



Reimaging in pediatric blunt spleen and liver injury[☆]

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ABSTRACT

Background: APSA guidelines do not recommend routine reimaging for pediatric blunt liver or spleen injury (BLSI). This study characterizes the symptoms, reimaging, and outcomes associated with a selective reimaging strategy for pediatric BLSI patients.

Methods: A planned secondary analysis of reimaging in a 3-year multi-site prospective study of BLSI patients was completed. Inclusion required successful nonoperative management of CT confirmed BLSI without pancreas or kidney injury and follow up at 14 or 60 days. Patients with re-injury after discharge were excluded.

Results: Of 1007 patients with BLSI, 534 (55%) met inclusion criteria (median age: 10.18 [IQR: 6, 14]; 62% male). Abdominal reimaging was performed on 27/534 (6%) patients; 3 of 27 studies prompting hospitalization and/or intervention. Abdominal pain was associated with reimaging, but decreased appetite predicted imaging findings associated with readmission and intervention.

Conclusion: Selective abdominal reimaging for BLSI was done in 6% of patients, and 11% of studies identified radiologic findings associated with intervention or re-hospitalization. A selective reimaging strategy appears safe, and even reimaging symptomatic patients rarely results in intervention. Reimaging after 14 days did not prompt intervention in any of the 534 patients managed nonoperatively.

Level of evidence: Level II, Prognosis.

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Current APSA and ATOMAC [1] guidelines for nonoperative management (NOM) of pediatric blunt liver and spleen injury (BLSI) do not recommend routine reimaging of BLSI. The literature on reimaging after blunt spleen and liver trauma has largely reached the consensus that routine reimaging without a clinical indication does not influence outcomes or patient management in adults [2–4] and children [5]. In a selective reimaging strategy for BLSI, the decision to reimagine after discharge is often influenced by injury severity and symptomatology.

Small early studies suggest that routine follow-up screening for pseudoaneurysms might be considered for children with high-grade

spleen and liver injuries [1,6,7]. In their sample of pediatric BLSI with selective reimaging 5–7 days after injury, Safavi et al. found that the overall splenic artery pseudoaneurysm (SAP) and hepatic artery pseudoaneurysm (HPA) rates were 5.4% and 1.7% respectively; rates were higher in high-grade injuries [6]. Others, however, claim that there is insufficient evidence to support or dispute routine follow-up reimaging to screen for SAP after NOM for blunt spleen trauma [8,9]. A similar study in adults showed a 4% hepatic pseudoaneurysm rate; however, HPA was not correlated with severity of liver injury [10].

APSA practice guidelines recommend that clinically stable patients treated with NOM for blunt liver [3,4,11,12] or spleen [4,13] injuries do not need follow-up reimaging in the absence of clinical deterioration, increased symptoms, or signs of spleen or liver abnormality. Giss et al. advocate a low threshold for reimaging pediatric blunt liver trauma when complications are suspected [14]. Uchida et al. [15] associated

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continuous symptoms after high-grade spleen trauma with delayed events hospital day 6–7 in patients 16 years of age or older. In a separate pediatric case series abdominal pain was the most frequent symptom associated with a finding of SAP, yet 3/8 children with SAP were asymptomatic when diagnosed [9]. A direct causal relationship between SAP and abdominal pain in the absence of bleeding remains speculative.

Most studies investigating injury characteristics, clinical course, and symptoms that may prompt consideration for reimaging are in adults [4,10,16], focus on reimaging prior to discharge [2,3,6,16] (see Sidhu, Shaw, Daly, Waldhausen, and Coldwell [17] and Friewald [18]), and/or are small, single institution case series or case reports [17,18]). Using a multi-center cohort with NOM management of BLSI standardized for all centers, we investigated the outcomes associated with a selective reimaging strategy after discharge in pediatric BLSI. The purpose of this secondary analysis is to (1) identify the rate of re-imaging with radiological findings associated with intervention when using a selective reimaging strategy and (2) identify associated symptoms and outcomes with a selective reimaging strategy in pediatric BLSI. Identifying the incidence and symptoms associated with delayed complications of pediatric BLSI may reduce the rate of necessary reimaging studies.

1. Materials and methods

1.1. Study population

This was a planned secondary analysis as part of a larger multi-center observational study of BLSI patients. Inclusion required CT-confirmation of BLSI in patients 18 years old or younger. Patients presented to one of ten Level 1 pediatric trauma centers (PTC) between April 2013 and January 2016. Patients with concurrent kidney or pancreas injury were excluded, as were patients who experienced potential reinjury mechanisms before follow-up. Patients were excluded if they failed NOM, did not have follow-up data, if follow-up did not indicate whether the patient had abdominal reimaging, or if the patient was still hospitalized at the time of follow-up. Participating centers were part of the Arizona-Texas-Oklahoma-Memphis-Arkansas + Consortium (ATOMAC +) and included: Phoenix Children's Hospital (Phoenix, AZ), The Children's Hospital at OU Medical Center (Oklahoma City, OK), Children's Medical Center, part of Children's HealthSM (Dallas, TX), Le Bonheur Children's Hospital (Memphis, TN), Dell Children's Medical Center (Austin, TX), Arkansas Children's Hospital (Little Rock, AR), Children's Healthcare of Atlanta (Atlanta, GA), Mercy Children's Hospital (Kansas City, MO), Akron Children's Hospital (Akron, OH), and American Family Children's Hospital (Madison, WI). All sites had previously adopted the ATOMAC Blunt Pediatric Spleen/Liver Injury Guideline (v11.0) for nonoperative management (NOM) as a standard of care [1]. All sites were approved by their site institutional review board for this study.

1.2. Data collection and definitions

Data were collected and managed with REDCap (Research Electronic Data Capture), hosted at Phoenix Children's Hospital [19]. REDCap is a secure, Web-based application designed to support data capture for research studies, providing (1) an intuitive interface for validated data entry; (2) audit trails for tracking data manipulation and export procedures; (3) automated export procedures for seamless data downloads to common statistical packages; and (4) procedures for importing data from external sources.

Data collected for this study included demographics, injury characteristics, radiology, procedures, course of treatment, length of stay, and short- (14 days post injury) and long- (60 days post injury) term outcomes. The data set included documentation on whether patients were placed or crossed into the unstable NOM pathway and whether NOM failed. NOM failure was defined as the use of laparoscopy or laparotomy before discharge. Angiography or angiembolization was not

considered failure for the purpose of this study. To determine reimaging rates after discharge, patients were followed up 14 days and 60 days post injury. Reimaging was defined as abdominal reimaging in at least one of the following modalities: computed tomography (CT), ultrasound, magnetic resonance imaging (MRI), angiography, and magnetic or endoscopic retrograde cholangiopancreatography (ERCP). Reimaging results were documented as normal, indicative of pseudoaneurysm, or indicative of another finding (e.g. healing, (pseudo)cysts, abscess, adhesions, pleural effusion). The 'other' findings were coded as either 'normal healing' (i.e. signs of healing with no findings), or 'atypical' (e.g. healing with cystic structures, abscess, biloma, pseudoaneurysm, etc.)

Parents and patients were instructed to return to the emergency department based on ATOMAC guidelines as standard of care [1]. More specifically, they were instructed to return to the emergency department (ED) for worsening symptoms (abdominal pain, pallor, dizziness, difficulty breathing, vomiting, shoulder pain, jaundice, gastrointestinal bleeding, black tarry stools). Prospective data were collected on patients who returned to the ED and/or were readmitted. Symptomatology information at follow-up or return to the ED/hospital was collected. The following signs and symptoms were followed at each time point: appetite loss, abdominal pain, fatigue, bloody stool, tarry stool, jaundice of the eyes, shoulder pain, and dizziness.

1.3. Statistical analysis

Descriptive statistics were used to summarize patient, injury, clinical and follow-up characteristics. Data were summarized as counts and percentages for categorical variables or mean and interquartile range (IQR) for ordinal and scale variables. Comparisons were made between categorical variables with χ^2 and Fisher's exact tests as appropriate, comparisons between ordinal variables were made using Wilcoxon rank sum tests, and comparisons between continuous variables were made with *t* tests and corrected for unequal variances as appropriate. Data were abnormally distributed and are therefore reported as median and interquartile range (IQR). Data were prepared for analysis and analyzed using R version 3.4.2 [20] in RStudio version 1.1.383 [21]. In addition to the base R stats package, the descr 1.1.4 [22] and psych 1.8.3.3 [23] packages were used to calculate descriptive and inferential statistics. Tests were two-tailed and statistical significance was assessed at the 0.05 level.

2. Results

During the study period a total of 1007 patients were enrolled. There were 155 excluded for concurrent kidney or pancreas injury and 22 excluded for NOM failure. There were 247 patients excluded because they did not have follow-up data, and 47 excluded because they were still hospitalized at follow-up or follow-up did not indicate whether the patient was reimaged. There were 2 additional patients excluded for reinjury before follow-up (see Fig. 1).

Of the 1007 patients, 534 met qualification for this study. Median age was 10.2 [IQR: 6, 14], median weight (kg) was 36.8 [22, 57], and 335 patients were male (63%). 263 (49%) patients had only a liver injury, 225 (42%) had only a spleen injury, and 46 (9%) had both. Median pediatric Glasgow coma score (GCS) was 15 [15]. Median injury grades were as follows: spleen = 3 [2, 4], liver = 3 [2, 3]; median injury severity score was (ISS) 14 [9, 22]. A total of 27 (6%) patients were reimaged with a qualifying method. Of the patients reimaged, one patient had an angiogram, nine had CT, and 19 had an ultrasound; 3 of these patients had both CT and an ultrasound. There were no abdominal MRI or ERCP reimaging studies. No patients were reimaged at both 14 and 60 days.

Patient injury and clinical course characteristics are presented in Table 1, dichotomized by presence of follow-up reimaging. Patients who were reimaged were older and there was a trend toward higher

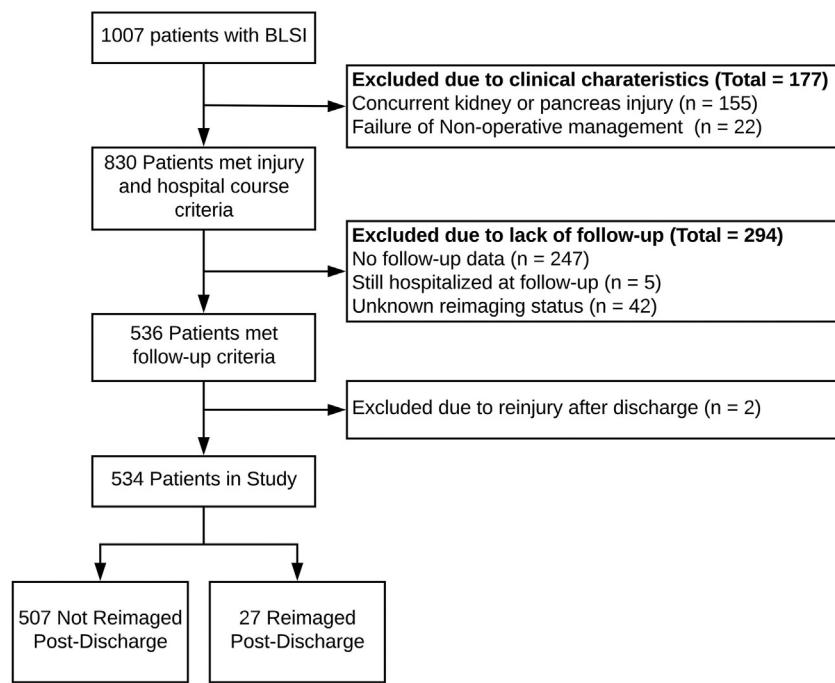


Fig. 1. STROBE diagram of reimaging follow-up. There were 1007 children with BLSI, 534 of whom qualified for the study. Of the study cohort, 27 patients had follow-up reimaging.

ISS for non-reimaged patients. There were no differences in the characteristics of patients who were or were not reimaged.

Table 2 describes the symptoms present in patients with and without post-discharge reimaging. A greater proportion of reimaged patients had abdominal pain compared to those who were not reimaged. There was no difference in the incidence of any other symptoms in patients who were or were not reimaged.

A total of 27 patients had follow-up reimaging after discharge. Of these patients, 8/27 (30%) showed signs of healing (without pseudocyst, pseudoaneurysm, or other clinical findings other than mild splenic enlargement) and 13/27 (48%) had radiographically normal exams. The median time to follow-up did not differ between patients who showed signs of healing and radiographically normal exams (35 [14, 39] vs. 21 [17, 66], $p = 0.13$). In the 6/27 (22%) remaining reimaged patients, there were two patients with splenic cysts, one patient with a hepatic cyst, one patient with an abscess and suspected abdominal adhesions with unremarkable liver and spleen, one patient's spleen was still partially devascularized (unchanged), and one patient presented with hematuria and showed traces of free fluid on a CT

cystogram and renal ultrasound. There were no pseudoaneurysms in any of the reimaged patients.

Five of the patients with reimaging were readmitted, three of whom had abnormal abdominal reimaging findings. Of the patients with abnormal findings, one showed intra-abdominal abscesses and adhesions and received surgical intervention. Another was readmitted for abdominal pain and found to have a post-traumatic splenic and ovarian cyst with no further intervention noted. The patient who presented with hematuria showed traces of free fluid on a CT cystogram and renal ultrasound. The hematuria was not suspected to be related to the previous spleen injury and the patient was admitted to urology for further examination. Urology placed a foley catheter during examination, but removed and discontinued it at discharge. Of the readmitted patients with normal reimaging, one had presented to the emergency department with abdominal pain and reported hematochezia; CT showed normal healing of a liver laceration and the patient remained in observation until passing a non-bloody stool. Another was readmitted for a pleural effusion; however, an abdominal angiogram was normal. Thus, there was no patient who had a follow-up abdominal angiogram who was readmitted for bleeding. All reimaged patients who had an intervention associated with their radiographic findings were within the 14 day follow-up period. No patients reimaged after 14 days were readmitted due to abnormal findings.

Table 1
Patient characteristics by reimaging status.

	No reimaging (n = 507)	Reimaging (n = 27)	p-Value
Age, median [IQR]	9.9 [5.7, 13.9]	13.3 [11.2, 15.3]	0.008*
Male, n (%)	320 (63)	15 (56)	0.43
Weight (kg), median [IQR]	36.3 [21.9, 57]	47.5 [33.4, 55.9]	0.97
GCS, median [IQR]	15 [15, 15]	15 [15, 15]	0.11
ISS, median [IQR]	16 [9, 22]	11.5 [8, 16]	0.06
Hospital LOS (h), median [IQR]	51 [35, 101]	50 [38, 69]	0.01*
Unstable Pathway, n (%)	116 (23)	8 (30)	0.43
Organ Injury, n (%)			
Liver	251 (50)	12 (44)	0.763
Spleen	213 (42)	12 (44)	
Liver and Spleen	43 (8)	3 (12)	
Grade of Injury, median [IQR]			
Liver	3 [2, 3]	3 [2, 4]	0.36
Spleen	3 [2, 4]	3 [3, 4]	0.14

Abbreviations: IQR = interquartile range; ISS = Injury Severity Score; GCS = Glasgow Coma Score; LOS = length of stay (hours).

Table 2
Patient follow-up symptoms by reimaging status.

	No Reimaging (n = 507)	Reimaging (n = 27)	p-Value
	n (%)	n (%)	
Abdominal Pain	68 (14)	11 (42)	<0.001*
Loss of Appetite	49 (10)	4 (16)	0.30
Dizziness	28 (6)	0 (0)	0.62
Fatigue	44 (9)	3 (13)	0.45
Shoulder Pain	39 (8)	0 (0)	0.40
Bloody Stool	5 (1)	1 (4)	0.23
Tarry Stool	2 (0.4)	1 (4)	0.13
Jaundiced Eyes	3 (0.6)	0 (0)	1

The n for each group at each symptom varies slightly based on the availability of data. Percentages are based on using the valid percent.

There were no reimaged patients who reported dizziness, shoulder pain, or jaundiced eyes, so these symptoms are removed from further analysis. Table 3 shows patient characteristics, symptoms at follow-up, and clinical course characteristics of patients who were reimaged at follow-up, dichotomized by whether reimaging findings were associated with hospitalization and intervention. Patients who had reimaging findings associated with readmission and intervention had lower grade spleen injuries than those who were reimaged but did not have findings associated with readmission or intervention.

Descriptively, the symptoms that occurred with atypical reimaging associated with hospitalization and/or intervention included reduced appetite, fatigue, and abdominal pain. Symptoms specifically occurring with reimaging findings that prompted surgical intervention in a patient were reduced appetite and fatigue. We compared the incidence of reimaging findings associated with intervention and hospitalization in patients with and without each symptom. A summary of these results can be seen in Table 3. Only reduced appetite approached significance for an association with reimaging findings resulting in intervention and hospitalization.

3. Discussion

Complications of BLSI requiring intervention after discharge are rare. Even selective post-discharge reimaging for symptoms was unlikely to be clinically significant. Of the 31 (6%) patients with post-discharge reimaging, only five (16%) patients were readmitted at follow-up and only three (10%) of reimaged patients had significant reimaging results (defined as anything other than normal or typical healing). Additionally, patients who were *not* reimaged by 14 days after discharge did not later require imaging, hospitalization or intervention. Thus, a post-discharge selective reimaging strategy appears to be safe in pediatric patients with isolated BLSI, and even selective reimaging is rarely associated with results prompting hospitalization or intervention.

Not surprisingly, the data indicate that, overall, reimaged patients have higher rates of reported abdominal pain than non-reimaged patients. However, abdominal pain was not statistically associated with reimaging findings prompting intervention or re-hospitalization. This is in contrast to a previous report listing abdominal pain as the most common symptom associated with delayed complications of blunt spleen trauma (specifically SAP) [9]. Instead, only reduced appetite

approached significance for an association with reimaging findings prompting hospitalization or intervention. Taken together, these results suggest that, although reimaged patients are more likely to have abdominal pain, reduced appetite was more predictive of a reimaging finding that coincided with hospital readmission or warranting further intervention. All patients who had imaging findings associated with readmission and intervention also presented with at least one symptom or sign of abnormality.

There is current disagreement as to whether higher BLSI injury severity is associated with delayed complications. In this study, reimaged patients had overall higher grade spleen injuries than those who were not reimaged, but injury grade was lower in patients with reimaging findings associated with hospitalization and intervention than patients whose reimaging did not prompt hospitalization and intervention. This finding contrasts previous studies that show higher rates of complications with higher injury grades [6,15].

Previous studies have found splenic pseudoaneurysm rates between 2 and 27% [8]. The current study did not identify any pseudoaneurysms and none of the potentially unidentified pseudoaneurysms became clinically important during the study period. The majority of atypical reimaging findings were cystic in nature. The only patient requiring surgical intervention had unremarkable organs and instead had post-traumatic abdominal and pelvic abscesses and adhesions requiring adhesiolysis as well as small bowel resection and repair of enterotomy. This care probably represents an associated subacute bowel or mesenteric injury.

Overall, 78% of patients with reimaging showed normal or typical healing results. Radiographic healing appears to follow typical timeframes. In children, grade I and II spleen injuries are typically healed radiographically within 2.5 to 4 months, grade III injuries within 2.5 to 6 months, and grade IV injuries up to 11 months [5,24]. Mild liver injuries in children have been reported to typically show normal imaging after 3 months, moderate injuries within 6 months, and severe injuries 15 months or more [25]. As all images in this study were acquired within approximately 2 months of injury, it is expected that some patients would still show radiographic healing at this time.

Most findings outside of normal or normal healing at reimaging did not result in intervention. Although splenic or hepatic pseudocysts were noted in 11% of reimaged patients, only one of these patients was also readmitted and this patient did not have any intervention. This suggests that even findings of post-traumatic pseudocysts rarely lead to intervention in BLSI without kidney or pancreas injury. Similarly, Lyass et al. found that reimaging in clinically stable adults with blunt splenic trauma did not affect patient management [2]. Allins et al. [16] showed that routine repeat CT imaging of adults with BLSI was not associated with subsequent exploratory laparotomy. Similar to our study, these adult studies suggest that, even when reimaging shows abnormalities, the likelihood of an intervention is low.

Previous small studies advocated routine reimaging BLSI within 7 to 10 days of injury [26]. All of the re-imaging findings and associated hospitalization or intervention occurred by the 14 day follow-up, suggesting that complications occur relatively early. Sidhu et al. [17], however, noted delayed hepatic complications in children with blunt liver injury. Our study was unable to confirm this concern.

The rate of post-discharge complications that required an intervention was lower than expected in our study. It is possible that the standardization of NOM and NOM adherence to this population contributed to the low rate of post-discharge complication detected by reimaging. It is also possible (and even probable) that the low rate of reimaging (6% of the study cohort) missed reimaging abnormalities that would have been otherwise detected. However, given that none of the patients who were not reimaged at 14 days later developed complications detected by reimaging and requiring an intervention, it is unlikely that *clinically important* imaging findings were missed.

Table 3
Reimaged patient characteristics by findings prompting intervention and hospitalization.

	No intervention (n = 24)	Intervention (n = 3)	p-Value
Age, median [IQR]	13.3 [11.5, 15.4]	13.05 [9.2, 14.2]	
Male, n (%)	13 (54)	2 (67)	1
Weight (kg), median [IQR]	46.1 [33.7, 56.7]	49.9 [35.9, 50.5]	0.72
GCS, median [IQR]	15 [15, 15]	15 [15, 15]	0.88
ISS, median [IQR]	13 [9, 16.5]	8 [7, 8]	0.13
Hospital LOS (h), median [IQR]	50 [40, 68.5]	41 [31.5, 85]	0.88
Unstable Pathway, n (%)	8 (33)	0 (0)	0.53
Organ Injury, n (%)			
Liver	12 (50)	0(0)	0.31
Spleen	9 (38)	3 (100)	
Liver and Spleen	3 (12)	0 (0)	
Grade of Injury, median [IQR]			
Liver	3 [2, 4]	-	-
Spleen	3 [3, 4]	2 [2, 2]	0.007*
Symptom present [†] , n (%)			
Abdominal Pain	10 (44)	1 (33)	1
Loss of Appetite	2 (9)	2 (67)	0.06
Fatigue	2 (10)	1 (33)	0.36
Bloody Stool	1 (5)	0 (0)	1
Tarry Stool	1 (5)	0 (0)	1

Abbreviations: IQR = interquartile range; ISS = Injury Severity Score; GCS = Glasgow Coma Score; LOS = length of stay (hours)

[†] The n for each group at each symptom varies slightly based on the availability of data. Percentages are based on using the valid percent.

3.1. Limitations

Post-discharge reimaging of BLSI was a relatively rare event in this dataset and intervention based on reimaging results was even less frequent. Even in a large cohort, this makes it difficult to have the statistical power to make strong statements about symptoms associated with reimaging that results in further medical intervention. Since there were no pseudoaneurysms in this cohort, it is not possible to determine their rate in this population, nor the associated symptoms. Additionally, since some symptoms were not associated with reimaging and or reimaging findings, it is difficult to describe the true rate at which they co-occur with reimaging and reimaging findings. As the reimaging in this cohort was selective, it is possible that there were patients who had undocumented pseudoaneurysms. If this is the case, however, it is likely they were either relatively benign in nature or follow-up reimaging was performed outside of the pediatric trauma center where the patient was managed. There is evidence to suggest that small post-traumatic splenic and hepatic pseudoaneurysms resolve without intervention [6,8,27,28], thus making their detection irrelevant.

4. Conclusions

In a selective abdominal reimaging strategy after successful NOM of pediatric BLSI, 6% of patients underwent reimaging. Of these, only 11% of studies identified showed significant radiologic findings associated with hospitalization, and only 1 patient underwent intervention (which was for an associated abscess with adhesions). Reimaging after 14 days did not prompt intervention in any of the 534 patients managed nonoperatively. Thus, post-discharge reimaging findings that are associated with intervention are rare and compose 0.6% (3/534) of the study cohort. A selective reimaging strategy appears safe, and even reimaging symptomatic patients rarely results in intervention.

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