Update of nonoperative management of blunt spleen and/or liver injuries in pediatric patients

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Abstract

Since its publication in 2000, the American Pediatric Surgical Association guidelines has been used to manage hemodynamically stable patients with blunt solid organ injuries. CT injury grade is used to guide ICU stay, overall length of hospital stay, activity restriction and pre-and post-discharge imaging. After publication, there has been growing evidence that these guidelines are too conservative. The purpose of this study is to review the current literature regarding non-operative management of liver and spleen injuries in children, and to review the management of children with spleen and/or liver injuries admitted to the Children's Hospital at the Health Sciences Centre in the past 5 years. Injury severity score, bed rest, oral intake, blood draws, blood transfusion, length of hospital stay, activity restriction and imaging were recorded. Forty-eight cases were included, 29 splenic injuries, 18 liver injuries and 1 case with both. Two cases failed non-operative management. Current literature provides ample evidence that an abbreviated management protocol based on hemodynamic stability rather than CT grade shortens hospital stay but does not compromise patient safety. The chart review demonstrated that all children who were admitted were safely discharged home; however, variations of management and resource utilization were observed. It is proposed that an abbreviated protocol based on hemodynamic parameters will decrease hospital stay, reduce hospital costs, increase patient satisfaction but remain safe.

Introduction

Hemodynamically stable children who present to hospital with isolated blunt spleen or liver trauma have been successfully managed without surgery for over half a century. The benefits of nonoperative management (NOM) include avoidance of splenectomy, post-splenectomy sepsis, surgical risks and decreased need of transfusion (1). Although NOM has become the standard of care, how this is achieved varies greatly amongst surgeons (2). Variations in management include grading based on imaging or physiologic parameters, length of intensive care unit (ICU) stay, duration of bed rest, activity restriction, diet orders, follow-up imaging and frequency of lab tests. The trend has been towards shorter hospital stays, fewer ICU admission, less activity restriction and less post-discharge imaging (3).

Abdominal injuries account for 10-15% of all pediatric trauma, and solid organs (liver, spleen and kidney) are more often injured compared to hollow organs (4). Blunt liver and spleen trauma therefore comprise a large portion of healthcare costs. Standardization by employing the newest practice guidelines will not only lead to greater patient satisfaction but will also improve resource utilization.

American Pediatric Surgical Association guidelines

In 2000, due to a lack of Class I evidence-based standards and guidelines, the American Pediatric Surgical Association (APSA) trauma committee published a management protocol for hemodynamically stable children with grade 1-4 injuries based on computed tomography (CT) injury grade (5). This protocol was based on a retrospective review of 856 case records of children with isolated spleen or liver injuries occurring between 1995 and 1997. In 1998, the data was analysed and consensus guidelines were created for hemodynamically stable patients (Table 1).

ICU admission was reserved for patients with an injury grade 4 or greater. This was based on evidence that transfusion rates were 2-10% and operation rates were less than 3% for grades 1-3 injuries, and that children with grade 4 injuries had a significantly higher rate of transfusion and operation. Hospital stay of ‘CT injury grade + 1’ day and activity restriction of ‘CT grade + 2’ weeks were based on what was observed to be safe at least of 25% of the time. Since fewer than

50% of patients reviewed had pre- and post-discharge imaging, routine imaging was not recommended. However, imaging was advised based on clinical presentation. A prospective study of the application of these guidelines showed a reduction in ICU stays, length of stay (LOS), follow-up imaging and activity restriction for each grade; resource utilization was optimized without compromising patient safety (6).

Table 1. APSA recommendations

	CT Grade			
	1	2	3	4
ICU stay (days)	none	none	none	1
Hospital stay (days)	2	3	4	5
Predischarge imaging	none	none	none	none
Postdischarge imaging	none	none	none	none
Activity restrictions (wks)	3	4	5	6

*Return to full-contact, competitive sports (ie, football, wrestling, hockey, lacrosse, mountain climbing) should be at the discretion of the individual pediatric trauma surgeon. The proposed guidelines for return to unrestricted activity includes "normal" age-appropriate activities.

**Adapted from Stylianos S. Evidence-based guidelines for resource utilization in children with isolated spleen or liver injury. The APSA Trauma Committee. J Pediatr Surg [Internet]. 2000;35(2):164–9.

Despite the success of the APSA guidelines, controversy remained whether CT grade should be used to guide management (7–9). Evidence started to emerge showing that these guidelines, however safe, may have been excessive and led to hospital stays which were longer than necessary and unnecessarily costly (8).

Hemodynamic based algorithms

In 2001, Mehall *et al.* challenged the APSA guidelines by proposing a standardized algorithm based on physiological parameters. Their recommendations were based on evidence from adult studies which revealed that hemodynamic stability predicts clinical outcomes better than CT grade (7,10,11). A standardized clinical algorithm was created using hemodynamic stability to stratify patients. Hemodynamic stability was defined using age-dependent norms for heart rate and systolic blood pressure. Children were kept fasted for 18 hours post-injury, and hematocrit was checked every 6 hours. If, after 18 hours, the child had no abdominal pain and a stable hematocrit greater than 21, they could ambulate and were given a regular diet. If at 48 hours post-injury, the child was tolerating a diet without abdominal pain and had a stable hematocrit, they were discharged with a scheduled ultrasound at 4 weeks. Of the 44 patients managed with this algorithm, 43 were treated nonoperatively without transfusion or delayed bleeding. One patient deviated from the pathway when fever and abdominal pain developed on the second day. A CT scan showed a large biloma which was drained percutaneously. All patients resumed school on discharge and noncontact sports after 1 month. Use of this algorithm was shown to decrease overall LOS to 48 hours and eliminated ICU admissions without affecting patient care. After 3 years, there were no documented delayed bleeds. Of 34 patients who received 1 month follow-up ultrasonography, 1 pseudoaneurysm was detected. This demonstrated that hemodynamic normality can safely direct course in hospital.

Since 1995, the Arkansas Children's Hospital has used a treatment pathway based on hemodynamic status to manage patients with blunt organ trauma (8). In a 2008 article "Throwing out the grade book", McVay *et al.* compared LOS using their hemodynamic status pathway to the then new APSA guidelines (8). McVay *et al.* believed that their method led to decreased LOS, reduce hospital charges, and returned children to normal activity faster than the APSA guidelines. They evaluated patients who were managed with their treatment algorithm during a 5-year period (Jan 1, 2002 to Dec 31, 2006). Upon discharge, all patients returned to normal activities with restriction of contact sports or gym class until follow-up ultrasound demonstrated healing. Labs were discontinued after 2-3 stable hematocrit measurements. Results showed that their algorithm led to decreased LOS compared to those proposed by the APSA guidelines (mean LOS 1.9 days vs 3.2), and demonstrated that return to normal activity while restricting gym and contact sports is safe.

St. Peter *et al*. also believed that the APSA guidelines lead to unnecessarily long hospital stays and in 2011 they validated their abbreviated bed rest protocol (9). Upon reviewing their experience, they developed an abbreviated protocol which consisted of 1 night of bed rest for injury grades 1 and 2, and 2 nights of bed rest for grades 3 or greater. These periods of bed rest were arbitrarily selected. The protocol was implemented for a 3-year period. A night was defined by the patient being in bed at morning rounds. Patients were then allowed to ambulate and a hemoglobin (Hgb) was drawn 4 hours later. Discharge occurred once Hgb results were stable and the patient did not require any other hospital care. Mean length of stay was 2.2 +/- 1.3 nights versus the APSA-recommended guideline of 3.6 +/- 1.1 nights. Of note, transfusion due to solid organ injury was necessary in 13% of cases; however, no patient had delayed bleeding or hospital readmission. No transfusions were given after the period of bed rest had ended. This report further emphasized the safety of abbreviated hospital stays.

ATOMAC practice guidelines

Before the APSA guidelines were established, blunt liver and spleen trauma was loosely managed by hemodynamic status (12). In 2012, ATOMAC (Arizona-Texas-Oklahoma-Memphis-Arkansas), a pediatric trauma consortium of the American College of Surgeons, reviewed the APSA guidelines and then developed a practice management guideline which has been adopted by many US pediatric trauma centres (12). These guidelines were based on the child’s physiological response to injury rather than CT grade. In 2015, the ATOMAC guidelines were evaluated using GRADE methodology. From this, six 1A recommendations were made which include: management should be based on hemodynamic status rather than grade of injury;

abbreviated bed rest of 1 day or less for stable patients is supported for children whose Hgb is stable with the use of bed rest on the day of admission to be discretionary until further evidence; a transfusion threshold of 7.0g/dL is safe; NOM in the face of peritonitis should be excluded from a practice management guideline for solid organ injury; failure to stabilize cannot have NOM dictated by algorithm alone without taking into account local resources and other injuries; and lastly, a NOM guideline can be applied to patients with multiple injuries where not contraindicated however other intra-abdominal injuries may take priority when necessary. A 1B recommendation states that patients without clinical signs of bleeding at presentation and stable Hgb can be discharged before 24 hours. They also made recommendations regarding diet progression, a variable unmentioned by many. A 2C recommendation states that patients not admitted to the ICU and without signs of ongoing bleeding may be allowed to drink and eat when comfortable and able. Notably, they point out a common misinterpretation of the original APSA guidelines: length of bed rest was not prescribed by APSA; however, bed rest has been generally misinterpreted for length of hospital stay.

Albert Children Hospital accelerated care pathway

Most recently, the Alberta Children Hospital (ACH) implemented an accelerated care pathway in 2014 to decrease bed rest, LOS, blood draws and improve resource utilization (13). This protocol allowed patients with grades 1 and 2 injuries immediate bathroom privileges. Patients with grades 3-5 injuries started on bed rest and ambulated on post-admission day 1 if stable (defined by a hemoglobin (Hgb) decrease less than 5g/dl). Blood draws were also standardized. Once the protocol was implemented, LOS became significantly shorter with a mean stay of 5.6 days in the pre-protocol groups versus 3.4 days in the post-protocol (p-value 0.0002). In addition, the post-protocol group mobilized faster (2.1 days vs 3.9 days) and had fewer blood draws after controlling for age, gender, injury grade, protocol group and Injury Severity Score (ISS). ACH determined that the new protocol resulted in a savings of $5966 per patient. Subgroup analysis, however, revealed no significant difference in LOS for grades 1 and 2 injuries (pre-protocol median 2.5 days, post-protocol median 1.0 days). There was, however, a significant difference in LOS for grades 3-5 injuries (median 5.0 days vs 3.0 days). Of note, there was no difference in ICU admissions or need for transfusions. ACH also suggested that low-grade injuries may not require hospitalization if Hgb levels are stable in the Emergency Department (ED). There was an increase in ED visits post-discharge (2.99% vs 7.46%) for pain management; however, there were no readmissions or mortalities in either group. This protocol appears to be safe yet decreases hospital costs.

<u>Failure of Nonoperative Management</u>

The current literature is limited with respect to cases of failed NOM as the success of NOM has exceeded 90% of cases (14). Nevertheless, understanding the cause of failed NOM is critical to further understanding which children can be safely managed with a nonoperative approach. In a retrospective analysis of seven designated level I pediatric trauma centres over a 6-year period, Holmes *et al.* sought to clarify predictors and time course of failed NOM in children with blunt solid organ trauma (liver, spleen, pancreas and kidney)(14). Of 1,818 patients, 1,729 were successfully managed nonoperatively. Eighty-nine (5%) required intraabdominal operations and were defined as having failed NOM. The reasons included hypovolemic shock (33%), peritonitis (27%), persistent hemorrhage (16%), hollow visceral injury-related (15%), isolated pancreatic injury (8%) and ruptured diaphragm (1%). Overall mortality was 0.8% (14 patients), all deaths occurred in the failure group. Shock was the reported clinical reason for 12 deaths. Results obtained revealed five variables associated with increased risk for failure of NOM: bicycle accidents, isolated grade 5 injury, greater than 1 solid organ injury, a summary abbreviated injury scare (sAIS) ≥ 4 and isolated pancreatic injury. Of note, bicycle-injured children have a higher rate of pancreatic injury compared to other mechanisms. Interestingly, falls were associated with a decreased risk of failing NOM. Rates of failure appear to rise and peak rapidly with peak failure occurring at 4 hours then plateaus at 36 hours. Thirty-eight % of patients failed NOM within 2 hours, this increased to 59% by 4 hours, 72% by 9 hours, 87% by 24 hours, 94% by 48 hours, 98% by 72 hours and 100% by 144 hours. These results further demonstrate the importance of hemodynamics in the early evaluation of solid organ injury as shock and hemorrhage together accounted for 49% of failed cases. Few other studies have examined the characteristics of patients who fail NOM, more multi-institutional data will be necessary to further improve the outcomes of blunt organ trauma.

Delayed bleeding

Delayed bleeding after initial hemostasis is rare, but patients are usually asymptomatic during the delay period (7,12). Most children who require transfusion or operation do so within 24 hours of injury. Furthermore, transfusion or operation are rarely required after the period of bed rest has been completed (7,9).

In 2009 a retrospective review of 303 children admitted to SickKids in Toronto with blunt splenic injuries between 1992-2006 was conducted (15). Only 1 (0.33%) child with an isolated grade 4 injury died of delayed bleeding 23-days post-injury. They found that only 14 cases of delayed splenic bleed were reported in the literature since 1980 with a median time from injury to delayed bleed of 8 days; none resulted in death. The authors speculated that the few reports of delayed splenic bleeding may be due to publication bias or may be an actual effect of NOM with bed rest and activity restriction.

Practice patterns in Canada

In 2009, Li *et al*. performed a survey of management patterns of blunt splenic injuries in Canada (2). As anticipated, pediatric general surgeons (PGS) reported managing more than 7 cases versus 1-3 for general surgeons (GS). PGS were more likely to report following APSA guidelines, and GSs were more likely to use subjective clinical judgement. Nearly half of GSs used CT grade to influence operative versus NOM for hemodynamically stable patients. PGS reported using NOM more frequently with fewer hospital resources than adult-oriented GS. In addition, PGS ordered fewer lab tests, had a higher threshold for surgical intervention, made more selective use of the ICU and used guidelines for LOS and activity restriction.

Purpose

The Children's Hospital at Health Sciences Centre (HSC) in Winnipeg serves a large population of children from Manitoba, Nunavut and western Ontario. Children who suffer from blunt spleen and liver injury from these areas are referred to the Pediatric Surgery team in Winnipeg for management. Since 2000, children who are hemodynamically stable have been successfully managed according to the APSA guidelines. Based on CT grading of the injury, patients are prescribed specific durations of ICU admission, hospital admission, pre-discharge imaging, post-discharge imaging and activity restriction. However, with the publication of several articles providing evidence that management based on physiological parameters is superior to CT grade-based care, the practice pattern in Winnipeg required updating.

The purpose of this project is to review the management of patients with blunt spleen and liver injuries at Winnipeg's Children Hospital. This information will subsequently be used to generate an algorithm and standardized order sheet for admission of these patients. Instituting the latest evidence based practice guidelines will improve patient and family satisfaction by expediting return to a regular diet, mobilization and hospital discharge, and improve resource utilization without compromising patient safety.

Methods

Approval was obtained by the University of Manitoba Health Research Ethics Board (HREB) and the HSC Pediatric Research Coordinating Committee.

Charts were reviewed of children less than 17 years of age at the time of admission with clinical or radiologic evidence of isolated spleen and/or liver injury as a result of blunt trauma. The chart review was limited to 5 years (January 2011 to December 2016). Only children admitted to the Children's Hospital HSC were included. Children with penetrating injuries and/or additional injuries (head, chest, spinal, intestines, pelvic or extremity fractures) were excluded. Children with other minor injuries, such as soft tissue injuries, which did not influence the variables evaluated were included.

Injuries were graded by CT scan (Tables 2 & 3 and Figure 1 in Appendix). If the grade was not explicitly stated, the grade was calculated from the time advised to return to activity assuming the surgeon followed the APSA guideline of 'CT grade of injury + 2' weeks of inactivity. If the date and time of injury were not recorded, the time of injury was assumed to have been 1 hour prior to the earliest recorded time on the ED documentation.

The following information was abstracted from each chart: patient demographics, mechanism of injury, time of injury, organs injured, ISS, hemodynamic stability, duration of bed rest, duration until initiation of oral intake, LOS, total number of blood draws, transfusions, operations, pre- and post-discharge imaging, and recommended time until return to unrestricted activity. Length of stay was determined by dates and times of admission and discharge. Bed rest was presumed complete when the patient was permitted to ambulate on the ward. Oral intake was defined as either clear fluids or diet as tolerated. In cases of injury to both liver and spleen, the grade of the more severely injured organ guided management.

The data was abstracted from both paper and scanned charts. All identifying information was removed. Data was entered and analysed with REDCap software. The primary outcomes assessed were overall LOS, resource utilization and patient safety.

Results

Between January 2011 and December 2016, 79 children with spleen and/or liver injuries were admitted to the Children's Hospital in Winnipeg. Of these patients, 31 were excluded because the mechanism of injury was not blunt or the child had associated injuries which influenced the variables evaluated. Associated injuries included basal skull fractures, pelvic fractures and femur fractures. Therefore, 48 patients were included, 29 with splenic injuries, 18 with liver injuries and 1 patient with a grade 4 splenic and a grade 1 liver injury. One child with a liver injury required a laparotomy, and 1 child with a splenic injury required a splenectomy; both were admitted to the ICU on presentation to hospital.

Table 4 depicts the patient demographics. The average age for spleen and liver injuries were 12 and 10 years, respectively. More children with spleen injuries than liver injuries were admitted to the ICU (17.24% vs 11.11%); however, there were more children with grades 4 and 5 spleen injuries (15 children) than grades 4 and 5 liver injuries (7 children).

Mechanisms of injury causing isolated liver and spleen injuries are depicted in Figure 2. Isolated spleen and liver injuries were most often caused by falls (27.1%) and sports (20.8%).

"Other injuries" included a pole which fell on the child and an unsecured tractor which pinned the patient.

Table 5 demonstrates resource utilization by all liver and spleen injured patients managed nonoperatively. Two patients who had laparotomy were excluded from this data as their resource utilization was altered by the need for surgery. Mean duration of bed rest, duration to oral intake, number of blood draws, mean LOS and advised activity restriction all increased with grade severity. All patients who were successfully managed without surgery were hemodynamically stable in the ED. No child with a grade 1 or 2 injury was admitted to the ICU.

Tables 6 and 7 detail the experience of the liver and spleen injured patients, respectively. One child with a splenic injury who was treated nonoperatively required a blood transfusion 17 hours after admission. Blood was given when the Hgb dropped from 90 g/L to 81 g/L in 7 hours. This child had the longest duration of bed rest of all cases included in this study (159.42 hours).

Diet orders at admission varied significantly with injury grade for both liver- and spleen-injured patients (Table 8). Most children were fasted at admission and progressed; however, several children were started on clear fluids or diet as tolerated. Of the 3 patients admitted with a grade 3 spleen injury, 1 was admitted on clear fluids, 2 were admitted on a diet as tolerated, and none were admitted fasting.

The majority of all children were limited to bed rest at admission. However, two grade 1 patients were allowed ambulation with no complications (Table 9).

Most children were advised to limit activity to activities of daily living post-discharge; however, several children were allowed "activity as tolerated excluding contact sports". There were no complications from these recommendations (Table 10).

Only 1 child in this study required repeat imaging during their hospital stay, but 16 children received post-discharge imaging (Table 11). The majority of follow-up ultrasounds were done to ensure that a pseudoaneurysm had not developed in the splenic artery. Of the 14 follow-up ultrasounds: 6 reports were unavailable, 6 were reported as normal, and 1 report noted a residual hematoma around and within the spleen. One ultrasound, done 5 weeks after discharge, found an incompletely healed spleen laceration; the child had 2 subsequent ultrasounds at 1 month intervals, both showing persistence of the laceration with hematoma.

Two patients had planned follow-up CT scans. One patient with a grade 4 injury was scheduled for a 5-week post-discharge CT but there was no evidence that it was completed. The other child with a grade 5 liver injury was seen in the ED 1 week after discharge due to abdominal pain. A CT at 1 week post-discharge showed dilated loops of bowel but the liver appeared normal.

Only 2 patients included in this study failed NOM and required surgical intervention. The fist was a 16-year-old child who sustained a CT grade 4 spleen injury after being struck by the handle bars of an all-terrain vehicle. The child initially presented to a rural hospital 1.5 hours away from Winnipeg and was transferred to the Children's Hospital in Winnipeg with labile vital signs and a Hgb of 140 g/L. In the Children's Hospital ED, the patient's systolic blood pressure dropped to 68 mmHg, the heart rate was over 100 per minute and a repeat Hgb decreased to 70 g/L. The patient received 2 units of blood and an urgent CT. After 24 hours of NOM in the ICU, 6 units of blood and 3 units of platelets the patient remained hemodynamically unstable; the Hgb was 84 g/L, the heart rate was over 120 per minute and systolic blood pressure less than 90 mmHg. The child underwent splenectomy on post-admission day 2. The operative report described the injury as grade 5 and the child was found to have 3 litres of blood in the abdomen. The child recovered without complication and was discharged home on post-operative day 2.

The second patient to fail NOM was a 13-year-old from a rural community who was struck by a large falling pole. The child was taken initially to a rural hospital. The patient was tachycardic, hypotensive and received 1500ml of normal saline, 500ml Pentaspan and 1 unit of blood with good response. The child was transferred to the Children's Hospital in stable condition where CT scan showed a grade 3 liver injury. The patient was initially admitted to the ICU but transferred to the ward the next morning. The child remained stable on bed rest but over the course of a week the abdomen became progressively distended with increasing bilirubin levels. Endoscopic retrograde cholangiogram showed a large bile leak from the right hepatic lobe, therefore, a biliary stent was placed. Unfortunately, the abdominal distention progressed and the child developed abdominal compartment syndrome. Repeat CT showed a large amount of loculated abdominal fluid. Midline laparotomy was performed, the abdomen was irrigated, drains were placed around the liver and a negative pressure abdominal dressing was applied to the open abdomen. The dressing was changed once in the OR then the abdominal wall was closed. The child did well postoperatively, diet was advanced, lab values normalized and no further complications were noted.

All patients included in this study were successfully discharged home. No deaths were recorded.

Table 4. Patient demographics

	Spleen	**Liver**	**Both**
Number	29 (60.4%)	18 (37.5%)	1 (2.1%)
Mean age (years)	12.21	10.34	13.69
Age range (years)	3.43-16.68	1.11-16.93	-
Mean LOS (days)	4.49	4.25	-
Duration to oral intake (hours)	13.43	11.58	-
ISS (mean)	12.07	9.83	20
Number admitted to ICU (%)	5 (17.24%)	2 (11.11%)	1 (100%)

LOS = length of stay, ISS = injury severity score

Figure 2. Mechanism of injury

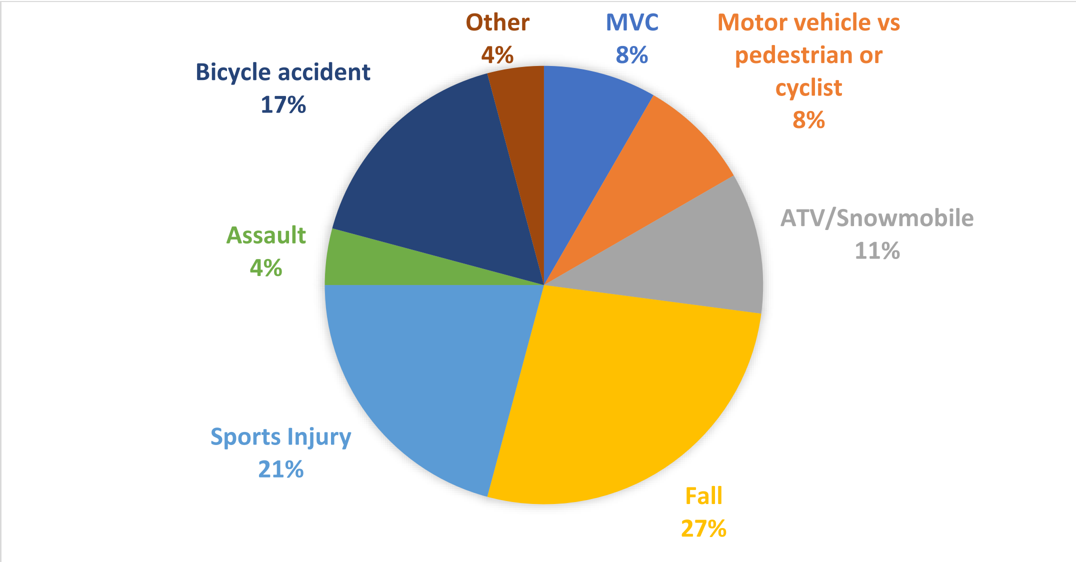

Table 5. Resource use in children with isolated blunt spleen and/or liver injury

CT grade	**1**	**2**	**3**	**4**	**5**
Number	5 (10.9%)	8 (17.4%)	15 (32.6%)	16 (34.8%)	2 (4.3%)
Mean LOS (days)	1.82 (1.10-2.48)	3.79 (1.86-6.06)	4.2 (2.85-5.40)	5.54 (3.00-7.65)	6.95 (6.59-7.32)
Hemodynamically stable in ED (%)	100%	100%	100%	100%	100%
Admitted to ICU (%)	0	0	1 (6.7%)	4 (25%)	1 (50%)
Admitted to monitored bed (%)	0	2 (25%)	3 (20%)	5 (31.3%)	0
Duration to oral intake (hours)	5.27 (0-10.68)	9.95 (0-45.75)	10.52 (0 -31.33)	16.56 (0-46.50)	45.42 (12.17-78.67)
Duration to AAT (hours)	22.33 (0-57.83)	73.94 (39.38-143.33)	74.84 (30.08-104)	111.01 (68-159.42)	129.75 (126.42-133.08)
Mean blood draws	2	5	5.4	7.19	10
Advised activity restriction (days)	12.8 (0-28)	31.5 (14-56)	40.21 (21-88)	48.81 (13-98)	45.50 (42-49)

2 patients who failed NOM and underwent surgery are excluded. LOS = length of stay, ED = emergency department, ICU = intensive care unit, AAT = activity as tolerated

Table 6. Resource use in children with isolated blunt liver injury

Liver Grade	1	2	3	4	5
# of cases (17)	3 (17.6%)	5 (29.4%)	4 (23.5%)	4 (23.5%)	1 (5.9%)
Mean LOS (days)	1.40 (1.10-1.91)	4.46 (3.71-6.06)	4.14 (3.25-5.13)	5.67 (4.71-7.51)	6.59
Hemodynamically stable in ED	100%	100%	100%	100%	100%
% Admitted to monitored bed	0	2 (40%)	1 (25%)	3 (75%)	0
% Admitted to ICU	0	0	0	1 (25%)	0
Duration to oral intake (hours)	2.89 (0-8.67)	15.92 (0-45.75)	3.81 (0-9.25)	20.29 (12.17-33.67)	12.17
Duration of bed rest (hours)	6.77 (0-20.33)	87.32 (66.17-143.33)	56.50 (30.08-84.25)	117.4 (88.5-159.17)	133.08
Mean blood draws	2	6	3.75	7.25	7
Advised activity restriction (days)	1 pt: 14 days 1 pt: AAT 1 pt: unknown	27.8 (14-42)	33.5 (28-36)	37.50 (13-53)	42

1 patient with a grade 3 liver injury who underwent laparotomy excluded. LOS = length of stay, ED = emergency department, ICU = intensive care unit, AAT = activity as tolerated, pt = patient

Table 7. Resource use in children with isolated blunt spleen injury

Spleen Grade	**1**	**2**	**3**	**4**	**5**
# of cases (28)	2 (7.1%)	3 (10.7%)	11 (39.3%)	11 (39.3%)	1 (3.6%)
Mean LOS (days)	2.44 (2.40-2.48)	2.68 (1.86-3.22)	4.23 (2.85-5.40)	5.37 (3.00-7.65)	7.32
Hemodynamically stable in the ED	100%	100%	100%	100%	100%
Required transfusion	0	0	0	1 (9%)	0
% Admitted to monitored bed	0	0	2 (18.2%)	2 (18.2%)	0
% Admitted to ICU	0	0	1 (9.1%)	2 (18.2%)	1 (100%)
Duration of bed rest (hours)	8.84 (7.00-10.68)	0	12.96 (0-31.33)	12.47 (0-38.17)	78.67
Duration to AAT (hours)	46.67 (33.5-57.83)	51.64 (39.38-62.50)	81.50 (55.37-104.00)	105.82 (68-159.42)	126.42
Mean blood draws	2	3.33	6	7.09	13
Advised activity restriction	25 (22-28)	37.67 (28-56)	42.90 (21-88)	51.36 (28-98)	49

1 patient with a grade 4 spleen injury who underwent splenectomy excluded. LOS = length of stay, ED = emergency department, ICU = intensive care unit, AAT = activity as tolerated

Table 8. Diet orders at admission vs. liver and spleen injury grade

Diet at admission	**Grade**				
	1	**2**	**3**	**4**	**5**
NPO	3 (60%)	4 (50%)	10 (66.7%)	13 (81.3%)	2 (100%)
CF	2 (40%)	3 (37.5%)	3 (20%)	-	-
DAT	-	1 (12.5%)	1 (6.7%)	3 (18.8%)	-
NG			1 (6.7%)		

NPO = nil per os, CF = clear fluids, DAT = diet as tolerated, NG = nasogastric

Table 9. Activity orders at admission vs. liver and spleen injury grade

Activity at admission	**Grade**				
	1	**2**	**3**	**4**	**5**
Bed rest	3 (60%)	8 (100%)	14 (93.3%)	16 (100%)	22 (100%)
Bed rest with bathroom privileges	-	-	1 (6.7%)	-	-
AAT	2 (40%)	-	-	-	-

AAT = activity as tolerated

Table 10. Activity recommendations at discharge vs. liver and spleen injury grade

Activity at discharge	**Grade**				
	1	**2**	**3**	**4**	**5**
Activity of daily living only	3 (60%)	7 (87.5%)	11 (73.3%)	9 (53.3%)	2 (100%)
Activity of daily living & delayed return to school	-	-	-	2 (13.3%)	-
Activity as tolerated excluding contact sports	1 (20%)	1 (12.5%)	4 (26.7%)	4 (25%)	-
Activity as tolerated	1 (20%)	-	-	-	-
Unknown	-	-	-	1 (6.3%)	-

Table 11. Post-discharge imaging orders vs. liver and spleen injury grade

Images ordered after discharge	**Grade**				
	1	**2**	**3**	**4**	**5**
None	5 (100%)	8 (100%)	9 (60%)	7 (43.8%)	1 (50%)
U/S (total 14)	-	-	6 (40%)	8 (50%)	-
CT (total 2)	-	-	-	1 (6.3%)	1 (50%)

Discussion

Nonoperative management has become the standard of care for hemodynamically stable children with blunt spleen and liver injuries. These injuries account for 10-15% of trauma in pediatrics and result in significant health care costs (4). Since its proposal, the APSA guidelines have been widely adopted for the nonoperative management of blunt spleen and liver injury (5,6). These guidelines were shown to reduce overall LOS, ICU admission and follow-up imaging while maintaining patient safety (6). Although the APSA guidelines have been fundamental in the discussion of blunt organ injury, they appear to be too conservative. Abbreviated protocols based on physiological parameters have resulted in shorter lengths of stay and overall better resource utilization without affecting morbidity and mortality (7–9,12,13). Despite this, there remain considerable variations in management style.

In 2001, Mehall *et al.* proposed that management of solid organ injuries be guided by hemodynamic status rather than CT grade; this proposal was based on evidence from adult literature (7). They prospectively assessed their standardized management algorithm. Their protocol reduced the LOS to 48 hours and eliminated ICU admission for hemodynamically stable patients while maintaining patient safety (7). St. Peter *et al.* validated their abbreviated protocol which arbitrarily assigned overnight bed rest for grades 1 and 2 injuries, and 2 nights for higher grades. They showed a significant decrease in LOS compared to the APSA guidelines; however, 18% of patients required transfusion within 24 hours of admission and in a follow-up study 11% required transfusions (16). No readmissions occurred for complications post-discharge (9). Subsequent to this McVay *et al.* reiterated that the controversy regarding management was ongoing but their management pathway based on hemodynamic status, which had been used prior to the creation of the APSA guidelines, was both safe and cost effective (8). In 2015, the ATOMAC guidelines were evaluated using GRADE methodology adding further evidence of the safety of management based on hemodynamic status rather than injury grade (12). Lastly, Daodu *et al*., demonstrated that their abbreviated protocol had a significant impact on LOS, specifically for grades 3-5 injuries (13).

Several studies proposed a cost savings secondary to decreased resource utilization, however, few have published an actual cost savings estimate per admission. Daodu *et al.,* who were the first Canadian-based study evaluating an abbreviate protocol, estimated a cost savings of $5966 CAD per admission (13). One US-based multi-institutional study in 2014 reported an annual cost saving of $19,928,194 for an abbreviated protocol (4). More information is needed to evaluate the actual cost savings of an abbreviated protocol.

This review reinforced the success of NOM in children with blunt spleen and liver injuries. All children included in this study progressed to a normal diet, ambulated on the wards and were safely discharged home. Only 2 cases returned to the ED but were safely discharged after being treated for pain. No repeat hospitalizations or deaths occurred from an isolated solid organ injury. The goal now is to optimize treatment while still identifying patients who are at the greatest risk of complications. Implementation of an abbreviated protocol based on hemodynamic stability provides the opportunity for cost-savings without affecting patient morbidity and mortality. In this study, the largest proportion of injuries were high-grade. Evidence has shown that high-grade injuries have the greatest potential for optimizing management and providing better resource utilization (13).

One foreseeable difficulty regarding shortening overall LOS is that we are currently not meeting the APSA recommendations. This is consistent with other institutions that follow the APSA guidelines but fail to meet proposed time frames (17,18). It is unclear why hospital stays continue to exceed recommendations despite growing evidence that even the guidelines are conservative. One possible explanation is that the recommendations made by APSA were based on total LOS and not bed rest, but the recommendations have commonly been misinterpreted in the literature (4,9,12).

Few studies propose guidelines on diet progression in the management of blunt liver and spleen trauma. Promoting a quick return to regular diet provides an opportunity to increase patient and parent satisfaction. The data in this review shows wide variation in diet orders at admission. Abbreviated protocols start a regular diet at 18 hours after admission if the child is not symptomatic and has a Hgb greater than 70 g/L, or start clear fluid diet immediately for injury grades 1 or 2 (12,13). The average duration to oral intake for the sample reviewed was 13.43 hours for spleen injuries and 11.58 hours for liver injuries. Some patients with high-grade organ injury were successfully started on oral intake at admission, which raises the question of why low-grade injured patients are kept fasting.

The APSA guidelines recommend that pre- and post-discharge imaging should not regularly be ordered, rather, imaging should be guided by the clinical scenario (5). In the 5 years reviewed, 14 post-discharge ultrasounds were ordered for grades 3 and 4 injuries, however, only 8 charts contained results. Two of the 8 studies were considered slightly abnormal. This further supports the recommendations that pre- and post-discharge imaging should not be routinely ordered.

Only 2 patients in this study returned to the ED post-discharge and both were treated for pain. Although the overall rate of delayed bleeding is small, the importance of discharge instructions for patients and their family should not be minimized. Care givers of patients being discharged should be educated regarding signs of re-bleed such as increasing abdominal or shoulder tip pain, pallor, dizziness, vomiting and jaundice. Although the data is limited, median time from injury to suspected re-bleed was 8 days, however, delayed bleeding has been reported as late as 28 days (15). As the latest evidence supports earlier discharge, it will be particularly important to educate patients and their care givers of these signs.

Guidelines pertaining to post-discharge activity restriction are sparse. The APSA guidelines recommend ‘grade of injury + 2’ weeks before returning to full-contact sports (5). This guideline have been generally accepted, however, there is little evidence either supporting or refuting this recommendation (19). There are no specific suggestions regarding return to school, however, this is permitted at most hospitals (19). Only 2 patients included in this study were discharged from the Children's Hospital with specific instructions for a delayed return to school. Our results support that it is safe to discharge children with instructions to return to school once discharged with full-contact activity restriction of 'grade + 2' weeks.

The principle limitation of this study is that this is a single centre retrospective review. The sample size limits the ability to perform significant statistical analysis. In particular, the number of grade 5 injuries are quite small. When examining variables such as mean LOS, duration to oral intake and duration of bed rest, outliers skewed the mean results. As this study reviewed charts retrieved from medical records, the data is also dependent on documentation at the time of admission. There were several cases where post-discharge imaging was scheduled, but it was unclear whether the patient did not attend the radiology appointment or if the imaging occurred and the results were not in the chart.

Many proposed abbreviated protocols have been examined in single institutions and have not been evaluated at the national level. This creates a challenge as multiple algorithms have been instituted and were shown to decrease overall LOS while maintaining safe outcomes for patients. In order to provide the best evidence-based medicine, the Children's Hospital in Winnipeg should update their management of children with isolated blunt liver and spleen injuries to one based on hemodynamic stability. Doing so will decreased hospital stay, reduce hospital costs and increase patient satisfaction while remaining safe. Creating a standardized algorithm and order set for Children's Hospital is the next step.

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Appendix

Table 2. Spleen injury scale

Grade	Injury Type	Description of injury
1	Hematoma	Subcapsular, <10% surface area
	Laceration	Capsular tear <1cm parenchymal depth
2	Hematoma	Subcapsular 10-50% surface area Intraparenchymal <5cm in diameter
	Laceration	1-3cm parenchymal depth which does not involve a trabecular vessel
3	Hematoma	Subcapsular, >50% surface area or expanding; ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma ≥ 5 cm or expanding
	Laceration	>3 cm parenchymal depth or involving trabecular vessels
4	Laceration	Laceration involving segmental or hilar vessels producing major devascularization (>25% of spleen)
5	Laceration	Completely shattered spleen
	Vascular	Hilar vascular injury with devascularized spleen

Adapted from Moore EE, Cogbill TH, Jurkovich GJ, et al. Organ injury scaling: spleen and liver (1994 revision). J Trauma 1995;38(3):323-4 (20)

Table 3. Liver injury scale

Grade	Injury Type	Description of injury
1	Hematoma	Subcapsular <10% surface area
	Laceration	Capsular tear <1cm parenchymal depth
2	Hematoma	Subcapsular, 10% to 50% surface area, intraparenchymal <10 cm in diameter
	Laceration	1-3 parenchymal depth, <10 cm in length
3	Hematoma	Subcapsular, >50% surface area or expanding, ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma > 10 cm or expanding
	Laceration	>3 cm parenchymal depth
4	Laceration	Parenchymal disruption involving 25% to 75% of hepatic lobe or 1-3 Couinaud's segments within a single lobe
5	Laceration	Parenchymal disruption involving >75% of hepatic lobe or >3 Couinaud's segments within a single lobe
	Vascular	Juxtahepatic venous injuries; ie, retrohepatic vena cava/central major hepatic veins
6	Vascular	Hepatic avulsion

Adapted from Moore EE, Cogbill TH, Jurkovich GJ, et al. Organ injury scaling: spleen and liver (1994 revision). J Trauma 1995;38(3):323-4 (20)

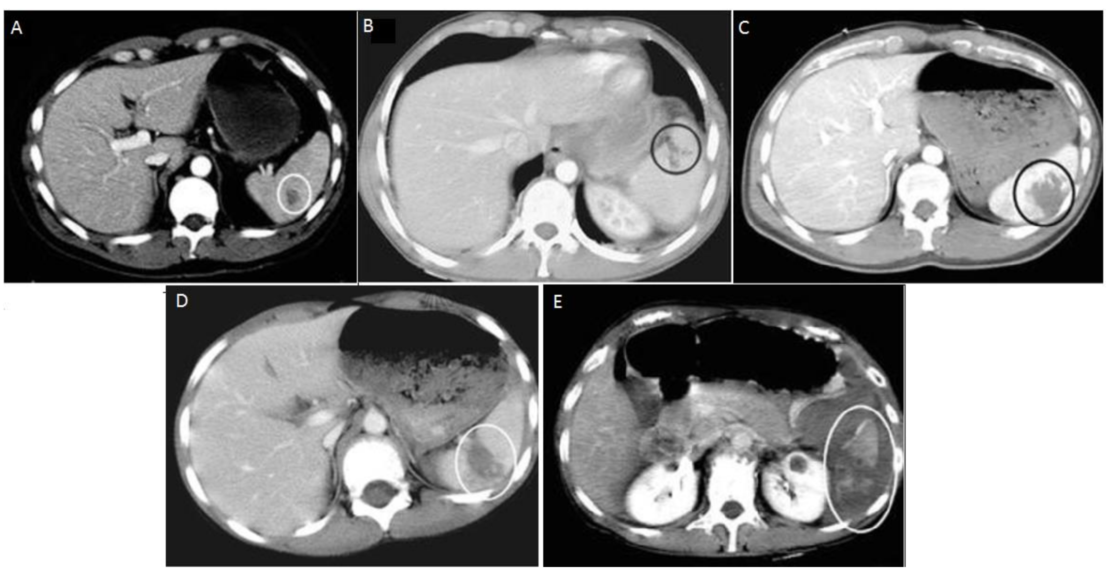

Figure 1. CT scan of grade 1-5 spleen injuries. (A) grade 1, (B) grade 2, (C) grade 3, (D) grade 4, (E) grade 5. Adapted from: Demetriades D. Spleen Injury Grading. In: Vincent J-L, Hall JB, editors. Encyclopedia of Intensive Care Medicine. Heidelberg: Springer Berlin Heidelberg; 2012. p. 2107–10. (21)

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