traumatic fascial defect or an injury identified to the spleen, liver, urinary tract (from the kidney to the urinary bladder), gastrointestinal tract (including the bowel or associated mesentery from the stomach to the sigmoid colon), pancreas, gallbladder, adrenal gland, or an intra-abdominal vascular structure. Spleen, liver, and kidney injuries were graded based on preexisting American Association for the Surgery of Trauma organ injury grading scales.[11,12] Grades III to VI were combined into a single category for descriptive purposes and were considered higher-grade injuries. Children with hematuria were not considered to have renal injuries unless a specific injury to the kidney was identified by radiography, by laparotomy, or at autopsy. Children were considered to have *isolated* solid organ injuries if the spleen, liver, or kidney injury was their only intra-abdominal injury, solid organ or otherwise, even if extra-abdominal injuries were present.

At the time of initial evaluation, the treating physician documented patient history and physical examination findings on a standardized data collection form. Data collected at the time of initial evaluation pertinent to this study included initial systolic blood pressure and Glasgow Coma Scale (GCS) score. Trained research coordinators and physician site investigators abstracted data from the medical records. All children undergoing laparotomies/laparoscopies had their operative reports independently abstracted by board-certified surgeons with extensive pediatric trauma experience to identify specific operative interventions and to make determinations about whether the procedures were therapeutic.

The primary study outcome in the parent study was solid organ injury undergoing acute intervention. Children with solid organ injuries were considered to have an acute intervention if they died because of their solid organ injuries or if they underwent any of the following: (1) therapeutic intervention to the solid organ injury at the time of laparotomy or other operative intervention, (2) blood transfusion secondary to abdominal hemorrhage from the injured solid organ, or (3) angiographic embolization to treat solid organ hemorrhage. Angiography that did not result in embolization was not considered a therapeutic intervention. Operative reports were reviewed for indications for operative intervention, estimated blood loss, and therapeutic intraoperative interventions. Intraoperative interventions were considered therapeutic if an organ was removed or repaired, hemostasis was achieved by operative means, or a stent/tube was placed in the case of renal injuries. Determination of whether a blood transfusion was given for abdominal hemorrhage was based on predefined criteria and made by the physician site investigator. If the intra-abdominal hemorrhage was considered to have contributed any portion to the need for transfusion, the patient was categorized as having a blood transfusion for abdominal hemorrhage. If the site investigator was unable to make a definitive determination on the reason for transfusion, a five-member study panel adjudicated this decision.

The secondary outcome was disposition from the ED. Patient dispositions were coded as death in the ED, home, ED observation, hospital ward, intensive care unit, operating suite, or transfer to a different institution. Patient disposition was considered home if they were discharged from the ED to any outpatient location (including the patient's actual home, jail, or a juvenile detention center). To prevent skewing of the data from small numbers, the comparison of intensive care unit and ward admissions was limited to centers with at least 10 total admissions in the specified category. To minimize the potential that other, nonabdominal injuries may have impacted the decision to admit to the intensive care unit, we performed a subanalysis of patient disposition for the subset of children with isolated intra-abdominal injuries, GCS scores of 15, and no thoracic injuries.

Categorical data were summarized using counts, percentages, and exact 95% confidence intervals (CIs) for proportions. Differences between intensive care unit admission rates for children with high- and low-grade solid organ injuries were estimated using logistic regression models and generalized estimating equations to control for within-site correlation. Differences between the rates of intervention between solid organ injuries were estimated using exact 95% intervals for differences in proportions. Differences between grades of isolated solid organ injuries for different organs were analyzed using Fisher's exact test. All analyses were conducted in SAS 9.4.

RESULTS

In the parent study, 12,044 children were enrolled. Of these, 605 (5.0%) were determined to have liver, spleen, or kidney injuries. The mean (SD) age of those with solid organ injuries was 10.7 (5.1) years, and 392 (65%) were male. The mechanisms of injury in these 605 children were as follows: motor vehicle collision in 181 (29.9%), fall in 109 (18.0%), pedestrian/bicyclist struck by a moving vehicle in 113 (18.7%), bicycle collision/fall in 57 (9.4%), motorized vehicle collision in 48 (7.9%), object struck abdomen in 75 (12.4%), other in 10 (1.7%), and unknown in 12 (2.0%). Twenty-four children (4.0%) died from the following causes: traumatic brain injury in 14, multiple blunt force trauma in 8, intra-abdominal injury in 1, and other in 1.

The 605 children with solid organ injuries had injuries to the spleen in 299 (49.4%), liver in 282 (46.6%), and kidney in 147 (24.3%). Four hundred sixty-one children (76%; 95% CI, 73–80%) had intraperitoneal fluid identified by abdominal CT scan, laparotomy, or autopsy. Four children underwent diagnostic peritoneal lavage; none of them were found to have intra-abdominal injury. Of the children with solid organ injuries, 418 (69%; 95% CI, 65–73%) had isolated solid organ injuries, including spleen in 197 (47.1%), liver in 157 (37.6%), and kidney in 64 (15.3%). The other 187 children (31%) had

TABLE 1. Injury Grade for the 418 Children With Isolated Solid Organ Injuries

Injury Grade	Spleen	Liver	Kidney
I	35 (17.8%)	40 (25.5%)	23 (35.9%)
II	50 (25.4%)	50 (31.8%)	14 (21.9%)
III–VI	112 (56.9%)	67 (42.7%)	27 (42.2%)
Total	197	157	64

$p < 0.01$ for differences in grades of spleen versus liver and kidney injuries.

multiple intra-abdominal injuries, including 19 (10%) with pancreatic injuries and 32 (17%) with gastrointestinal injuries.

Of the 418 children with isolated solid organ injuries, 299 (72%; 95% CI, 67–76%) had intraperitoneal fluid. The grades of the injuries in children with isolated solid organ injuries are shown in Table 1. The percentage of injuries that were higher grade was significantly greater for spleen injuries than for either liver or kidney injuries ($p < 0.01$).

ED dispositions and associated grade of injuries for the 418 children with isolated solid organ injuries are shown in Table 2. Admission to an intensive care unit bed varied by organ injured as well as by injury grade. Seven children were discharged home from the ED, of whom five (71.4%) had Grade I or II kidney injuries. The most common ED disposition was to the inpatient ward, including more than half of the children with high-grade kidney or spleen injuries. Of the 73 children admitted to the intensive care unit with Grade I or II injuries, 66 (90%; 95% CI, 81–96%) did not require interventions of any kind. Rates of intensive care unit admission varied considerably by center, both for isolated Grade I and II injuries as well as for isolated injuries Grade III or higher. For those sites with more than 10 children with intra-abdominal injuries, intensive care unit admission rates ranged from a low of 9% to a high of 73% for children with Grade I and II injuries (Fig. 1). Intensive care unit admission was more likely for children with higher-grade injuries (odds ratio, 1.6; 95% CI, 1.0–2.5; $p = 0.067$) but was still quite variable, ranging from 18% to 82% (Fig. 2) among centers with at least 10 cases. In the subanalysis of children with isolated solid organ injuries, GCS scores of 15, and no thoracic injuries, 22 (20%) of 110 children with Grade I and II injuries were admitted to the intensive care unit (range between sites regardless of number of cases of 0–100%), and 44 (41%) of 108 children with Grade III or higher injuries were admitted to the intensive care unit (range between sites regardless of number of cases of 0–100%).

Children with isolated solid organ injuries were less likely to undergo acute interventions (54/418, 13%; 95% CI, 10–17%) compared to those children with additional abdominal injuries (66/187, 35%; 95% CI, 29–43%). Acute interventions for those children with isolated solid organ injuries, stratified by injury grade, are shown in Table 3, along with median lengths of stay for children with different organ injuries and grades. Laparoscopy was performed in 10 children. None of those children had therapeutic interventions. Six (6.1%) of the 98 children with isolated Grade I solid organ injuries had blood transfusions for abdominal hemorrhage and one (1.0%) underwent a therapeutic laparotomy. These children are described in Table 4.

Of the 299 children with spleen injuries, 22 (7.4%; 95% CI, 4.7–10.9%) were treated with splenectomy including 6 (3.0%) of 197 (95% CI, 1.1–6.5%) with isolated injuries and 16 (15.7%) of 102 (95% CI, 9.2–24.2%) with nonisolated injuries. Grades of injuries in these 22 children were as follows: Grade III in 5, Grade IV in 6, and Grade V in 11. Of the 85 children with isolated Grade I or II spleen injuries, 3 (3.5%) underwent transfusion and none required laparotomy.

One patient with an isolated Grade I liver injury underwent therapeutic laparotomy. That patient had a devastating head injury and a positive abdominal ultrasonography examination result. At laparotomy, the liver injury was identified and packed because the patient was hemodynamically unstable. The patient arrested in the operating room and was not able to be resuscitated. The patient was categorized as having a therapeutic laparotomy

TABLE 2. ED Disposition for the 418 Patients With Isolated Solid Organ Injuries by Injury Grade

	Grade I			Grade II			Grade III – VI		
	Spleen	Liver	Kidney	Spleen	Liver	Kidney	Spleen	Liver	Kidney
Home	0 (0.0)	0 (0.0)	2 (8.7)	1 (2.0)	0 (0.0)	3 (21.4)	1 (0.9)	0 (0.0)	0 (0.0)
Ward	13 (37.1)	24 (60.0)	13 (56.5)	27 (54.0)	29 (58.0)	8 (57.1)	53* (47.7)	23 (34.3)	17 (63.0)
Short stay/observation	5 (14.3)	1 (2.5)	2 (8.7)	0 (0.0)	0 (0.0)	1 (7.1)	0 (0.0)	1 (1.5)	0 (0.0)
Operating suite	2 (5.7)	1 (2.5)	2 (8.7)	2 (4.0)	0 (0.0)	0 (0.0)	8 (7.2)	6 (9.0)	0 (0.0)
Intensive care unit	14 (18.2)	14 (35.0)	4 (17.4)	18 (36.0)	21 (42.0)	2 (14.3)	45 (40.5)	35 (52.2)	9 (33.3)
Transferred	1 (2.9)	0 (0.0)	0 (0.0)	2 (4.0)	0 (0.0)	0 (0.0)	4 (3.6)	2 (3.0)	1 (3.7)
Total	35	40	23	50	50	14	111	67	27

Percentages in parentheses.
*Two children underwent angiographic embolization of their splenic injuries prior to ward admission.

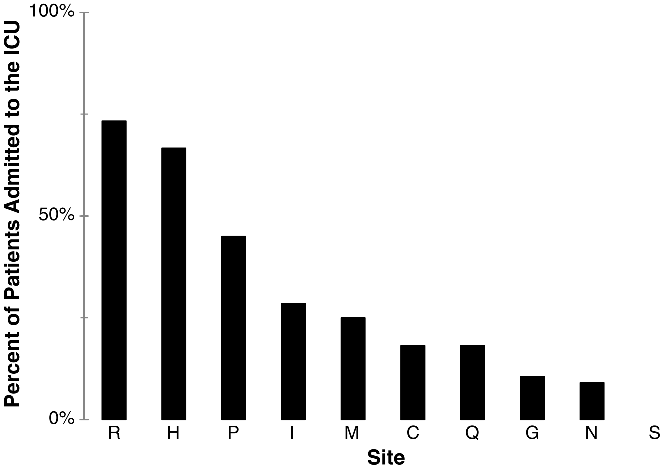

Figure 1. Intensive care unit admission rates by center for isolated Grade I and II injuries.

because packing was one of the predefined therapeutic interventions. The patient's death, however, was caused by his head injury and was unrelated to his liver injury. Four additional children with isolated Grade I or II liver injuries received blood transfusions, for a total intervention rate of 5.6% (5/90) in children with isolated Grade I or II liver injuries. No children with isolated Grade I or II kidney injuries required specific interventions.

Rates of intervention were considerably higher for children with higher-grade injuries, with blood transfusions occurring most commonly. All eight therapeutic laparotomies for children with isolated spleen injuries were performed in the 112 children with higher-grade injuries, for an operative intervention rate in this group of children of 7.1% (95% CI, 3.1–13.6%). The operative interventions consisted of one splenorrhaphy, one partial splenectomy, and six splenectomies. All eight children who underwent angiographies also had high-grade spleen injuries, and six underwent embolization. No children with liver or kidney injuries underwent embolization.

Of the children with isolated high-grade liver injuries, 12 (17.9%) of 67 (95% CI, 9.6–29.2%) underwent interventions, with most of the interventions again consisting of blood transfusions. Four children (6.0%) in the high-grade liver injury cohort underwent therapeutic laparotomies. A higher percentage of children with high-grade kidney injuries underwent either any intervention (25.9%) or surgical intervention (14.8%) than did children with spleen or liver injuries.

Review of the operative notes revealed 17 therapeutic operative interventions. The four interventions in children with renal injuries were all retrograde urethrograms and stent/drain placements performed for diagnosis and treatment of Grade III to IV injuries. The primary indication for operative intervention was listed on the operative note of 12 of the 13 therapeutic laparotomies performed for liver and spleen injuries. Shock was the primary indication in eight of the cases, peritonitis in two, a declining hematocrit in one, and abdominal compartment syndrome in one. The amount of blood loss was described as "massive" in one operative note, and a volume was listed on 10 other operative notes. The average volume listed was 1,545 mL.

In children with solid organ injuries, the surgical intervention rate at non-freestanding children's hospitals (28 of 297, 9.4%; 95% CI, 6.1–13.3%) was slightly higher than at freestanding children's hospitals (17 of 308, 5.5%; 95% CI, 3.3–8.7%), a difference in rates of 3.9% (95% CI, −4.1% to 11.9%).

Operative intervention rates for children with isolated solid organ injures were 11 (5.4%) of 205 (95% CI, 2.7–9.4%) at non-freestanding children's hospitals and 6 (2.8%) of 213 (95% CI, 1.0–6.0%) at freestanding children's hospitals, a difference in rates of 2.6% (95% CI, −7.1% to 12.2%). These differences, however, did not reach statistical significance

DISCUSSION

In this study, we identified a very low rate of intervention in children with solid organ injuries after blunt trauma. However, we also identified considerable variability in the ED disposition of these children.

The rate of solid organ intra-abdominal injuries in our overall study cohort of children with both isolated solid organ and multiple abdominal injuries was approximately 5%. We also found in the overall cohort that spleen and liver injuries were approximately equal in frequency and that kidney injuries occurred only approximately half as often as injuries to either of the other organs. When solely considering isolated solid organ injuries, spleen injuries were slightly more common than liver injuries, and isolated kidney injuries were substantially less common. The relative frequency of spleen and liver injuries is similar to that identified in a large population based series of mostly adult patients.[5] The mechanisms of injury in the overall cohort of children with any abdominal injuries were characteristic for a pediatric trauma series and differed from the distribution seen in adults, with a lower percentage injured in motor vehicle crashes and higher percentages of pedestrians or bicyclists struck by motorized vehicles and patients injured in bicycle crashes.[2,13,14]

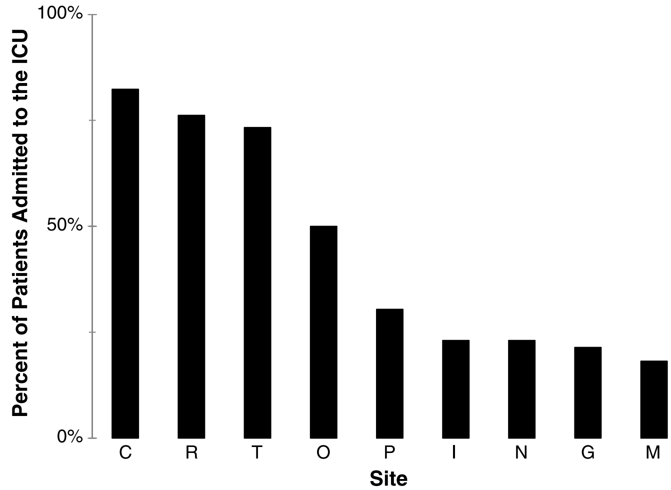

Figure 2. Intensive care unit admission rates by center for isolated Grade III or higher injuries.

TABLE 3. Therapy for Children With Isolated Solid Organ Injuries

	Total Observation	Therapeutic Operative Intervention	Blood Transfusion	Angiography	Any Therapy	Total Patients	Hospital Stay, Median (IQR), d
Spleen							
Grade I	32 (19.2)	0 (0.0)	3 (12.0)	0 (0.0)	3 (10.0)	35 (17.7)	3 (2,6)
Grade II	50 (29.9)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	50 (25.4)	3 (3–4)
Grade III–V	85 (50.9)	8 (100.0)	22 (88.0)	6 (100.0)*	27 (90.0)	112 (56.9)	4 (3–6)
Total	167	8	25	6	30	197	
Liver							
Grade I	37 (26.4)	1 (20.0)	3 (18.8)	0 (0.0)	3 (17.7)	40 (25.5)	2 (1–6)
Grade II	48 (34.3)	0 (0.0)	2 (12.5)	0 (0.0)	2 (11.8)	50 (31.9)	3 (2–4)
Grade III–VI	55 (39.3)	4 (80.0)	11 (68.8)	0 (0.0)	12 (70.6)	67 (42.7)	4 (2–6)
Total	140	5	16	0	17	157	
Kidney							
Grade I	23 (40.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	23 (35.9)	2 (1–4)
Grade II	14 (24.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	14 (21.9)	2.5 (2–4)
Grade III–V	20 (35.1)	4 (100.0)	5 (100.0)	0 (0.0)	7 (100.0)	27 (42.2)	4 (3–6)
Total	57	4	5	0	7	64	
Total	364	17	46	6	54	418	

*Two children underwent angiographic embolization of their spleen injuries before ward admission.
Percentages and IQRs in parentheses.
One patient with a Grade III spleen injury was discharged home before the diagnosis of spleen injury (i.e., a missed injury) and is not included in the table.
IQR, interquartile range.

Approximately three quarters of the children with isolated solid organ injuries had intraperitoneal fluid, usually identified by abdominal CT scan. The finding that one in four children with intra-abdominal injuries did not have intraperitoneal fluid has implications for the use and reliability of the Focused Abdominal Sonography for Trauma (FAST) examination.[15,16]

The management of children with solid organ injuries has evolved during the last three decades.[2,5,13,17,18] This evolution has been characterized by decreased rates of operative intervention and greater reliability on diagnostic imaging studies as clinicians appreciate that many solid organ injuries are self-limited, will heal on their own, and do not require major intervention. The development of a more frequent nonoperative approach was inaugurated by changes in the management of pediatric patients. As early as the late 1960s, Upadhyaya and Simpson[19] recognized that pediatric patients with spleen injuries do not frequently require splenectomy. A controversial concept at the time, over the ensuing 10 years to 15 years, it became apparent that children with spleen injuries, in particular low-grade spleen injuries, rarely required splenectomy and could be safely observed. The realization that nonoperative management could be successfully performed in children led gradually to changes in the management of adults with spleen injuries.[3,17,20–22]

The American Pediatric Surgical Association published guidelines in 2002 with recommendations for the management of children with isolated spleen and liver injuries, including recommendations about appropriate ED disposition.[22] The guidelines call for ward admission for children with grades I, II, or III spleen or liver injuries. We found in our multi-institutional series that 40% of the children with isolated Grade I spleen injuries and 36% with Grade II injuries were admitted to intensive care units. The respective percentages for isolated liver injuries were essentially the same. Intensive care unit admission rates varied considerably by center for both low-grade injuries (Grades I and II) as well as higher-grade injuries (Grades III and VI), even in children with no associated head or thoracic injuries. These findings are particularly interesting

TABLE 4. Characteristics of the Six Children With Isolated, Grade I Solid Organ Injuries Who Had Acute Interventions

Age, y	Mechanism	Abdominal Injury	Initial SBP	Initial GCS Score	Additional Significant Torso Injuries	LOS, d	Intervention
0.4	Unknown	Liver	80	15	Hemothorax, rib fracture, pneumothorax, pulmonary contusion	7	Transfusion
1	Occupant MVC	Spleen	85	3	Cardiac contusion, pulmonary contusion	2	Transfusion
2	Ped/bike MVC	Spleen	140	3	Pulmonary contusion	1	Transfusion
5	Ped/bike MVC	Spleen	125	4	Pulmonary contusion, pubis fracture	20	Transfusion
5	Occupant MVC	Liver	106	6	Rib fracture	9	Transfusion
17	Ped/bike MVC	Liver	109	3	Hemopericardium, hemothorax	2	Transfusion/laparotomy

Additional significant injuries include injuries to the chest, pelvic fractures, or femur fracture.
LOS, length of stay; MVC, motor vehicle collision; Ped, pedestrian; SBP, systolic blood pressure.

given the fact that many of the hospitals participating in our study are children's hospitals, and our findings suggest possible room for improved resource use in this patient population. The findings are not surprising, however, as a national survey suggested a wide range in ED dispositions in children with minor intra-abdominal injuries.[23] A prospective, multi-institutional study using the American Pediatric Surgical Association guidelines in 832 pediatric patients with isolated spleen and liver injuries demonstrated that resource use could be decreased without any negative effects on morbidity or mortality.[24]

Not surprisingly, the splenectomy rate in children with isolated spleen injuries was related to the grade of spleen injury, with all of the splenectomies occurring in children with Grade III or higher injuries. Splenectomy rates also varied with the overall severity of intra-abdominal injuries. The overall rate of splenectomy for children with any spleen injuries was 7.4%, a rate similar to a series in the literature for children's hospitals and lower than the rate in a population-based series including nonchildren's hospitals.[20,25,26] The splenectomy rate in children with isolated injuries was much lower than the rate in children with multiple intra-abdominal injuries, which likely reflects both a higher overall severity of injury and a desire to remove the spleen at surgery to eliminate splenic bleeding as a postoperative concern. The higher operative intervention rate in children with multiple intra-abdominal injuries also argues for closer monitoring of children with multiple intra-abdominal injuries than for children with isolated solid organ injuries.

Interventions in children with Grade I injuries were rare as only six patients underwent specific therapy for their injuries. In the six children with Grade I injuries that received blood transfusions, only two had other injuries (hemothoraces) producing blood loss. The remaining four had severe traumatic brain injuries, and the transfusions were likely, at least in part, an attempt to keep the hematocrit elevated and maximize oxygen carrying capacity.

All of the angiographies performed in our series were on children with spleen injuries; no angiographic procedures were performed in children with either liver or kidney injuries. Angiography was used in 4.1% of the overall patient population with isolated spleen injuries but 7.1% of children with Grade III or higher spleen injuries. These rates are similar to those seen in some adult and pediatric series but lower than the rates at aggressive adult centers, where angiography rates range from 20% to 30%.[27–29] No children with lower-grade injuries were treated with angiography. Although the numbers are small, embolization was performed in most of the children who underwent angiographies.

Our findings are consistent with the fact that while angiography is a potential tool in the treatment of liver and kidney injuries, it is only rarely necessary or used in children.[6,30–35] Puapong et al.[31] reported only three cases of liver embolization during a 10-year experience with 2,477 blunt pediatric trauma patients at one large county hospital.

The operative intervention rate of 6.3% for children with isolated kidney injuries is somewhat higher than the rates of operative intervention reported in a previous pediatric series[36] but similar to national rates for all patients with kidney injuries.[37] This may reflect a varied level of experience in the different centers in this multicenter study, the fact that nonpediatric specialists may have been involved in a large number of these cases or may just be a by-product of the fairly small numbers involved and the fact that all of the interventions for renal injuries were retrograde urethrography and stent placement.

Previous work suggests that patients treated at children's hospitals are less likely to undergo splenectomies after injury.[21] Because this finding is from older data, we sought to determine if this discrepancy in treatment by facility type persists. We noted that operative interventions were more common at non-freestanding children's hospitals compared with freestanding children's hospitals, although the differences did not reach statistical significance. Possible explanations for the difference are that management approaches are systematically different at the two types of hospitals, that adult surgeons are more involved with the management of injured children at non-freestanding children's hospitals, or that systematic differences in injury severities between the two types of hospitals occurred.[21,27,38]

Our study has certain limitations. It represents the practices at a select group of hospitals across the United States, including many children's hospitals, and thus, it may not reflect practice at all hospitals. The use of prospectively collected data, however, allows for more granular detail in the evaluation of the management of pediatric blunt abdominal injury. We focused our analysis on children with solid organ injuries (spleen, liver, or kidney); children with gastrointestinal or pancreatic injuries may be different. In addition, children may have been admitted to the intensive care unit for other injuries. We performed a subanalysis to exclude children with substantial nonabdominal injuries or multiple intra-abdominal injuries that might warrant intensive care unit admission, however, and substantial variability in ED disposition remained. Our study population also did not include transfer patients with previous imaging, and the characteristics of that population could differ from the characteristics of our study population.

The determination of blood transfusion was based on review of the medical records. As children with multiple injuries may have had multiple sources of blood loss, the solid organ injuries may have only contributed partially to the need for blood transfusion. We were conservative in our analysis, however, and if the abdominal injury was believed to provide any contribution to the need for transfusion, the patient was considered to have the outcome of interest.

In summary, most children with solid organ injuries are managed with observation. Almost all children with isolated intra-abdominal solid organ injuries, regardless of the grade of injury, are admitted to the hospital. Many, even those with low-grade injuries, are initially cared for, however, in intensive care units, a finding contrary to published guidelines for the management of children with such injuries. Operative and angiographic interventions are rarely needed for isolated spleen, liver, or kidney injuries in children. Increased compliance with published guidelines for the management of pediatric intra-abdominal solid organ injuries might lead to better use of resources without deleterious effects on patient outcome.

AUTHORSHIP

D.H.W. contributed in the study design, acquisition of data, data analysis, interpretation of data, creation of figures, performance of literature search, drafting of manuscript, critical revision of manuscript, and study supervision.

N.K. contributed in the study design, acquisition of data, data integrity, critical revision of manuscript, and study supervision. A.C. contributed in the acquisition of data and critical revision of manuscript. J.M. contributed in the acquisition of data, critical revision of manuscript, and study supervision. P.E. contributed in the study design, acquisition of data, and critical revision of manuscript. J.K. contributed in the acquisition of data, critical revision of manuscript, and study supervision. P.M. contributed in the acquisition of data, critical revision of manuscript, and study supervision. L.L. contributed in the acquisition of data, critical revision of manuscript, and study supervision. L.J.C. contributed in the data integrity, data analysis, interpretation of data, creation of figures, critical revision of manuscript, and study supervision. K.Y. contributed in the acquisition of data, critical revision of manuscript, and study supervision. K.L. contributed in the acquisition of data, critical revision of manuscript, and study supervision. J.F.H. obtained grant funding for the project, conceived the study, and contributed in the acquisition of data, data integrity, data analysis, interpretation of data, creation of figures, critical revision of manuscript, and study supervision.

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