A follow-up aCT scan demonstrated large subcapsular fluid collections and a hepatic artery pseudoaneurysm near the base of the liver laceration (Fig. 1). As a result of these findings, the child was transferred to our institution for further treatment of the hemobilia and pseudoaneurysm.

Once at our institution, he subsequently underwent angiography with combined coil and hemostatic gel embolization of the pseudoaneurysm, which was found to be arising from the right hepatic artery. A follow up aCT scan demonstrated no flow in the pseudoaneurysm.

Nine days after his procedure, the child again developed sudden onset of right upper quadrant pain, associated with a temperature of 38.2 °C as well as a mild leukocytosis to 13,000/µL and elevations in aspartate aminotransferase (AST) and alanine aminotransferase (ALT) of up to 583 IU/L and 306 IU/L. A right upper quadrant ultrasound found massive gallbladder distension, intrahepatic and common bile duct dilation, and a soft tissue density in the distal duct system, believed to be a clot causing obstruction. With these findings, the child was diagnosed with hemocholecystitis and managed with bowel rest and trimethoprim-sulfamethoxazole leading to resolution of his symptoms. A follow up ultrasound 2 days later showed reduced gallbladder distension with a normal common bile duct. Persistent and separate fluid collections within the liver parenchyma were again noted but were unchanged from previous imaging and presumed to be hematomas. The child was ultimately discharged home on hospital day thirteen with restriction to light activity.

Given the severity of injury, the child was evaluated frequently in trauma clinic with monthly abdominal ultrasounds that
demonstrated persistent fluid collections within the liver parenchyma over a 3-month period. Due to lack of resolution and concern for potential infectious complications, a percutaneous drain was placed under ultrasound guidance with return of 240 cc of bile stained fluid aspirate. The bilirubin of the fluid was 4.5 gm/dL, consistent with biloma. Biliary output continued over the next few days and was concerning for a persistent bile duct leak. Contrast injected into the percutaneous drain demonstrated uptake into the biliary tree (Fig. 2A). Ultimately an ERCP with cholangiogram was performed, and extravasation of contrast was found from a branch of the right main hepatic duct (Fig. 2B). The bile leak was treated with a sphincterotomy and biliary stent placement. This resulted in a progressive decrease in bile drain output, and the patient was discharged on hospital day six with a percutaneous drain and stent in place as well as prophylactic trimethoprim-sulfamethoxazole.

Ten days after discharge, the child was evaluated with ultrasound, which showed reduced cavity space, although the drain continued to have bilious output. While the initial plan was to leave the drain in place for a full 6 weeks, it was inadvertently dislodged and removed approximately 3.5 weeks after placement. At that time, the patient was clinically well with no reported symptoms and no accumulation of fluid. He remained asymptomatic, and the biliary stent was removed endoscopically 10 weeks after placement. The patient has since returned to return to his normal daily activities without any further problem.

2. Discussion

The liver is the most commonly damaged organ in blunt abdominal trauma. Non-operative management is the hallmark of treatment for the vast majority of children that incur blunt hepatic injury [1–3]. For pediatric patients treated non-operatively, guidelines for the appropriate utilization of resources based on the CT liver injury grade have existed for well over a decade, but recent literature has reported management based primarily on patient hemodynamics [3,4]. Present APSA guidelines recommend nonoperative management with length of stay and activity restrictions based on grade of injury [3].

Indications for procedural intervention in a patient with blunt hepatic injury include hemodynamic instability or generalized peritonitis, no response to an initial resuscitation effort, or a continued transfusion requirement [4]. Although laparotomy with perihepatic packing has been the traditional modality to achieve hemostasis, hepatic arterial embolization has also emerged as a valid option in hemodynamically stable patients with high-grade hepatic injuries when contrast extravasation is seen on CT scan or when there is evidence of continuous hemorrhage despite laparotomy. While hepatic angioembolization has been supported in the adult literature, pediatric utilization remains anecdotal [5].

In adults, a retrospective review of 530 blunt liver injuries found that routine in-hospital follow-up scans were not indicated regardless of injury grade in asymptomatic patients as these scans were low yield, did not impact clinical outcome, and were cost-ineffective [6]. Similarly, APSA presently does not recommend predischarge or postdischarge imaging of patients with isolated liver injury [3]. This is based on the findings that overall rates of complications are rare. Giss et al. found an overall complication rate of only 3.4% out of 185 patients with blunt hepatic injury managed nonoperatively. All of these complications were in patients who had grade III or higher liver injuries [1].

One of the potential complications following high grade liver injury is hepatic artery pseudoaneurysm formation. One retrospective review of pediatric patients with isolated liver injury treated nonoperatively found a 1.7% rate of pseudoaneurysm formation, all from grade IV injuries [7]. The authors suggest that the
rate of pseudoaneurysm formation may be higher as not all patients underwent follow-up imaging, suggesting that many pseudoaneurysms may go undetected. Additionally, pseudoaneurysms may be asymptomatic and may not present until days or even months following the initial injury. They are most frequently discovered at the time a patient presents with hemobilia with symptoms of abdominal pain, gastrointestinal bleeding, and occasionally jaundice [8]. Patients may also present with hemodynamic instability following intraperitoneal pseudoaneurysm rupture [7,9,10]. While the gold standard for diagnosis and management has historically been angiography, CT angiography has been the initial study of choice in more recently reported cases [9,11]. It has been suggested that high grade liver injuries may warrant routine screening for pseudoaneurysms despite its low incidence due to the potential for risk for this life-threatening hemorrhage [7]. Additionally, prophylactic treatment has been advocated even in asymptomatic patients to avoid rupture [7,12]. However, the true incidence of pseudoaneurysms and pseudoaneurysm rupture in pediatric hepatic trauma remain unknown. As such, there are no high-grade recommendations for the screening and management of hepatic pseudoaneurysms. Our patient did not receive any follow-up imaging prior to his readmission for hematemesis secondary to pseudoaneurysm as imaging is not indicated in asymptomatic patients [3,6].

Historically, pseudoaneurysms have been treated with hepatic lobectomy. Recent advances in angiography, however, has allowed endovascular embolization to become the first line of treatment and has been shown to be safe and effective with decreased morbidity than surgery even in young children [13]. Risks of embolization include distal coil migration, hepatic abscess, and hepatic necrosis [14]. Several case reports have described the safe and effective use of angioembolization for the management of traumatic pseudoaneurysms in children (Table 1) [7,9,12,15,16].

In addition to hematemesis and potential for shock, bleeding into the biliary tree may lead to blood coagulation within the biliary tract, resulting in obstruction and subsequent hemobilia with symptoms of abdominal pain, gastrointestinal bleeding, and occasionally jaundice. While bile itself is fibrinolytic and may lead to clot degradation, persistent clot may also eventually convert to gallstones [17]. If the blood clot obstructs the cystic duct, cholecystectomy may be required [18]. Treatment options for more distal obstructions include fibrinolytics through percutaneous cholecystostomy [19], endoscopic sphincterotomy [20], operative common bile duct exploration, or conservative management with prophylactic antibiotics, analgesics and bowel rest.

Finally, bile leaks secondary to biliary tract injuries are more common complications with reported incidence of 1–6% in adult liver injuries [21], although pediatric rates have not been established. These patients often have an insidious presentation of vague abdominal symptoms without any changes in liver biochemistry. Bile leaks have been associated with pseudoaneurysms due to the close proximity of vessels to the biliary system.

Abdominal ultrasound or CT may reveal a fluid collection consistent with biloma while HIDA scan or cholangiography may show active extravasation. Sharif et al. recommended early HIDA scans in high risk patients, including those with liver lacerations greater than 4 cm or extending into the porta hepatitis [22]. While our patient met the criteria of a severe liver injury, HIDA scans are not routinely done at our institution for traumatic liver injuries. Although this may have allowed for earlier diagnosis of biliary tract injury, HIDA scans may still miss distal biliary injuries and will overlook delayed bile leaks secondary to duct ischemia [23].

Free bile leaks resulting in diffuse peritonitis may require operative washouts and drainage. Stable patients with localized contained collections, however, may be amenable to radiographically guided percutaneous drainage. Endoscopic retrograde cholangiopancreatography (ERCP) has become an effective diagnostic and treatment modality, even in young children. ERCP has been shown to find biliary leaks even in the setting of normal HIDA scans [24]. Management of bile duct leaks with sphincterotomy and stenting have lead to high success rates, while complications from the ERCP alone such as bleeding or perforation are reported to be rare [24,25]. Other complications may include stent dislodgement, blockage, or cholangitis. We have summarized the 2 largest case series of traumatic bile leaks in children (Table 2) [25,26]. All of these patients were managed without laparotomies and were symptom-free with normal liver function at the time of outpatient follow-up. In conclusion, complications following blunt hepatic trauma are rare but are diverse and often require a multidisciplinary approach for treatment. The trauma surgeon must be aware of the potential for these complications as well as their unique presentations and management options. We illustrate an excellent teaching case in which a single patient develops multiple complications following injury high grade with successful outcome.

### Conflict of interest statement

The authors have no disclosures.

---

**Table 1** Summary of management of pediatric pseudoaneurysm resulting from blunt hepatic trauma.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Date of pseudoaneurysm diagnosis (post injury day)</th>
<th>Presentation of pseudoaneurysm</th>
<th>Management</th>
<th>Hospital days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safavi et al. [7]</td>
<td>10</td>
<td>Hemorrhage due to rupture</td>
<td>Angiographic embolization</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Hemorrhage due to rupture</td>
<td>Laparotomy</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Not specified</td>
<td>Asymptomatic</td>
<td>Angiographic embolization</td>
<td>15</td>
</tr>
<tr>
<td>Hacker et al. [9]</td>
<td>9</td>
<td>Hemorrhage due to rupture</td>
<td>Angiographic embolization</td>
<td>43</td>
</tr>
<tr>
<td>Yi et al. [12]</td>
<td>0</td>
<td>Asymptomatic</td>
<td>Angiographic embolization</td>
<td>58</td>
</tr>
<tr>
<td>Bardes et al. [15]</td>
<td>10</td>
<td>Hematemesis</td>
<td>Angiographic embolization</td>
<td>36</td>
</tr>
<tr>
<td>Hardcastle et al. [16]</td>
<td>11</td>
<td>Hemorrhage due to rupture</td>
<td>Angiographic embolization</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ERCP, stent</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ERCP, stent</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ERCP, stent</td>
<td>20</td>
</tr>
</tbody>
</table>

**Table 2** Summary of management of traumatic bile leaks in children.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Age (y)</th>
<th>Gender</th>
<th>Management</th>
<th>Hospital days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Castagnetti et al. [25]</td>
<td>12</td>
<td>Female</td>
<td>Percutaneous drainage, ERCP, stent, angiographic embolization</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Female</td>
<td>Percutaneous drainage, ERCP, stent</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Male</td>
<td>Percutaneous drainage, ERCP, stent</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Male</td>
<td>Percutaneous drainage, ERCP, stent</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Male</td>
<td>Percutaneous drainage, ERCP, stent</td>
<td>58</td>
</tr>
<tr>
<td>Almarambi et al. [26]</td>
<td>3</td>
<td>Male</td>
<td>Percutaneous drainage, ERCP, stent</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Female</td>
<td>Percutaneous drainage, ERCP, stent</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Male</td>
<td>Percutaneous drainage, ERCP, stent</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Male</td>
<td>Percutaneous drainage, ERCP, stent</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Male</td>
<td>Percutaneous drainage, ERCP, stent</td>
<td>20</td>
</tr>
</tbody>
</table>
Acknowledgments

Thomas J. Desmarais is a Doris Duke Clinical Research Fellow supported by the Doris Duke Charitable Research Foundation. Dr. Choi is also supported by The Marion and Van Black Endowed Pediatric Surgical Fellowship.

References


