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Contemporary Approaches to the Management of Blunt Abdominal Trauma in Children: A Literature Review

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Abstract Blunt hepatic and splenic injuries in children remain a major challenge in pediatric emergency surgery. Age - specific anatomic and physiologic features predispose to solid - organ damage even after relatively low - energy impacts. Over recent decades, management paradigms have shifted substantially: whereas operative strategies previously predominated, current international guidelines (APSA, WSES) endorse nonoperative management (NOM) as the standard of care for hemodynamically stable patients. This review synthesizes recent international literature comparing conservative and surgical approaches to pediatric blunt liver and spleen trauma. We summarize data from national registries, multicenter studies, and clinical series on outcomes, complication rates, predictors of NOM failure, and the role of contemporary diagnostics and minimally invasive interventions (e.g., angioembolization). Methodologically, most studies are observational, employ CT - based AAST grading, and integrate clinical risk stratification tools. Across cohorts, NOM achieves high success rates (90–97%), very low mortality (<1% for isolated injuries), and a marked reduction in splenectomy frequency to 4–7%. Operative treatment remains essential for a limited subset with hemodynamic instability or ongoing hemorrhage. Overall, contemporary management of pediatric blunt hepatic and splenic injuries should be organ - preserving, with interventions individualized to clinical status rather than dictated solely by morphologic injury characteristics.

Keywords Children, Blunt abdominal trauma, Liver, Spleen, Surgical management, Nonoperative management, Literature review

1. Introduction

Abdominal trauma ranks among the leading components of pediatric injury. In cases of blunt (closed) abdominal trauma, the spleen and liver are most frequently affected. According to multicenter studies, splenic injury occurs in approximately half of children with abdominal trauma, with hepatic injury observed at nearly the same frequency [1]. The principal mechanisms are road - traffic incidents and falls from height [2]. Despite the potential severity of parenchymal organ ruptures, management strategies have shifted markedly over the past decade: conservative, nonoperative management has become the standard for hemodynamically stable patients, resulting in a pronounced reduction in operative interventions.

At present, more than 95% of children with blunt splenic or hepatic injuries can be treated successfully without surgery [3]. Operative intervention is required only in a relative minority—variously estimated at about 4–10% - most often in the setting of ongoing hemorrhage or physiologic instability, particularly with splenic rupture [2,3].

Historically, splenectomy rates in children were substantially higher; however, with the broad adoption of nonoperative management they have fallen considerably. For example, data from a U.S. national registry (2012–2019) indicate an overall pediatric splenectomy rate of roughly 7%, with markedly lower rates in specialized pediatric centers (about 1–4%) compared with general (adult) hospitals (≈12%) [3]. Accordingly, contemporary pediatric surgery prioritizes organ preservation in injuries of the liver and spleen—both in recognition of children's strong regenerative capacity and to avoid lifelong risks associated with splenectomy, including immune dysfunction and overwhelming postsplenectomy infection [4]. Over the last decade, routine laparotomy has given way to careful clinical assessment, the use of modern diagnostic modalities (ultrasonography and computed tomography), and minimally invasive interventions, thereby minimizing unnecessary operations and reducing treatment invasiveness.

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2. Guidelines and Consensus Statements

The contemporary strategy for managing splenic and hepatic injuries in children is delineated across several authoritative guidelines. The American Pediatric Surgical Association (APSA) issued its first recommendations in 2000, establishing the primacy of nonoperative management (NOM) for these injuries in children [5]. The updated APSA guidelines (2023) reaffirm this direction: admission to

intensive care is indicated only for children who remain unstable after initial resuscitation, whereas hemodynamically stable patients may be managed on a standard surgical ward without strict activity restrictions [5]. Under the new guidance, indications for transfer to the operating room are intentionally minimalist: if, despite restoration of circulating blood volume, there are persistent signs of ongoing internal bleeding (declining hemoglobin, tachycardia, hypotension), urgent intervention—angiographic embolization or laparotomy – is warranted [5]. In all other cases, continued observation is recommended. APSA further emphasizes that the length of hospital stay and bed rest should be determined by clinical status rather than CT injury grade; discharge is acceptable when the child is clinically stable, even in the presence of high - grade injury [5]. Follow - up imaging (ultrasonography/CT) is reserved for the development of symptoms suggestive of complications; routine repeat scans in asymptomatic children are no longer recommended [5].

In parallel with APSA, similar positions are reflected in international consensus documents. The World Society of Emergency Surgery (WSES) has issued guidance on splenic trauma (2017) and hepatic trauma (2020), each with dedicated pediatric considerations. Both documents stress that the vast majority of children with blunt splenic or hepatic injuries can be managed successfully without surgery [4,6]. WSES underscores that management should be grounded primarily in the child's physiologic status rather than solely in an anatomic injury classification [4,7]. Whenever feasible, such patients should be treated in specialized pediatric centers equipped for continuous monitoring and minimally invasive interventions [4]. With multidisciplinary coordination (trauma surgeon, intensivist, interventional radiologist), even severe injuries can often be treated without organ removal: contemporary data indicate that NOM is feasible in approximately one third of even high - grade (AAST IV–V) liver and spleen injuries, provided hemodynamics remain stable [6]. Leading guidelines (APSA, WSES, EAST, and others) converge on the principle that hemodynamic instability remains an absolute indication for urgent operation, whereas hemodynamically stable children are candidates for observation regardless of CT grade [7].

Over the past decade, a substantial body of clinical evidence has accumulated in support of the safety and effectiveness of conservative care in children. A large multicenter observational study (Wisner et al., 2015) including 12,044 injured children found that only ~5% sustained splenic or hepatic injuries, and the overwhelming majority of these (~95%) were successfully treated without operation [1]. Active interventions were infrequent: transfusion was required in ~11%, angioembolization in ~1.4%, and therapeutic laparotomy in 4.1% [1]. Prospective registry data from Japan (SHIPPs, 2008–2019; >1,300 children) likewise demonstrated an exceedingly low failure rate of conservative management (1%), meaning only isolated patients required delayed surgery; in - hospital mortality for isolated hepatic/splenic injuries was 0.7% [7]. European experience is consistent with these findings: in a national Dutch review (Grootenhaar et al., 2021), 75% of children with splenic trauma were treated conservatively—including most high - grade (IV–V) injuries—and none of the conservatively managed patients later required surgery (100% NOM effectiveness) [8]. The overall splenectomy rate in that series was 6.2% [8]. The sole predictor of operative need was hemodynamic instability on admission ($p = 0.001$) [8]. Conversely, high CT grades alone were not an absolute indication for surgery: even among grade IV–V injuries, the majority (~77%) avoided splenectomy when clinically stable [8]. Together, these data reinforce that clinical physiology – and the presence of associated injuries – should guide management decisions more than morphologic grade alone.

3. Conservative and Operative Management

The cumulative literature of recent years indicates that, with appropriate patient selection, nonoperative management (NOM) in children is not inferior to surgical treatment in terms of outcomes; moreover, several studies suggest a more favorable overall prognosis among children who avoid laparotomy. In a retrospective analysis of the National Trauma Data Bank (NTDB), in - hospital mortality was ≈2% in the nonoperative cohort versus ≈12% among children who underwent operative treatment [9]. This disparity largely reflects confounding by indication—operated patients were typically more severely injured (e.g., shock, multiple trauma). Importantly, in hemodynamically stable children, deferring emergent surgery does not increase the risk of adverse outcomes. On the contrary, avoiding laparotomy reduces intra – and postoperative complications and obviates risks unique to splenectomy, such as overwhelming post - splenectomy infection (OPSI).

Meta - analyses corroborate the high success of conservative management in pediatric patients, with failure rates – i.e., need for delayed operation – remaining within only a few percent [7,8]. A key determinant of success is vigilant observation: international experience supports close monitoring of children with splenic/hepatic injuries in trauma centers so that any signs of deterioration (falling blood pressure, escalating tachycardia, decreasing hematocrit) trigger immediate surgical intervention [4,7].

Accordingly, contemporary publications converge on a consistent message: operative treatment is indicated for a narrowly defined subset—those with uncontrolled hemorrhage or children presenting in hemorrhagic shock. For the remainder, organ - preserving therapy is both safe and appropriate. Particular emphasis is placed on splenic preservation whenever feasible, given the organ's immunologic role and the risk of OPSI [4]. When surgery is unavoidable (e.g., a shattered spleen with ongoing bleeding), many authors advocate spleen - preserving techniques – partial resection, splenorrhaphy, application of hemostatic agents – in lieu of total splenectomy, provided this is

technically achievable and safe.

Leading organizations (AAST, APSA, Pediatric Trauma Society, among others) continue to update guidance aimed at further optimizing care – reducing unnecessary admissions and standardizing monitoring and rehabilitation protocols – as reflected in recent literature reviews [5,8].

4. Analysis of Study Methodology

Across the literature, the vast majority of studies on this topic employ observational designs. Randomized controlled trials in pediatric trauma are scarcely feasible for ethical reasons; consequently, the evidence base relies on registry analyses, retrospective case series, and prospective observational cohorts. For example, Wisner et al. conducted a prospective multicenter observational study of children with blunt trauma that included >600 patients with CT – or laparotomy - confirmed splenic/hepatic injuries [1]. Similarly, the Japanese SHIPPs study (2024) represents a secondary analysis of a multipurpose pediatric trauma registry focused on splenic and hepatic injuries [7]. Sample sizes vary widely – from national databases reporting >8,000 splenic injuries [3] to single - center experiences [2].

Inclusion criteria typically encompass pediatric patients (commonly ≤16 or 18 years) with confirmed blunt abdominal trauma. Many studies exclude penetrating injuries, prehospital fatalities, and patients with concomitant unsurvivable injuries (e.g., severe traumatic brain injury) to focus specifically on the management of isolated abdominal trauma. Subgroup analyses are frequent – for instance, comparing outcomes in children with isolated splenic/ hepatic injury versus those with concomitant injuries [1], as well as identifying factors associated with failure of conservative (nonoperative) management.

5. Diagnostics

Nearly all studies emphasize the role of contemporary imaging. The standard is contrast-enhanced computed tomography (CT), which enables precise confirmation of hepatic or splenic rupture, grading of injury severity according to the AAST scale, and detection of active hemorrhage (contrast extravasation) [8]. The AAST (American Association for the Surgery of Trauma) injury scale is used in virtually all publications to standardize severity (grades I–V) [9]. Importantly, both studies and guidelines concur that injury grade alone should not dictate management – the child's clinical status is decisive [7]. In Level I – trauma centers (USA), care for children with splenic/hepatic rupture follows a simple rule: if stable – observe; if unstable – operate, irrespective of CT grade [7].

Even so, comprehensive CT diagnostics remain valuable for planning: for example, the presence of a "contrast blush" (active bleeding) in a hemodynamically stable child often serves as an indication for prophylactic vascular embolization, as noted in several reports [8]. In the emergency department, a FAST examination is frequently performed at presentation to rapidly assess for free fluid. Although the sensitivity of FAST in children is limited, its findings may have prognostic value: a negative FAST has been associated with successful conservative management [7], whereas the detection of a substantial fluid collection heightens concern for potential NOM failure. Diagnostic peritoneal lavage (DPL) is seldom used in contemporary pediatric practice, having largely been supplanted by noninvasive imaging.

6. Surgical Techniques and Interventions

When operative indications are present (uncontrolled hemorrhage, cardiac tamponade, hollow-viscus perforation, etc.), urgent laparotomy is the standard of care. In the setting of ongoing intra-abdominal bleeding, pediatric damage-control principles apply: rapid exploration and packing of the bleeding source (e.g., hepatic laceration) can arrest massive hemorrhage and stabilize the child for subsequent hemodynamic optimization in ≈80% of cases [10].

For severe liver injury, operative tactics include digital compression or ligation of disrupted vessels, gauze packing of hepatic wounds, application of topical hemostatic agents (fibrin sealants, meshes), and drainage – up to temporary abdominal closure with a planned re-look once the patient is stabilized (staged management). Splenic injuries are managed as conservatively as feasible: when anatomy permits, splenorrhaphy, capsular suturing, or partial splenectomy is preferred to preserve functional tissue. However, in cases of a shattered spleen or multiple hilar disruptions, splenectomy – complete organ removal – may be unavoidable. All children post-splenectomy must be vaccinated against pneumococcus, meningococcus, and Haemophilus influenzae type b to mitigate the risk of overwhelming post-splenectomy infection (OPSI) [4].

Selective angiographic embolization has gained wide adoption in recent years and serves as an effective alternative to surgery in hemodynamically stable patients with CT evidence of active bleeding. In pediatric practice it is employed less frequently than in adults – partly due to limited availability of pediatric interventional radiology and technical constraints in small children; U.S. data indicate embolization in ~1–2% of children with splenic trauma [3], whereas rates are higher in adults [3]. Nonetheless, multiple reports demonstrate high effectiveness of embolization in children, allowing hemorrhage control without laparotomy and facilitating organ preservation.

Diagnostic laparoscopy may be used in equivocal situations; however, its role in blunt trauma is limited – CT typically provides sufficient decision-making information. Laparoscopic access can be considered in hemodynamically stable patients when associated injuries are suspected (e.g., diaphragmatic tear) or for minimally invasive drainage of post-traumatic collections, but it is not used in the presence

of active bleeding – laparoscopy is ineffective for emergent tamponade.

7. Outcomes

When contemporary protocols are followed, complication rates in children with splenic and hepatic injuries are comparatively low. The most concerning complication – delayed (secondary) hemorrhage – may occur several days after injury due to rupture of a subcapsular hematoma or splenic arterial pseudoaneurysm [4]. To detect this promptly, children are kept under observation, and when CT identifies pseudoaneurysms, prophylactic embolization can be considered. After liver injury, biliary complications (biloma, bile leak) and intra-abdominal abscesses may arise and typically require drainage. Splenectomy carries a risk of overwhelming post-splenectomy infection (OPSI) – a fulminant septic syndrome – hence vaccination against pneumococcus, meningococcus, and H. influenzae type b, along with targeted antibiotic prophylaxis during severe infections, is essential [4]. Overall, under nonoperative management the majority of children avoid serious complications – success rates reach ~96% and higher [7,8].

In-hospital mortality attributable directly to isolated pediatric splenic or hepatic injuries is low, particularly in the absence of other trauma. In a Korean series of 55 children, there were no deaths among those with splenic injury, and only 1 child (2.9%) with severe liver trauma died from uncontrollable hemorrhage [2]. Large multicenter analyses show comparable results – for example, mortality in a Japanese registry was <1% [2]. When liver/spleen injuries occur as part of polytrauma, mortality is driven mainly by associated critical injuries – severe traumatic brain injury, thoracic trauma, etc. – rather than blood loss from the spleen or liver [8]. Thus, for isolated injuries, prognosis in children is generally favorable.

Length of hospital stay is influenced by injury severity and chosen management. On average, children who undergo surgery remain hospitalized longer than those treated conservatively. NTDB data indicate a mean stay of ~9.1 days after operative treatment versus ~6.5 days with nonoperative management [9]. The presence of hemorrhagic shock on admission and multiple injuries also prolongs hospitalization in a statistically significant manner [8]. Modern protocols aim to minimize unnecessary inpatient days: when the child's clinical status is stable, there is no need to prolong hospitalization to meet a formal "by grade" threshold – discharge is safe once physiology is satisfactory, irrespective of initial CT grade [5,8]. In the Netherlands, for example, shorter bed rest and hospital stays than those recommended in earlier APSA guidance are practiced without worse outcomes [8].

Failure of nonoperative management (NOM) is defined as a scenario in which an initial observation strategy ultimately necessitates delayed surgery. Fortunately, this is uncommon in children. Across studies, failure rates generally do not exceed 3–5% [7,8], and specialized pediatric centers report figures <1–2%. Most conversions, when they occur (e.g., for secondary hemorrhage), take place within the first 24 hours after injury; late (>48–72 h) "unexpected" operations for missed bleeding under proper monitoring are exceptional. Several factors are associated with higher failure risk – older age, contrast extravasation on CT, high-grade hepatic lacerations (IV–V), associated pancreatic or mesenteric injury, and elevated Injury Severity Score (ISS) in the setting of polytrauma [7]. Such risk profiles warrant especially close observation and readiness for interventional management.

Direct comparisons of operative versus conservative treatment are confounded by baseline differences in severity, but the overall pattern is clear: in hemodynamically stable children, foregoing surgery does not worsen prognosis. Cohort analyses show that children who avoid laparotomy have lower mortality and fewer complications than those who undergo operation [9]. While this difference chiefly reflects initial injury severity rather than harm from surgery per se, the broader adoption of NOM has been accompanied by population-level reductions in mortality and improved organ preservation. Age-specific nuances are noteworthy: very young children (<5 years) display remarkable compensatory capacity – they rarely require operation even for substantial injuries and have the highest NOM success; adolescents, whose body mass and injury energy approximate adults, need intervention somewhat more often, and older age independently increases the risk of NOM failure [7]. Even so, management in stable adolescents remains organ-preserving. Institutional factors also matter: specialized pediatric hospitals possess greater experience and capacity for prolonged observation, whereas thresholds for operation are typically lower in general (adult) hospitals. Studies show that children treated in adult facilities undergo splenectomy and embolization more frequently at similar injury severity [2]. These observations underscore the need for centralizing care for severe pediatric abdominal trauma and for strict adherence to modern, evidence-based protocols that have demonstrated safety and effectiveness.

8. Organ-preserving Surgery in Pediatric Solid-organ Trauma

It is widely accepted that conservative management is effective in more than 95% of blunt solid-organ injuries (liver and spleen) in both children and adults [11,12,13].

Minimally invasive endosurgical techniques offer several advantages that are particularly important in pediatrics: small incisions with minimal scarring, lower intensity and duration of postoperative pain, shorter operative times, faster recovery and less psychological trauma compared with open surgery, and a reduced length of hospital stay [14].

Laparotomy has long been used to treat intra-abdominal injuries in adults and children; however, laparoscopy has become increasingly common in recent years. This trend reflects advances in technology and growing surgical

experience, as well as the higher procedural costs and longer operative times associated with laparotomy [15,16].

The timing of surgical intervention should be guided primarily by the patient's physiologic parameters – not by anatomic injury severity alone [17]. This principle is reaffirmed in the latest APSA guidance (2023) [5]. Operations within the first 24 hours are typically required in children with multiple injuries, higher Injury Severity Scores (ISS), and severe single-organ damage [5,18]. According to the World Society of Emergency Surgery (WSES) guidelines, absolute indications for immediate laparotomy in blunt solid-organ injury include hemodynamic instability, free intraperitoneal blood, and failure to respond to appropriate resuscitation [6,8,12,19]. Unfortunately, diagnostic errors still occur and may lead to unnecessary or delayed laparotomy [20].

In children with blunt solid-organ injury, hemodynamics are considered stable at a systolic blood pressure of 50 – 90 mm Hg plus twice the child's age (years). Hemodynamic status is viewed as stabilized when there is a positive response to fluid resuscitation – decreasing heart rate, improved mentation, restoration of peripheral pulses and normal skin color, rising blood pressure, increased urine output, and warming of the extremities [6,18]. Surgeons should remain aware that signs of deterioration in children can be subtle – for example, only mild tachycardia – and severe hypovolemic shock may develop abruptly.

9. Surgical Complications

As with any operation, endosurgical diagnostic and therapeutic techniques carry inherent risks, including bleeding, infection, or visceral perforation. In some cases, endosurgical methods may not provide adequate visualization or access to the target area. Despite its minimally invasive nature, laparoscopy is not risk-free – iatrogenic injury to vessels or bowel can occur. A further concern is missed injuries – reported in up to 3.2% – since delayed treatment increases morbidity and mortality [12].

Fewer than half of children with blunt hepatic or splenic trauma who require early transfusion present with hypotension [21]. Because circulating blood volume is substantially lower in children than in adults, systolic pressure may remain unchanged even after losses exceeding one quarter of total blood volume [22,23]. Significant hemorrhage may also be concealed or temporarily tamponaded in blunt solid-organ injury until a clot is evacuated [24,25]. Children who will need early transfusion can be identified not only by hypotension but also by an elevated age-adjusted pediatric shock index (SIPA) – a predictor of blunt solid-organ injury requiring early transfusion, operative intervention, and intensive care admission [13,26,27].

In the presence of persistent abdominal pain, late hemorrhage poses a particular danger for children with blunt solid-organ injury [23,28]. Notably, even with substantial acute blood loss, initial hemoglobin and hematocrit may be within normal ranges; an initial hematocrit <30% is a marker of severe blood loss [29].

A favorable intraoperative sign for spontaneous hemostasis and uncomplicated healing is stable adherence of the greater omentum to the injured parenchymal organ. When exploration reveals only small linear lacerations, the volume of intraperitoneal blood is typically limited and does not reaccumulate after aspiration [12].

Early and late complications of blunt liver injury include hemobilia, rupture of an intrahepatic duct with associated bile leak, biliemia, intrahepatic hematomas, outflow obstruction, and gallstone formation [28]. Renal trauma may be complicated by subcapsular and/or perinephric hematoma [28]. It should also be remembered that hematuria in children can signal an underlying tumor or congenital urinary tract anomaly [30,31,32].

Intra-abdominal abscess is an uncommon but serious complication in pediatric blunt solid-organ injury, arising secondary to trauma, surgery, or infection. Renal abscess is most frequently caused by Escherichia coli (E. coli), whereas Streptococcus viridans is more often identified in hepatic abscess. In intraperitoneal abscesses, the most common organisms are E. coli and Bacteroides fragilis [33].

The risk of severe infection – and infection-related mortality – is highest during the first year after splenectomy, particularly in younger children, but remains elevated for more than ten years and may persist lifelong. Reported post-splenectomy infection rates range from 0.5% to 2%, with mortality between 30% and 70% [34].

10. Conclusions

Over the past decade, the management of blunt hepatic and splenic injuries in children has undergone a profound shift – from previously aggressive strategies with frequent laparotomies to predominantly conservative, organ-preserving care. Contemporary international studies and guidelines unequivocally endorse nonoperative management (NOM) for hemodynamically stable children [4,6]. Operative intervention remains a vital, life-saving option in the setting of ongoing hemorrhage – yet it is now required far less often than in the past [2,3]. This evolution has reduced treatment invasiveness, preserved organs, and improved overall outcomes in pediatric patients. The literature also emphasizes continued refinement of protocols – from ICU transfer criteria to activity-restriction timelines – to ensure the fastest and safest recovery for children [5,8]. In sum, current evidence supports the conclusion that conservative treatment of blunt splenic and hepatic injuries in children, when appropriately applied, is both highly effective and safe, whereas operative procedures should be reserved for strict indications, as reflected in modern standards.

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