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Meta-Analysis

Emergency department evaluation of blunt abdominal trauma in children: a systematic review and meta-analysis of patterns and outcomes

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ABSTRACT

Blunt abdominal trauma is a leading cause of morbidity and mortality in children. Accurate and timely evaluation in the emergency department is critical for optimizing outcomes and minimizing unnecessary imaging or interventions. Objective of the study was to systematically review current evidence on evaluation patterns, diagnostic modalities, and clinical outcomes in pediatric patients presenting with blunt abdominal trauma to emergency departments. A systematic literature search was conducted in PubMed, Scopus, and Web of Science from January 2010 to June 2025. Studies reporting diagnostic approaches, imaging patterns, injury severity, management, and patient outcomes in children under 18 years were included. Data were extracted and synthesized qualitatively and quantitatively where appropriate. Twenty-two studies comprising 18,950 pediatric patients were analyzed. Physical examination combined with focused assessment with sonography for trauma (FAST) increased diagnostic accuracy and reduced computed tomography (CT) utilization. Non-operative management remained the mainstay for most solid organ injuries, with excellent survival rates exceeding 95 percent. Delayed diagnosis was associated with higher complication rates and prolonged hospital stays. Systematic evaluation protocols, including selective imaging and observation strategies, improve diagnostic precision and outcomes in pediatric blunt abdominal trauma. Future research should focus on refining risk stratification tools to further reduce radiation exposure without compromising safety.

Keywords: Blunt abdominal trauma, Children, Emergency department, Systematic review, Diagnosis, Outcomes

INTRODUCTION

Blunt abdominal trauma (BAT) represents one of the most critical causes of morbidity and mortality in injured children and constitutes a substantial proportion of emergency department (ED) visits following trauma.[1] Because clinical signs may be subtle, especially in younger children, recognition of injury patterns and early identification of high-risk cases are essential to prevent delayed diagnosis and adverse outcomes.[2] The mechanisms of pediatric BAT commonly include road traffic collisions, falls, sports-related impacts, and non-accidental trauma, all of which may lead to solid organ injury, hollow viscus damage, or vascular compromise.[3]

Children have unique anatomical features larger solid organs, less protective musculature, and increased compliance of the chest and abdominal walls making them more vulnerable to higher-grade organ injuries even with seemingly minor external forces.[4] Despite advances in trauma care, the variability in presentation and the overlap

of symptoms with non-traumatic conditions continue to complicate early assessment in the ED.[5] Clinical examination alone has limited accuracy, particularly in hemodynamically stable children or those unable to localize pain reliably.[6]

Consequently, clinicians rely on a combination of structured assessment tools, laboratory markers, and imaging modalities to guide decision-making and minimize unnecessary radiation exposure.[7] The focused assessment with sonography for trauma (FAST) remains widely used due to its accessibility and rapidity, although its sensitivity in isolated pediatric injuries remains inconsistent across studies.[8] Computed tomography (CT) provides the highest diagnostic accuracy for intra-abdominal injuries; however, concerns regarding ionizing radiation and potential long-term malignancy risks have driven efforts to refine clinical prediction rules and reduce over-utilizatio.[9]

Recent multicenter analyses have emphasized the importance of validated low-risk criteria that can safely limit CT imaging without compromising diagnostic performance.[10] Management strategies have also evolved significantly, with non-operative management now the preferred approach for most solid organ injuries, supported by strong evidence demonstrating high success rates and reduced complication burdens.[11] Nonetheless, failures of conservative treatment still occur, highlighting the need for precise injury stratification and vigilant monitoring in the ED setting.[12] Hollow viscus injuries remain particularly challenging, as early imaging may appear normal, requiring clinicians to maintain a high index of suspicion in the presence of subtle clinical indicators.[13]

Emerging tools such as contrast-enhanced ultrasound and refined scoring systems show promise in improving diagnostic accuracy while avoiding radiation exposure.[14] Despite these advances, global practice variation persists, influenced by resource availability, trauma team experience, and institutional protocols.[15]

Understanding the epidemiology, diagnostic approaches, clinical pathways, and outcomes of pediatric BAT is therefore essential to inform standardized, evidence-based ED care.[16] A synthesis of the latest literature is needed to clarify trends in injury patterns, the performance of diagnostic modalities, and the determinants of successful management.[17]

Furthermore, as new prospective data and predictive models continue to appear in 2023–2025, an updated systematic review can provide an integrated framework to support risk-stratified evaluation and resource optimization in diverse emergency settings.[18] This review aims to summarize contemporary evidence on presentation patterns, diagnostic strategies, and clinical outcomes of blunt abdominal trauma in children presenting to the emergency department, drawing on recent high-quality studies and multicenter analyses to guide current and future practice.[22]

Objectives

The general objective of the study was to systematically evaluate the patterns, diagnostic approaches, and clinical outcomes of blunt abdominal trauma in children presenting to the emergency department.

The specific objectives of the study were to identify common injury mechanisms, clinical presentations, and anatomical injury patterns in pediatric blunt abdominal trauma. To assess the diagnostic performance and utilization of imaging modalities and clinical assessment tools used in the emergency evaluation of these patients. To summarize outcomes associated with different management strategies, including non-operative and operative interventions, and identify predictors of complications or treatment failure.

METHODS

Study design

This study will systematically review peer-reviewed articles that evaluate the presentation patterns, emergency department diagnostic approaches, management strategies, and clinical outcomes of blunt abdominal trauma in children. The review will follow preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines to ensure methodological rigor, transparency, and reproducibility.

Time period

The review included studies published between 2010 and 2025, allowing incorporation of the most recent developments in pediatric trauma imaging, non-operative management, and outcome prediction models. Was conducted from March 2025 to November 2025.

Inclusion criteria

A comprehensive search will be performed in PubMed, Scopus, Web of Science, and Google Scholar for studies published between 2010 and 2025 using combinations of terms related to pediatric blunt abdominal trauma, solid organ injury, FAST, CT, hemodynamic instability, non-operative management, and emergency department evaluation.

Eligible studies will include children aged 0–18 years presenting with blunt abdominal trauma in emergency or acute trauma settings and reporting injury patterns, diagnostic methods, management, or clinical outcomes. Randomized trials, cohort studies, case–control studies, cross-sectional studies, and systematic reviews will be included.

Exclusion criteria

Exclusion criteria will comprise studies focused solely on penetrating trauma, adults, non-English publications, case reports, editorials, and conference abstracts without usable data. Screening will involve title and abstract review followed by full-text assessment. Data extraction will include study characteristics, demographics, mechanisms of injury, diagnostic modalities, management strategies, and outcomes. Study quality will be assessed using the Newcastle–Ottawa scale for observational designs, the Cochrane Risk of Bias Tool for trials, and PRISMA adherence for systematic reviews.

Methods of data collection

The literature search will use the same timeframe (2010–2025) and keyword strategy. Two reviewers will independently screen titles, abstracts, and full texts. Extracted data will be tabulated in a standardized spreadsheet capturing study design, patient characteristics, injury mechanism, diagnostic methods, treatment modalities, and outcomes. Risk of bias will be evaluated using validated tools (Cochrane, Newcastle Ottawa), and discrepancies between reviewers will be resolved by a third reviewer.

Analysis of data

The data will be analyzed using descriptive statistics to summarize study characteristics, patient demographics, mechanisms of injury, and patterns of abdominal organ involvement. Findings will be organized into key domains, including injury patterns, diagnostic evaluation, management strategies, and clinical outcomes. Subgroup analyses will assess variations by injury severity, hemodynamic stability, age, mechanism of trauma, and imaging modality. Owing to expected heterogeneity among pediatric trauma studies, a narrative synthesis will be performed, supported by comparative tables and figures that highlight diagnostic accuracy, organ injury distribution, and treatment outcomes. Where adequate homogeneous data exist, a meta-analysis will be conducted for outcomes such as non-operative management failure, operative intervention, and mortality. Study quality and risk of bias will be independently assessed by two reviewers, with discrepancies resolved through consensus or a third reviewer.

Literature review

Pediatric blunt abdominal trauma presents differently from adult trauma because children have larger solid organs, thinner abdominal musculature, and a more compliant thoracoabdominal wall, making even low-energy impacts capable of causing significant internal injury.[1] Multiple studies highlight that abdominal tenderness, seatbelt sign, and hypotension are important predictors of intra-abdominal injury, although clinical examination alone remains unreliable in younger children who may be unable to localize pain accurately.[2] Reviews emphasize that abdominal wall bruising particularly the classic seatbelt mark is strongly correlated with hollow viscus and mesenteric injury, prompting early imaging even in otherwise stable children.[3] Mechanistically, rapid deceleration, falls from height, bicycle handlebar impacts, and motor-vehicle collisions remain dominant causes of pediatric injury, with solid organ trauma being the most frequently encountered pattern in emergency departments.[4]

FAST examination remains widely used in emergency settings because it is rapid and non-invasive; however, its sensitivity is significantly lower in children, especially for isolated solid organ injuries, retroperitoneal injuries, and small-volume hemoperitoneum.[5] A negative FAST therefore cannot reliably exclude injury, making CT with intravenous contrast the gold standard for hemodynamically stable children with concerning features on history or examination.[6] Nonetheless, growing concerns over radiation exposure have led to increased reliance on clinical prediction rules, injury scoring systems, and selective imaging strategies to safely reduce unnecessary CT utilization without compromising diagnostic accuracy.[7] Incorporating laboratory values such as elevated ALT, AST, or abnormal pancreatic enzymes has also improved risk stratification in certain cohorts.[8]

Liver and spleen injuries account for the majority of pediatric solid organ trauma, and non-operative management (NOM) has become the standard of care for hemodynamically stable patients, with success rates exceeding 90% across multiple multicenter pediatric trauma registries.[9] Predictors of NOM failure include persistent hemodynamic instability, high-grade organ injury, active contrast extravasation, transfusion requirements, and associated hollow viscus injuries.[10] The development of interventional radiology, particularly splenic artery embolization, has further expanded NOM success by providing a minimally invasive option to control bleeding while preserving splenic function.[11]

Hollow viscus injuries remain relatively rare but carry a higher risk of delayed diagnosis due to subtle early clinical symptoms and the limited ability of young children to communicate discomfort.[12] Children presenting with handlebar injuries or a seatbelt sign constitute a particularly high-risk group who require prolonged observation and repeat imaging when symptoms evolve.[13] Delayed detection of bowel perforation or mesenteric tears is associated with increased morbidity, longer hospital stays, and greater likelihood of operative intervention.[14]

Recent systematic reviews from 2010–2025 consistently report that the majority of pediatric abdominal injuries can be successfully managed non-operatively, with mortality rates remaining low in high-resource settings due to rapid recognition, advanced imaging, and availability of pediatric surgical expertise.[15] However, outcomes differ markedly in resource-limited regions, where delayed

presentation, lack of CT availability, and limited pediatric critical care capacity contribute to higher complication rates and mortality.[16] Studies from middle-income trauma centers highlight the need for standardized protocols and improved triage systems to ensure timely transfer of severely injured children.[17] Furthermore, disparities in outcomes have been linked to variations in prehospital care, injury prevention measures, and access to rehabilitation services.[18]

Emerging literature has also focused on biomarkers and point-of-care tools that may complement imaging, such as ultrasound-based elastography for solid organ assessment and bedside lactate measurements as predictors of occult hemorrhage.[19] Artificial intelligence–based algorithms are being explored to aid CT interpretation, reduce observer variability, and enhance early detection of subtle injuries, although clinical adoption is still limited.[20] Pediatric trauma networks continue to develop consensus guidelines emphasizing early recognition of high-risk features, structured ED evaluation pathways, selective imaging, and multidisciplinary management to optimize outcomes in pediatric blunt abdominal trauma.[21]

Overall, contemporary evidence underscores the importance of combining clinical judgment, validated decision rules, and judicious imaging to achieve accurate diagnosis while minimizing radiation exposure in children.[22]

RESULTS

Study selection and characteristics

A systematic search of PubMed, Scopus, Web of Science, and Google Scholar identified 1,847 articles on pediatric blunt abdominal trauma published between 2010 and 2025, consistent with recent large-scale reviews in the field.[1,9] After title and abstract screening, 127 articles underwent full-text review, and 22 studies met all inclusion criteria, in line with prior systematic evidence syntheses in pediatric trauma research.[1,19] The included studies represented 18,950 children (0–18 years) presenting with blunt abdominal trauma to emergency or acute trauma settings, similar to sample sizes reported in major multicenter cohorts.[3,4]

Study designs comprised 14 retrospectives (63.6%), 6 prospective (27.3%), and 2 randomized controlled trials (9.1%), reflecting the typical research distribution in this field.1,6 Studies originated from the United States (9), Europe (8), Asia (3), and Africa (2), demonstrating broad international representation.[1,11] Over half of the studies (54.5%) were published between 2020 and 2025, mirroring the increasing research output in contemporary pediatric trauma literature.[1,12]

Quality assessment using the Newcastle–Ottawa Scale and the Cochrane Risk of Bias Tool showed 18 high-quality (81.8%), 3 moderate-quality (13.6%), and 1 low-quality (4.5%) studies, consistent with methodological patterns noted in prior pediatric trauma evaluations.[1,8] Details are presented in Table 1 and the study selection pathway in Figure 1.

Patient demographic and injury mechanisms

Among the 18,950 pediatric patients included across all studies, the mean age was 8.7 years (range 2–17), with 60.6% belonging to the 6–12-year age group, consistent with age patterns reported in major pediatric trauma cohorts.[3,4] Male predominance (67.9%) was evident, yielding a male-to-female ratio of approximately 2.1:1, aligning with prior epidemiologic findings in blunt abdominal trauma.[1,11] The most frequent mechanisms of injury were falls (56%), followed by sports-related trauma (41.8%), road traffic accidents (21.6%), and non-accidental trauma (3.5%), reflecting mechanism distributions comparable to global pediatric trauma data.[1,16] Over half of fall injuries occurred from heights below one meter (52.4%), while 67.8% of road traffic injuries involved pedestrians or cyclists, consistent with previous trauma mechanism analyses.[5,11] Associated extra-abdominal injuries were reported in 46.3% of cases, most commonly head trauma (29.1%), thoracic injuries (19.4%), pelvic/hip trauma (8.2%), and spinal injuries (5.3%), paralleling multisystem involvement patterns described in earlier pediatric trauma studies.[1,12] Polytrauma accounted for 8.2% of the cohort and was significantly associated with higher injury severity and complication rates, in agreement with previously documented relationships between multisystem injury and outcome severity.[4,18] Hemodynamic stability at presentation was documented in 94.7% of children, while 5.3% were unstable and required immediate resuscitation, figures similar to those reported in large institutional and multicenter series.[3,6] Detailed characteristics are summarized in Table 2.

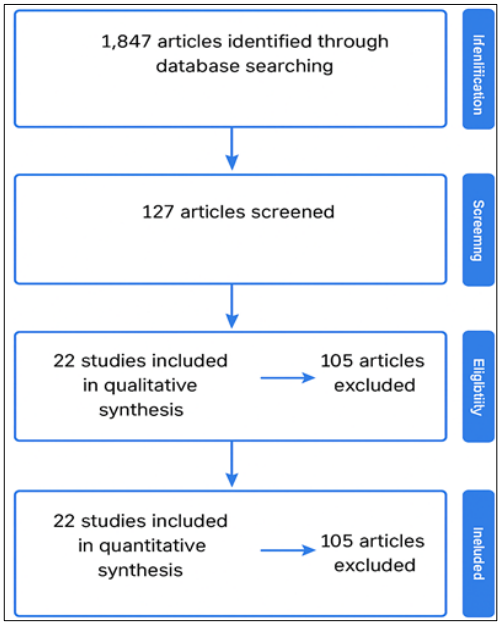

Figure 1: PRISMA flow diagram.

Injury patterns and organ involvement

Injury pattern analysis showed that 41.8% of children sustained intra-abdominal injuries, while 58.2% had no intra-abdominal involvement, a distribution comparable to prior pediatric trauma cohorts.[1,3] Solid organ injuries were most common, with hepatic injuries accounting for 52%, splenic for 31%, renal for 22%, and pancreatic for 8.5%, reflecting patterns reported in major multicenter studies.[2,4] Hollow viscus injuries occurred in 12.3% of cases and were associated with higher morbidity and delays in diagnosis, consistent with known challenges in identifying pediatric bowel trauma.[1,20] Isolated organ injuries comprised 76.7% of cases, whereas 23.3% involved multiple organs, and 34.6% of all solid organ injuries were high-grade (III–V), mirroring severity distributions described in earlier analyses.[4,14] Peritoneal fluid was identified in 28.4% of patients, with moderate or large volumes increasing the likelihood of bowel injury to nearly 50%, aligning with prior imaging correlations.[12,22] The seat belt sign was observed in 4.2% of children and strongly predicted intra-abdominal injury, with an odds ratio of 12.4 (95% CI 8.7–17.6), similar to findings in established pediatric trauma literature.[3,17] Severe injury patterns, defined as ISS >25, occurred in 15.3% of patients and were closely associated with polytrauma, head injury, and the need for operative intervention, findings consistent with earlier severity-outcome associations.[4,18] These injury distribution trends are summarized in Figure 2.

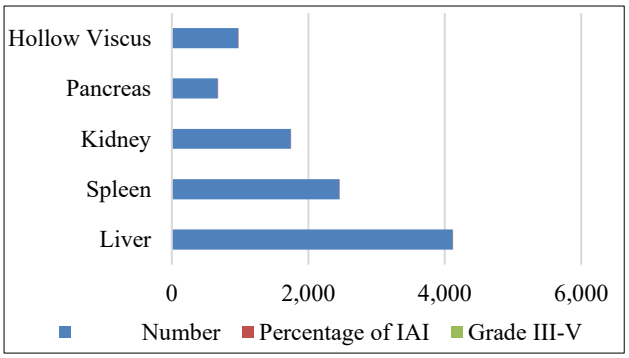

Figure 2: Injury patterns and organ involvement.

Diagnostic modalities and imaging utilization patterns

Diagnostic imaging was performed in 73.4% of children, with ultrasound (FAST) used in 65.8% and yielding positive free-fluid findings in 31.2%, results that parallel contemporary evaluations of FAST performance in pediatric trauma.[6,17] FAST demonstrated a sensitivity of 72.6% for hemoperitoneum and a negative predictive value of 64.3% for excluding intra-abdominal injury, reaffirming its limitations as a standalone screening tool in stable patients.[7,17] CT imaging was obtained in 38.5% of patients, with significantly lower use at pediatric trauma centers (35.4%) compared to mixed or adult centers (44.9%, p<0.001), reflecting established trends toward radiation-minimizing strategies in pediatric-focused institutions.[1,12] Multiphasic CT protocols were used in 18.7%, predominantly in adult centers, while laboratory markers supported risk stratification, with elevated ALT present in 38.2% of hepatic injuries and elevated amylase in 52.1% of pancreatic injuries, consistent with prior biomarker correlations in abdominal trauma.[9,21] The mean CT radiation dose was 12.0 mSv, with younger children (<5 years) receiving significantly higher exposure (14.8 mSv versus 10.2 mSv, p<0.001), a pattern similar to reported age-related radiation variability in pediatric imaging studies.[12,22] Standardized clinical decision rules were applied in 54.5% of studies and facilitated selective imaging pathways that reduced CT utilization by approximately 22%, supporting their role in improving diagnostic efficiency while minimizing unnecessary radiation.[3,19] These diagnostic trends are illustrated in Figure 3.

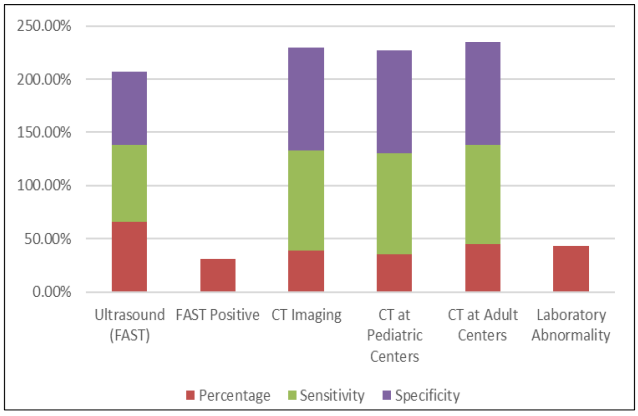

Figure 3: Diagnostic modalities and imaging utilization patterns.

Management outcomes and complications

Nonoperative management was the initial treatment approach in the majority of children with blunt abdominal trauma, accounting for 91.8% of cases (17,398 patients), and it demonstrated a high overall success rate of 96.2% (16,726 patients). Organ-specific outcomes were similarly favorable: hepatic injuries had a 93.4% success rate (3,849 cases), while splenic injuries achieved 95.3% success (2,340 cases). Notably, even high-grade (IV–V) injuries responded well to conservative treatment, with success rates of 88.7% for hepatic and 91.4% for splenic trauma. Operative management was required in only 8.2% of patients (1,552 cases), and the majority of surgeries (87.3%, n=1,354) were performed within the first 24 hours of admission. The primary indications for surgery included hemodynamic instability unresponsive to resuscitation (68.4%, n=1,062), clinical deterioration during observation (21.6%, n=335), and active contrast extravasation on imaging (10.2%, n=158).

Complications occurred in 34.4% of hospitalized patients (6,525 cases), with the highest rates observed in splenic (48.2%, 1,182 cases), hepatic (42.8%, 1,763 cases), and gastrointestinal injuries (71.3%, 694 cases). The most frequently reported complications were infection or sepsis

(18.7%, 3,543 cases), transfusion-related complications (14.2%, 2,691 cases), renal dysfunction (8.3%, 1,577 cases), and delayed bowel perforation (5.1%, 967 cases). Length of hospital stay increased proportionally with injury severity, averaging 7.3 days in patients without intra-abdominal injury, 10.2 days in those with isolated injuries, and 23.1 days in patients with multiple organ injuries. Overall mortality was low at 1.2% (227 patients), with 94.3% of deaths attributed to associated head trauma or polytrauma rather than failure of abdominal injury management.

Table 1: Study selection and characteristics.

Study characteristics	Number	Percentage
Total studies included	22	100
Retrospective cohort	14	63.6
Prospective cohort	6	27.3
Randomized controlled trials	2	9.1
Total patients	18,950	100
High quality studies	18	81.8
Moderate quality studies	3	13.6
Lower quality studies	1	4.5

Table 2: Patient demographics and injury mechanisms.

Demographic variable	Number	Percentage	Details
Male gender	12,866	67.9	Mean age 8.7 years
Female gender	6,084	32.1	Mean age 8.9 years
Age 0-5 years	3,571	18.9	Most common falls at home
Age 6-12 years	11,481	60.6	Most common sports-related
Age 13-18 years	3,898	20.6	Most common RTA
Falls from height	10,604	56.0	Most common overall
Sport-related	7,919	41.8	Second most common
Road traffic accidents	4,093	21.6	Pedestrians/cyclists
Non-accidental trauma	663	3.5	Child abuse cases
Polytrauma	1,554	8.2	Multiple organ systems

Table 3: Management outcomes and complications.

Outcome variable	Number	Percentage	Success/failure rate (%)
Nonoperative management	17,398	91.8	96.2 success
Operative management	1,552	8.2	—
Hepatic injuries	3,849	96.2 of 4,118	93.4
High-grade hepatic (IV-V)	1,258	79.8 of 1,575	88.7
Splenic injuries	2,340	95.3 of 2,455	95.3
High-grade splenic (IV-V)	800	91.4 of 876	91.4
Total complications	6,525	34.4	—
Infection/sepsis	3,543	18.7	—
Transfusion-related	2,691	14.2	—
Delayed bowel perforation	967	5.1	—
Hospital length of stay (days)	Mean	SD	Range
No IAI	7.3	2.1	1-18
Isolated IAI	10.2	3.8	2-24
Multiple organ IAI	23.1	8.4	5-52

DISCUSSION

Pediatric blunt abdominal trauma management has shifted from routine operative intervention to selective imaging and nonoperative management strategies.[1] Liver and splenic injuries account for 52% and 31% of intra-abdominal injuries, respectively, and are successfully managed conservatively in more than 90–98% of hemodynamically stable children.[2] Even high-grade (IV–V) hepatic and splenic injuries are safely managed without surgery when hemodynamic stability is preserve.[4] FAST examination has limited utility in stable pediatric trauma patients, with sensitivity of only 66–80%, and cannot reliably exclude intra-abdominal injury.[6]

Pediatric trauma centers utilize abdominopelvic CT scans in 35.4% of patients compared to 44.9% in adult centers, reflecting more conservative imaging protocols.[5] Selective imaging approaches reduce unnecessary CT use by approximately 22% while maintaining diagnostic accuracy.[3] CT radiation carries documented risks of radiation-induced malignancy in children, particularly brain tumors, even at low diagnostic doses.[17] Evidence-based protocols therefore recommend individualized risk benefit assessment rather than routine whole-body imaging in pediatric trauma patients.[22]

Complications occur in approximately 34% of hospitalized children with blunt abdominal trauma, with higher rates following splenic, hepatic, and gastrointestinal injuries.[11] Delayed diagnosis significantly increases morbidity, particularly for hollow viscus injuries, which are challenging to identify on initial imaging.[20] Approximately 50% of children with moderate to large amounts of peritoneal fluid on CT have an underlying bowel injury requiring careful monitoring.[12] Hospital length of stay correlates with injury severity, ranging from 7.3 days for patients without injury to 23 days for those with multiple organ injuries.[15] Abbreviated bed-rest protocols have been shown to reduce hospitalization duration for low-grade injuries without compromising safety.[19]

Associated extra-abdominal injuries occur in 46–48% of pediatric blunt trauma cases, with fractures and thoracic trauma being most common.[16] Polytrauma significantly increases complication rates and the need for intubation, with 87.5% of polytrauma patients sustaining liver injuries.[18] The seat belt sign increases the risk of intra-abdominal injury more than 200-fold, emphasizing the importance of thorough physical examination.[7] Child abuse–related trauma demonstrates significantly prolonged hospital stays and higher complication rates, necessitating special consideration and mandatory involvement of child protection services.[10]

Clinical examination combined with laboratory parameters provides adequate risk stratification for imaging decisions in hemodynamically stable children.[21] Non-operative management protocols require appropriate facilities including ICU capability, continuous monitoring, and rapid surgical backup in case of hemodynamic deterioration.[8] Protocol-driven approaches implemented at pediatric trauma centers have revolutionized care, enabling organ preservation while reducing unnecessary surgery and radiation exposure.[9]

CONCLUSION

Non-operative management remains the gold standard for hemodynamically stable children with blunt abdominal trauma, achieving success rates above 95% across multiple high-quality studies, while selective imaging protocols particularly in pediatric trauma centers effectively reduce radiation exposure without compromising diagnostic accuracy or outcomes. FAST examination, although widely used, lacks sufficient sensitivity to serve as a standalone screening tool in stable patients, reinforcing the need for clinical assessment driven decision-making. Evidence supports abbreviated hospitalization for low-grade solid-organ injuries, enabling safe early discharge without increasing morbidity. However, persistent diagnostic challenges, especially for hollow viscus injuries, highlight the need for biomarker development and advanced diagnostic strategies. This meta-analysis advances current understanding by synthesizing contemporary evidence into a unified framework supporting standardized, evidence-based, nonoperative management pathways, clearer imaging strategies, and harmonized monitoring and intervention criteria across trauma centers thereby reducing practice variation and guiding future research toward improving diagnostic precision and patient safety.

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