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Outcomes and Safety of Non-operative Strategies in Pediatric Blunt Splenic Trauma: A Systematic Review and Meta-Analysis

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Abstract

Purpose: To offer a thorough analysis of the safety and efficacy of non-operative management in pediatric blunt splenic trauma.

Methods: This systematic review included studies published in English; randomized controlled trials, prospective cohort studies, retrospective cohort studies, and case series with a minimum of ten or more patients. The review included studies enrolling pediatric patients (≤18 years) with clinically or radiologically confirmed blunt splenic injury. Studies were required to report at least one of the following outcomes: success rate of non-operative management (NOM), complications, postponed surgery, duration of hospital stay, intensive care unit (ICU) admission, or fatality. The primary outcome of interest was the success rate of non-operative management.

Results:

Across 43,801 children with blunt splenic damage, 88.1% underwent non-operative management (NOM) and 11.9% operative management (OM). NOM was mainly applied to stable children with low-grade injuries, while OM was reserved for high-grade or unstable cases. NOM was associated with high success (>95%), lower ICU admission, shorter hospital stay (5–10 days), rare, delayed surgery (<5%), low mortality, and minimal complications.

Conclusion: Non-operative management of pediatric blunt splenic trauma is safe and effective in stable children, with high success rates and low mortality.

Keywords

Pediatric, Splenic trauma, non- operative management, blunt abdominal trauma, splenic rupture.

Introduction

Abdominal trauma significantly contributes to morbidity and mortality in the pediatric age group, with the spleen being the most often injured organ**.** Due to essential physiological and anatomical differences between adults and children, they display unique damage patterns and require specialized treatment strategies [1]. Abdominal injuries may result in considerable intraperitoneal bleeding, increasing the risk of mortality significantly [2]. Motor vehicle accidents and falls from heights are the primary causes of injury, while non-accidental trauma and sports-related injuries occur less frequently. Despite the clinical significance of abdominal trauma in pediatric patients, the most effective approach for identifying intra-abdominal injuries is still contested [3].
In the last forty years, non-operative management (NOM) has established itself as the standard treatment for children with traumatic liver and splenic injuries [4]. This method often entails rigorous bed rest, hemodynamic surveillance, and meticulous clinical observation. NOM has exhibited an instant success rate surpassing **98%** [5,6]. Although many traumatic abdominal injuries can be managed conservatively, a certain group of individuals necessitates surgical intervention either urgently or following unsuccessful non-operative treatment. The choice to undertake surgery is determined by various factors, including the child's hemodynamic condition, trauma mechanism, physical examination results (such as abdominal ecchymosis or seatbelt marks), laboratory data, imaging findings, medical history, and the existence of concomitant injuries, including thoracic, orthopedic, or neurological trauma [7].

The research aims to assess the results and safety of non-operative therapy for blunt splenic trauma in pediatric patients by a systematic review and meta-analysis. The objectives are to assess the success rates of nonoperative versus operative interventions and to study resource utilization by examining the need for critical care hospitalization, blood transfusions, and other healthcare resources in both management strategies.

Methods & Materials

Literature Review:

This review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards to reduce selection bias and guarantee methodological transparency [8]. The study protocol was pre-registered in the PROSPERO database with the registration ID CRD420251125745 [9]. This study relied solely on previously published studies, thereby negating the need for ethical approval.

A comprehensive systematic search was conducted in **August 2025** across the following electronic databases: (1) **PubMed**, and (2) **Google Scholar**. The search strategy incorporated the following combination of keywords: *(blunt splenic injury OR splenic trauma OR blunt abdominal trauma) AND (pediatric OR children OR child) AND (nonoperative management OR non-operative treatment OR conservative treatment OR observation).*

Studies were screened and selected according to the **PICOTS** framework (Population, Intervention, Comparison, Outcome, Timeframe, and Study design) to ensure alignment with the review objectives and inclusion criteria [10].

Methodology for selecting studies:

To be included in our systematic review, studies must satisfy the following criteria: (1) studies published without time frame limitations, (2) studies involving pediatric patients (≤18 years) diagnosed with blunt splenic injury

confirmed by clinical or radiologic evaluation, (3) studies reporting Non Operative Management (e.g., observation, bed rest, monitoring, blood transfusion without surgery), (4) Operative Management including stratified analysis by injury grade/severity within non-operative groups, (5) studies reporting outcomes of interest such as success rate of NOM, complication rate (e.g. Delayed rupture, infection), need for delayed surgery, length of hospital stay, ICU admission, and mortality, (6) only studies published in English will be included, and (7) eligible study designs include (RCTs), prospective or retrospective cohort studies, and large case series with ≥10 patients.

Our systematic review excluded studies based on the following criteria: (1) studies involving adult or mixed-age populations without isolated pediatric data, (2) studies focusing exclusively on OM or interventional radiology (e.g. Embolization) without comparison to non-operative outcomes, (3) studies lacking a control or subgroup comparison for NOM, (4) studies that did not report clinical outcomes relevant to the review question, (5) case reports, editorials, reviews, conference abstracts, and studies with fewer than 10 patients.

Process of screening and data extraction:

Two independent reviewers concurrently screened and evaluated the papers by title and abstract, utilizing the Rayyan web application for systematic reviews [11].

The complete text of the articles was subsequently evaluated by four separate reviewers, with discrepancies addressed by a third reviewer. Subsequently, data extraction was conducted by four reviewers for the specified variables:

Data extracted included: (1) total patients, (2) NOM patients, (3) OM patients, (4) male/female totals, (5) male NOM, (6) male OM, (7) female NOM, (8) female OM, (9) age range, (10) AAST grade NOM, (11) injury mechanism NOM, (12) admission vitals NOM, (13) transfusion need NOM, (14) Hb levels NOM, (15) AAST grade OM, (16) injury mechanism OM, (17) admission vitals OM, (18) transfusion need OM, (19) Hb levels OM, (20) ICU admission NOM, (21) length of stay NOM, (22) delayed surgery NOM, (23) mortality NOM, (24) NOM success/failure, (25) ICU admission OM, (26) length of stay OM, (27) delayed surgery OM, (28) mortality OM, (29) OM success/failure, (30) wound infection NOM, (31) pneumonia NOM, (32) ARDS NOM, (33) wound infection OM, (34) pneumonia OM, and (35) ARDS OM. All extracted data were cross-checked to avoid duplication.

Assessment of quality and bias risk:

The overall quality assessment of the included studies was performed using the Methodological Index for Non-Randomized papers (MINORS) [12].
MINORS is a recognized tool for assessing the methodological quality of non-randomized studies. The evaluation comprises 8 questions for non-comparative studies and 12 items for comparative studies, each assessed on a 0-2 scale, resulting in an ultimate result of 16 for non-comparative studies and 24 for comparative studies. Two writers independently assessed the level of quality of the included studies using the MINORS tool, with any inconsistencies resolved through discussion.

Statistical* Analysis *Plan:

A meta-analysis was conducted with the 'metafor' package of R Studio to compare non-operative and operative management outcomes in pediatric blunt splenic trauma. Effect sizes were computed as risk ratios (RRs) for dichotomous outcomes and standardized mean differences (SMDs) for continuous measures. All aggregated estimates employed the random-effects model to address inter-study variability. Heterogeneity was evaluated utilizing I^2 statistics, τ^2, and Q-tests. Continuity corrections (0.5) were applied when zero-event cells occurred. Subgroup analyses were performed for complications (pneumonia, wound infection, ARDS). Bias in publications

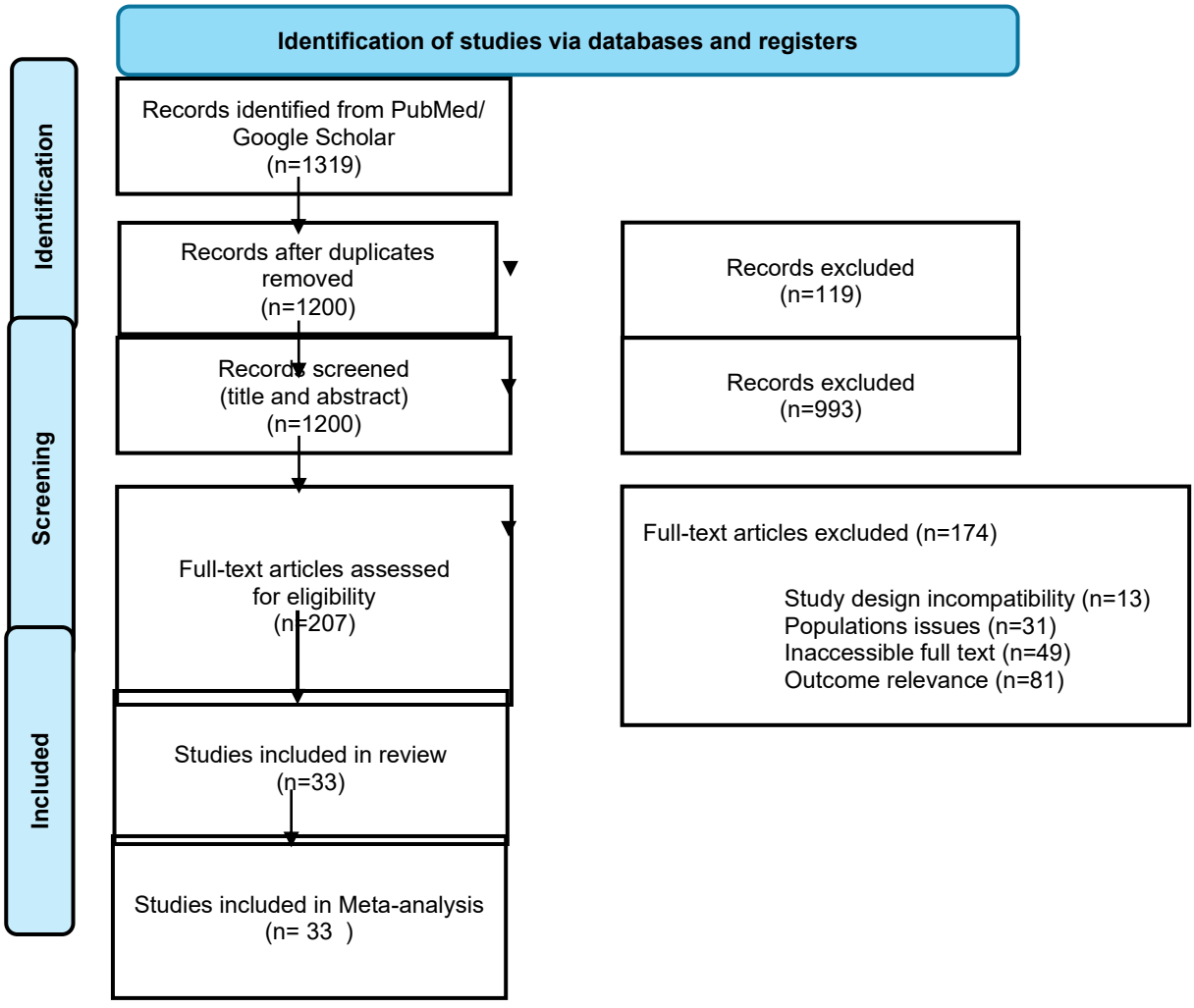
was evaluated using funnel plots. Statistical significance was established at $p < 0.05$, and analyses followed PRISMA guidelines. Studies reporting 'NR' (not reported) for a given outcome were excluded from the pooled analysis for that specific outcome on a per-outcome basis. No imputation of missing data was performed. The number of studies contributing to each pooled estimate is therefore outcome-specific and is indicated in the corresponding forest plot. For outcomes available only from non-comparative case series (i.e., NOM-only studies without an OM control group), single-arm proportional meta-analyses using the logit transformation were conducted to estimate pooled event rates within the NOM cohort. These single-arm estimates were reported separately and were not combined with NOM vs. OM risk ratio analyses. Direct comparative analyses (RR, SMD) were restricted to studies reporting outcomes in both NOM and OM groups.

Results

The literature's findings

The systematic review process began with the identification of 1,319 records from PubMed and Google Scholar. After eliminating duplicate articles, the final count is 1200 articles. Subsequently, 1200 articles were evaluated by title and abstract, leading to the elimination of 993. The remaining 207 full-text articles were then assessed for eligibility. During this final phase, 174 articles were excluded based on detailed criteria: study design incompatibility (n=13), population issues (n=31), inaccessible full text (n=49), and lack of outcome relevance (n=81). Ultimately, 33 studies published between 1985 and 2024 met all inclusion criteria and were included in the final systematic review, with nearly all using a retrospective design (32 out of 33, or 97%) ***[Figure 1]***.

Figure 1. A summary of the PRISMA flowchart utilized for the selection of studies included in this review.



The most common design was the retrospective cohort study (8 studies, 24.2%) [13-20], followed by retrospective review (7 studies, 21.2%) [21-27]. Retrospective analysis [28-32] and retrospective study [33-37] each accounted for five studies (15.2% each). A retrospective observational study was used in 4 studies (12.1%) [38-41]. The remaining designs—retrospective case series, retrospective comparative study, and retrospective cross-sectional—each had 1 study (3.0%) [42-44]. One study (3.0%) was a secondary analysis of a prospective study [45].

In terms of country of publication, the United States had the most contributions, with 11 (33.3%)[15-18, 21, 23, 25, 35, 37, 40, 45], followed by the Netherlands with 4 (12.1%) [13, 14, 19, 30]. Turkey [28, 29, 39] and Australia [22, 24, 27] each had 3 (9.1%). The United Kingdom [34, 44], Egypt [33, 43], and Canada [26, 31] each had 2 (6.1%). Nigeria, Austria, China, Romania, Denmark, and France each contributed 1 (3.0%) [42, 32, 20, 36, 38, 41]. This distribution highlights a significant concentration of the sample from the United States and Western Europe.

A description of the characteristics of the included studies

Across all the studies included, 43,801 patients were identified. The sample sizes varied greatly, ranging from 24 to 24,128 patients per study. When broken down by management strategy, patients were divided into two treatment groups. The Non-Operative Management encompassed 27,916 (88.1%) patients, with patient numbers ranging from 11 to 21,789. Conversely, the Operative Management arm included 3,755 (11.9%) patients, with numbers ranging from 0 to 2,399. There is a significant difference between the total number of patients (43,801) and the number explicitly assigned to the two treatment groups (31,671), indicating that 12,130 patients were included in the overall study population but were not expressly assigned or reported as receiving non-operative or operative treatment. The studies predominantly included a pediatric and adolescent population, with age ranges spanning from birth to 18 years. Data on the mean age showed some variability, with reported values ranging from 6.2 to 14.5 years; the average of the reported means is approximately 10.5 years. The combined gender data across the studies showed a consistent male predominance, with typical Male: Female (M: F) ratios around 3:1 or 4:1 (e.g., M:72 F:20, M:32 F:12) ***[Table 1]***. This discrepancy is attributable to studies that reported only aggregate totals without stratifying patients into NOM or OM subgroups (e.g., Wisner 2015, n=12,044; Davies 2009, n=486). These studies contributed to descriptive summaries and single-arm pooled analyses, but were excluded from direct NOM vs. OM comparative calculations."

Table 1. Characteristics of included studies comparing non-operative and operative management of pediatric blunt splenic trauma

Author (Year)	Journal	Study Design	Country	G1 (NOM)	G2 (OM)	Total	Age Mean (SD) (Range)	G1 (NOM) M: F	G2 (OM) M: F	Total M: F
Osifo (2007)	J Indian Assoc Pediatr Surg	Retrospective case series	Nigeria	18	6	24	12.4 (2–18 y)	NR	NR	15:9
Mabrouk (2018)	Egypt J Hosp Med	Retrospective	Egypt	117	6	123	6.43 (2–12 y)	79:38	NR	83:40

Campbell (2014)	J Pediatr Surg Specialties	Retrospective	UK	22	7	29	2.5–15.5 y	NR	NR	21:8
Teuben (2020)	Patient Safety Surg	Retro cohort	Netherlands	52	10	62	≤17 y	38:14	7:3	45:17
Baiomy (2022)	Ain Shams Med J	Retro comparative	Egypt	130	10	140	9.96 ±2.41 (6–16 y)	NR	NR	105:35
Shinn (2021)	J Vasc Interv Radiol	Retrospective	USA	21,789	2,399	24,128	12.2 ±4.4 (<18 y)	NR	NR	17,346:6,704
Stefanopol (2024)	Chirurgia	Retrospective	Romania	27	5	32	10.8 (1–17 y)	13:14	5:0	18:14
Grootenhaar (2021)	World J Emerg Surg	Retro cohort	Netherlands	97	33	130	11.3 ±4 (3–17 y)	61:36	21:12	82:48
Kirkegård (2015)	Danish Med J	Retro observational	Denmark	34	2	36	≤16 y	21:13	2:0	23:13
Duron (2014)	Am Surgeon	Retrospective review	USA	180	3	180	12.8 (0–18 y)	NR	NR	136.8:43
Wisner (2015)	J Trauma Acute Care Surg	Prospective secondary analysis	USA	NR	NR	12,044	10.7 ±5.1 (<18 y)	NR	NR	392:213
Arslan (2015)	Ann Ital Chir	Retrospective	Turkey	84	6	90	8.3 ±5.4 (1–17 y)	NR	NR	64:26
Karadeniz Cerit (2018)	Ulus Travma Acil Cerrahi	Retrospective	Turkey	83	5	88	8.8 (57.75 mo)	NR	NR	61:27
De Jong (2011)	Eur J Pediatr Surg	Retrospective	Netherlands	41	20	51	13 (0–18 y)	NR	NR	49:15
Davies (2009)	J Pediatr Surg	Retrospective	Canada	294	9	486	10 ±4.5 (0–18 y)	NR	NR	347:M
Ardley (2018)	Eur J Trauma Emerg Surg	Cross-sectional	UK	22	7	29	14.5 ±3.6 (4–18 y)	NR	NR	23:7
Choong (1993)	J Paediatr Child Health	Retrospective	Australia	28	20	48	9.5 (0–15 y)	NR	NR	30:19
Singer (2013)	Eur J Pediatr	Retrospective	Austria	81	81	170	9.7 (1–17 y)	NR	NR	79% male
Kakkasseril (1982)	Arch Surg	Retrospective	USA	21	7	28	10 (2–17 y)	NR	NR	17:11
Thompson (2006)	ANZ J Surg	Retrospective	Australia	33	6	39	7.8 (0–15 y)	NR	NR	2.25:1
Schwartz (1994)	J Pediatr Surg	Retrospective	USA	11	25	36	6.9 (G1), 9.1 (G2)	NR	NR	NR
Moore (2010)	J Trauma	Retro cohort	USA	62	NR	62	12 (1–17 y)	45:17	NR	45:17
Zabolotny (2002)	Can J Surg	Retrospective	Canada	44	3	47	10.4 (5–17 y)	37:7	NR	NR
Pranikoff (1994)	J Pediatr Surg	Retrospective	USA	50	0	50	11 ±5 (0–18 y)	NR	NR	NR
Gandhi (1999)	Retrospective cohort	USA	49	0	49	9.6 ±3.6 (4.5–12.9 y)	NR	NR	NR	
Jen (2010)	Ann Surg	Retro cohort	USA	4199	923	5089	0–18 y	3157:1042	704:219	3833:1256
Muehrcke (1987)	Am J Emerg Med	Retro cohort	USA	18	6	24	12 (G1), 17 (G2), (4–18 y)	NR	NR	21:3
Avanoglu (1998)	Eur J Pediatr Surg	Retro observational	Turkey	78	96	174	7.3 (1–16 y)	NR	NR	98:34
Frumiento (2000)	J Pediatr Surg	Retro observational	USA	40	0	40	11.7 ±5 (<17 y)	32:8	NR	32:8
Beasley (1985)	ANZ J Surg	Retrospective	Australia	49	42	92	6 m–15 y	NR	NR	72:20
Veger (2008)	Eur J Trauma Emerg Surg	Retro cohort	Netherlands	34	12	46	13.2 ±4.4 (0–18 y)	NR	NR	32:12
Wang (2024)	Frontiers Surg	Retro cohort	China	46	6	52	6.2 ±2.8 (0–15 y)	29:17	5:1	34:18
Oumar (2014)	J Indian Assoc Pediatr Surg	Retro observational	France	83	0	83	NR	NR	NR	NR

(NOM) Non-Operative Management (OM) Operative Management

Patient-reported outcomes, complications, and clinical outcomes

Notably, the injury profiles across the included studies show that children who managed non-operatively generally presented with lower AAST injury grades, while those undergoing surgery more often had high-grade (IV–V) splenic injuries, reported by Osifo (2007), Mabrouk (2018), Baiomy (2022), and Grootenhaar (2021) [42, 33, 43, 14]. The mechanisms of the injury were similar across both groups, with road traffic accidents, falls, and sports-related trauma being the most common causes in nearly all studies. The vital signs at presentation consistently differed between groups. Children in the NOM cohorts were usually hemodynamically stable, while OM patients showed features of instability with low systolic blood pressure, tachycardia, or rapid deterioration (Osifo 2007, Arslan 2015, Thompson 2006, and Schwartz 1994) [42, 28, 24, 25]. The need for transfusion also reflected injury severity. NOM groups typically required minimal or no transfusion, whereas OM groups frequently required a significant amount of blood replacement, which included 100% transfusion rates in several studies, such as Osifo (2007), Zabolotny (2002), and Avanoglu (1998) [42, 26, 39]. Where reported, the hemoglobin levels were generally higher in NOM patients, with lower values seen in the OM group, as demonstrated by Stefanopol (2024) and Grootenhaar (2021) [36, 14] ***[Table 2]***.

Table 2. Injury profile and early clinical status of pediatric patients managed non-operatively versus operatively for blunt splenic trauma.

Study ID	AAST (G1)	AAST (G2)	Mechanism of Injury (G1)	Mechanism of Injury (G2)	Vital Signs (G1)	Vital Signs (G2)	Transfusion (G1)	Transfusion (G2)	Serum Hb (G1) (mixed units†)	Serum Hb (G2) (mixed units†)
Osifo (2007)	I–III	IV–V	RTA (50%), falls, domestic, sports	RTA majority, falls, 1 gunshot	Stable after fluids	SBP 50–80, HR >110	7/18	100%	1.74 ±0.08	1.55 ±0.07

Mabrouk (2018)	I–III	IV–V	Traffic 59%, falls 29%, bicycle/sports	High-impact trauma	Stable	Unstable	9 pts (mean 700 mL)	6 pts (mean 900 mL)	NR	NR
Campbell (2014)	II–III	III–IV	RTA, falls, sports	Multisystem RTA	Stable	Unstable (ISS 21–75)	4 pts	1–8 units	NR	NR
Teuben (2020)	Grade 3 (2–4)	Grade 4–5	Motorcycle 29%, falls 19%, bicycle 13%, MVA 12%	High-impact blunt trauma	SBP 117, HR 88, GCS 15	SBP 120, HR 110	Small number (<2 units)	All 10, 1–4 units	7.5 (6.7–8.1)	7.1 (5.8–7.4)
Baiomy (2022)	I–III	IV–V	RTA's main cause, falls next	RTA, falls	Stable	Unstable	1 pt	7/10	0.62	0.62
Shinn (2021)	I–III mostly	IV–V	Blunt trauma	NR	Stable	Unstable	Not reported	Not reported	NR	NR
Stefanopol (2024)	I–III	III	Mixed	Not reported	Stable	Unstable	3/27	4/5	7.06	5.22
Grootenhaar (2021)	I–V	IV–V	Low-energy trauma	High-energy trauma	Stable	Unstable	22–25%	45.5%	7.2	6.3 ±1.6
Kirkegård (2015)	II–III mainly	Grade 5	Traffic, falls, sports	Traffic	Stable	Initially stable → deterioration	4 pts	Both operative pts transfused	NR	NR
Duron (2014)	Grade ≈2.7	Grade IV	NR	NR	NR	NR	14.4%	Same	NR (reported in g/dL only)	NR
Wisner (2015)	I–III	IV–VI	Blunt	Blunt	Stable	Unstable	46 (11%)	Not reported	NR	NR
Arslan (2015)	I–IV	III–IV	Falls 51%, traffic 31%	Same	SBP 110/70	SBP 105/65	38 pts	6 pts	11	8.5
Karadeniz Cerit (2018)	Low-grade	High-grade	NR	NR	Stable	Not provided	33 pts	33 pts	NR	NR
De Jong (2011)	Not stated	Not stated	Traffic, motorcycle, bicycle, falls	Same	Stable	Unstable	Not given	Not given	NR	NR
Davies (2009)	Not stated	Not stated	NR	NR	Stable	Unstable	NR	3%	NR	NR
Ardley (2018)	Mix of I–V	III–V	NR	RTA/bicycle	17 stable / 5 unstable	5 unstable / 2 stable	Not stated	3 pts	NR	NR
Choong (1993)	NR	NR	Road trauma, falls	Same	Stable except 9 unstable	More unstable	14 pts	17 pts	NR	NR
Singer (2013)	Grades 3–4 present	Same	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	NR	NR
Kakkasseril (1982)	Not detailed	Not detailed	MVA, bicycle, sledding, falls, sports	Same	Stable	Unstable	9 pts	Not detailed	≈7.5 mmol/L	7.7–12.9 g/dL
Thompson (2006)	I–IV	II–V	Falls 46%, MVI	MVI	HR 112, SBP 116	HR 144, SBP 118	4 pts	5 pts	12.1 g/dL	11 g/dL
Schwartz (1994)	Not stated	Not stated	MVA, falls	MVA, pedestrian, bicycle	Mostly stable	Some unstable	2/11	14/25	Hct 34.4	Hct 30.6
Moore (2010)	I–V	NR	MVC, falls, ATV, sports	NR	Not given	NR	NR	NR	NR	NR
Zabolotny (2002)	I–IV	I–IV	Blunt trauma	Same	Not stated	Not stated	4 pts	100%	NR	NR
Pranikoff (1994)	I–V	NR	Blunt trauma	NR	Stable	NR	NR	NR	NR	NR
Gandhi (1999)	I–V	NR	MVA, falls, bicycle, sports	NR	Stable	NR	2 pts	NR	NR	NR
Jen (2010)	I–IV	I–IV	Blunt	Blunt	Stable	Unstable	Not reported	Not reported	NR	NR
Muehrcke (1987)	Not stated	Not stated	MVA, falls, fights	Same	Stable	Stable definition	Low (<2 units)	High (6–9 units)	NR	NR
Avanoglu (1998)	Not stated	Not stated	MVC, falls	MVC, falls	Stable	Unstable	12/37	100%	NR	NR
Frumiento (2000)	I–IV	NR	MVA, sports, falls, bicycle	NR	Stable	NR	5 pts	NR	NR	NR
Beasley (1985)	Not reported	Not reported	MVA, bicycle, horse, sports	Same	Stable	Unstable	11 pts NOM	23 pts OM	NR	NR
Veger (2008)	I–IV	III–V	Bicycle 30%, scooter 30%, falls, sports	Same	SBP 112/48, HR 111	For grade 4 injuries	1/34	Splenectomy 100%	7.3	6.8–7.9
Wang (2024)	Not stated	Not stated	Car (30%), fall (17%), blunt	Car, falls	HR 111, SBP 106	HR 130, SBP 107	10 pts	6 pts	101	105.8

Oumar (2014)	Grades I–IV	NR	Contusion	NR	NR	NR	NR	NR	NR	NR

† Hemoglobin values are reported in units as provided by each study (g/dL, g/L, mmol/L, or hematocrit %). Wang (2024) values of 101 and 105.8 are reported in g/L. Schwartz (1994) values represent hematocrit (%). Direct cross-study comparison of absolute values is not recommended.

Table 3 shows consistent differences in resource utilization and outcomes between non-operative management (NOM) and operative management (OM). ICU use was generally lower or unnecessary in NOM, and there are many studies that reported no ICU need, such as Campbell (2014) and Arslan (2015) [34, 28]. In contrast, OM frequently required ICU admission, as reported in cohorts like Teuben (2020) and Stefanopol (2024) [13, 36]. The length of stay (LOS) was also shorter in NOM across nearly all studies, which typically ranged from 5 to 10 days. OM groups often required longer hospitalization, sometimes exceeding 14–20 days, as seen in

Baiomy (2022) and Wang (2024) [43, 20]. The delay of surgery in NOM was uncommon, which is generally below 5% as reported in Teuben (2020) and Beasley (1985) [13, 27]. The mortality was extremely low in NOM, with most studies reporting zero deaths, whereas OM mortality was higher, particularly in cases involving multisystem trauma, as documented by Campbell (2014) and Choong (1993) [34, 22]. The rate of success for NOM was consistently high and often above 95%, with several studies reporting 100% success, including Osifo (2007) and Frumiento (2000) [42, 40].

Table 3. Outcomes and resource utilization in pediatric blunt splenic trauma treated with non-operative versus operative management

Study ID	ICU (G1)	ICU (G2)	LOS (G1)	LOS (G2)	Need for Delayed Sx (G1)	Need for Delayed Sx (G1)	Mortality (G1)	Mortality (G2)	Success Rate (G1)	Success Rate (G2)
Osifo (2007)	NR	NR	7–14 d	14–21 d	None	None	0	1	100% success	83.3% success
Mabrouk (2018)	NR	NR	5–10 d	8–14 d	None	4	0	1	100%	83.3%
Campbell (2014)	None	ICU/PHDU	4–22 d	5–22 d	None	None	0	3	100%	57%
Teuben (2020)	Median 3 d	Median 4 d	Median 9 d	Median 12 d	3 pts	None	0	1	94.2%	90%
Baiomy (2022)	Not recorded	3–5 d	9 d	11 d	3 pts	3 pts	0	2	97.7%	97.7%
Shinn (2021)	Not reported	0–118 d	2–5 d	1–211 d	None	NR	257	134	98.5%	100% procedural success
Stefanopol (2024)	1–27 d	6–18 d	1–42 d	12–20 d	None	None	0	0	100%	100%
Grootenhaar (2021)	3.5 ±5.6 d	7.3 ±10 d	8–10 d	16.1 ±10.9 d	None	None	4	1	99%	100%
Kirkegård (2015)	2–3 d	2–3 d	7 d	7–10 d	2 pts	2 pts	0	0	88–94%	100% survival
Duron (2014)	Not provided	Not provided	Not provided	Not provided	3 pts	3 pts	0	0	98.3%	Not provided
Wisner (2015)	NR	NR	NR	NR	NR	NR	1	NR	NR	NR
Arslan (2015)	1.5 d	2.5 d	5 d	8.5 d	NR	NR	0	0	93%	NR
Karadeniz Cerit (2018)	2.85 d	NR	10.42 d	NR	1	NR	0	2	NR	50% success
De Jong (2011)	0–2 d	Same	7–12 d	Same	1	2	0	4	97%	85%
Davies (2009)	NR	NR	5 d	5 d	NR	NR	1	1	99%	99%
Ardley (2018)	NR	NR	5.4–6.6 d	5.4–11.3 d	1	1	2	2	100%	6/7 success
Choong (1993)	NR	NR	Extended stay	3 weeks	1	NR	0	9	100%	NR
Singer (2013)	NR	NR	17.6 d	14 d	2	1	1	1	79%	NR
Kakkasseril (1982)	Mean 2.7 d	NR	13 d	20 d	None	NR	0	1	100%	Surgical success
Thompson (2006)	Mean 4.1 d	Mean 4.1 d	Mean 7.7 d	15.8 d	None	NR	0	0	100%	100%
Schwartz (1994)	Mean 4.3 d	Mean 5.1 d	8.4 d	9.9 d	None	NR	0	0	100%	Similar to NOM
Moore (2010)	NR	NR	NR	NR	None	NR	0	NR	100%	NR
Zabolotny (2002)	36% admitted	NR	9.2 d	NR	1	NR	0	0	98% success	Surgical success
Pranikoff (1994)	≥24 h	NR	7 d	NR	None	NR	0	NR	100%	NR
Gandhi (1999)	1.36 d	NR	6.68 d	NR	None	NR	1	NR	97%	NR
Jen (2010)	NR	NR	6.1 d	7.9 d	3.3%	0.3%	NR	NR	96.7%	NR
Muehrcke (1987)	2–3 d	NR	10.8 d	13.8 d	0	0	0	1	100%	100% postop success
Avanoglu (1998)	All admitted	All	7.2 d	10.6–12.5 d	0	NR	1	All deaths due to	NR	NR

								other injuries		
Frumiento (2000)	3.4 d	NR	8.6 d	NR	0	NR	0	NR	100%	NR
Beasley (1985)	NR	NR	Up to 21 days	7–21 d	12	0	0	0	53%	NR
Veger (2008)	2 d	4 d (splenectomy) / 0.8 d (splenorrhaphy)	11.9 d	NR	3	1	0	1	91.2%	Splenectomy 100%, Splenorrhaphy 85.7%
Wang (2024)	2.3 d	5 d	13.2 d	20.5 d	NR	NR	1	0	High success	NR
Oumar (2014)	NR	NR	NR	NR	1	NR	0	NR	98.7%	NR

Notably, the complication rate shows that both non-operative (NOM) and operative management (OM) are associated with very low rates of wound infection, pneumonia, and ARDS in children with blunt splenic trauma. Studies like Osifo (2007), Stefanopol (2024), Grootenhaar (2021), and Moore (2010) reported no complications in either group [42, 36, 14, 15]. There are a few studies that showed minor differences. Teuben (2020) recorded single cases of wound infection,

pneumonia, and ARDS in NOM, with similar findings in OM [13]. Arslan (2015) noted more wound infections in NOM (15 cases) as compared to OM (1 case) [28], while Thompson (2006) reported pneumonia only in the NOM group [24] ***[Table 4]***.

Table 4. Complication rates following non-operative versus operative management of pediatric blunt splenic trauma.

Study ID	Wound Infection G1	Wound Infection G2	Pneumonia G1	Pneumonia G2	ARDS G1	ARDS G2
Osifo (2007)	0	0	0	0	0	0
Mabrouk (2018)	0	NR	NR	NR	NR	NR
Campbell (2014)	NR	NR	NR	NR	NR	NR
Teuben (2020)	1	0	1	1	1	1
Baiomy (2022)	NR	NR	NR	NR	NR	NR
Shinn (2021)	NR	NR	NR	NR	NR	NR
Stefanopol (2024)	0	0	0	0	0	0
Grootenhaar (2021)	0	0	0	0	0	0
Kirkegård (2015)	NR	NR	NR	NR	NR	NR
Duron (2014)	NR	NR	NR	NR	NR	NR
Wisner (2015)	NR	NR	NR	NR	NR	NR
Arslan (2015)	15	1	NR	NR	NR	NR
Karadeniz Cerit (2018)	NR	NR	NR	NR	NR	NR
De Jong (2011)	NR	NR	NR	NR	NR	NR
Davies (2009)	NR	NR	NR	NR	NR	NR
Ardley (2018)	NR	NR	NR	NR	NR	NR
Choong (1993)	NR	NR	NR	NR	NR	NR
Singer (2013)	NR	NR	NR	NR	NR	NR
Kakkasseril (1982)	0	0	0	0	0	0
Thompson (2006)	NR	NR	5	0	NR	NR
Schwartz (1994)	0	0	0	0	0	0
Moore (2010)	0	0	0	0	0	0
Zabolotny (2002)	0	0	0	0	0	0
Pranikoff (1994)	0	0	0	0	0	0
Gandhi (1999)	0	0	0	0	0	0
Jen (2010)	NR	NR	NR	NR	NR	NR
Muehrcke (1987)	NR	NR	NR	NR	NR	NR
Avanoglu (1998)	NR	NR	NR	NR	NR	NR
Frumiento (2000)	NR	NR	NR	NR	NR	NR
Beasley (1985)	NR	NR	NR	NR	NR	NR
Veger (2008)	NR	NR	NR	NR	NR	NR
Wang (2024)	NR	NR	NR	NR	NR	NR
Oumar (2014)	NR	NR	NR	NR	NR	NR

Analyzing biases, assessing quality, and determining the level of evidence

The MINORS assessment revealed that the included studies had total scores ranging from 8 to 18[12]. The scores for comparative studies ranged from 11/24, recorded by Avanoglu (1998)[39], Veger (2008)[19], and Beasley (1985)[27], to a maximum of 18/24 achieved by Teuben (2020)[13]. Meanwhile, non-comparative studies ranged from 8/16, the lowest score shared by

Mabrouk (2018)[33], Stefanopol et al. (2024)[36], Duron (2014)[21], and Frumiento (2000)[40], to a high of 11/16, achieved by Kirkegård et al. (2015)[38] and Pranikoff (1994)[37]. The most common methodological limitations were two universal drawbacks related to study design characteristics. Firstly, prospective data collection was a limitation, as 32 included studies scored 0 in this domain, indicating a predominantly retrospective nature. Secondly, the prospective calculation of sample size was also a major universal limitation, with all 33 studies scoring 0 in this domain. Overall, the methodological quality of the included studies was moderate to low, and therefore, the findings should be interpreted with caution ***[Table 5-6]***

Table 5. MINORS evaluation method for non-randomized non-comparative research.

	A clearly stated aim of the study	Inclusion of consecutive patients	Prospective data collection	Endpoints appropriate to the study aim	Unbiased assessment of endpoint	Follow-up period appropriate to the aim of the study	Loss to follow-up <5%	Prospective calculation of sample size	Overall Score
Osif, 2007	2	2	0	2	1	1	2	0	10/16
Mabrouk, 2018	2	2	0	2	1	1	0	0	8/16
Campbell, 2014	2	2	0	2	1	2	1	0	10/16
Stefanopol et al., 2024	2	2	0	2	1	1	0	0	8/16
Grootenhaar et al., 2021	2	2	0	2	1	2	0	0	9/16
Kirkegård et al., 2015	2	2	0	2	2	1	2	0	11/16
Wisner, 2015	2	2	2	2	1	1	0	0	10/16
Ardley, 2018	2	2	0	2	1	1	1	0	9/16
CHOONG, 1993	2	1	0	2	1	1	0	0	9/16
Thompson, 2006	2	1	0	2	1	2	2	0	10/16
Moore, 2010	2	2	0	2	1	2	1	0	10/16
Zabolotny, 2002	2	2	0	2	1	2	1	0	10/16
Pranikoff, 1994	2	2	0	2	1	2	2	0	11/16

Frumiento, 2000	2	2	0	2	1	1	0	0	8/16
Oumar, 2014	2	2	0	2	1	2	0	0	9/16
Duron, 2014	2	2	0	2	1	1	0	0	8/16

Table 6. MINORS evaluation tool for non-randomized comparative research

	A clearly stated aim of the study	Inclusion of consecutive patients	Prospective data collection	Endpoints appropriate to the study aim	Unbiased assessment of endpoint	Follow-up period appropriate to the aim of the study	Loss to follow-up <5%	Prospective calculation of sample size	An adequate control group	Contemporary groups	Baseline equivalence of groups	Adequate statistical analyses	Overall Score

Teuben, 2020	2	2	0	2	1	2	1	0	1	2	1	2	18/24
Baiomy, 2022	2	2	0	2	2	1	0	0	2	2	1	2	16/24
Shinn et al., 2021	2	2	0	2	1	0	0	0	2	2	1	2	14/24
De Jong, 2011	2	2	0	2	1	1	0	0	2	1	1	2	14/24
Davies, 2009	2	2	0	2	1	1	0	0	2	1	1	2	14/24
Singer, 2013	2	2	0	2	1	2	1	0	2	0	1	1	14/24
Kakkasseril, 1982	2	2	0	2	1	1	1	0	2	1	0	1	13/24
Schwartz, 1994	2	1	0	2	1	1	0	0	2	2	1	0	12/24
Gandhi, 1999	2	2	0	2	1	2	0	0	1	0	2	1	13/24
Jen, 2010	2	2	0	2	1	2	1	0	2	2	1	2	17/24
Muehrcke,1987	2	2	0	2	1	1	1	0	2	1	0	1	13/24
Avanoglu, 1998	2	1	0	2	1	1	0	0	2	1	1	1	11/24
Beasley, 1985	2	2	0	2	1	1	0	0	2	0	0	1	11/24
Veger, 2008	2	1	0	2	1	1	0	0	2	1	0	1	11/24
Wang, 2024	2	2	0	2	1	1	0	0	2	2	1	2	15/24
Arslan, 2015	2	2	0	2	1	1	0	0	2	2	1	2	15/24
Karadeniz Cerit, 2018	2	2	0	2	1	1	0	0	2	2	2	2	16/24

Meta-Analysis for the Safety and Efficacy of Non-Operative Management

This meta-analysis evaluates clinical outcomes of non-operative as compared to operative management in pediatric blunt splenic trauma. Notably, non-operative management demonstrated

that there was an excellent success rate with RR of 0.97 (0.98–0.99, $p < 0.0001$, $I^2 = 0\%$). This showed that NOM is highly reliable and has a superior success rate for the management of blunt splenic trauma in hemodynamically stable patients ***(Figure 2)***. Moreover, the need for ICU was also lower in the NOM group. The SMD of –0.95 (–1.70 to –0.1925, $p = 0.0139$, $I^2 = 79.9\%$) shows that NOM patients generally needed fewer ICU days. This reflected quicker stabilization without the physiological burden of the surgery ***(Figure 3)***. For early complications (infection, pneumonia, ARDS), no significant difference was observed between groups, with RR of 0.61 (0.20–1.88, $p = 0.3940$, $I^2 = 0\%$). This showed the safety of NOM despite avoiding operative intervention ***(Figure 4)***. The difference in blood transfusion need was substantial. NOM showed that there is a much lower requirement of blood transfusion (RR = 0.23, 95% CI: 0.17–0.32, $p < 0.0001$, $I^2 = 82.1\%$). This reflects that there is a reduced blood loss and a more stable clinical course for nonoperative management ***(Figure 5)***. Most importantly, mortality was significantly lower with NOM, with RR of 0.12 (95% CI: 0.06–0.2358, $p < 0.0001$, $I^2 = 5.5\%$). This indicates a clear survival advantage with NOM, which reinforces it as the safer approach for management of pediatric blunt splenic trauma ***(Figure 6)***.

Figure 7 shows a funnel plot for assessment of potential publication bias. While the plot appears broadly symmetrical, this interpretation should be made with caution given the limited number of comparative studies available per outcome — formal Egger's or Begg's tests were not applicable for most outcomes due to insufficient study numbers (<10 comparative studies). Visual symmetry alone cannot exclude publication bias, and selective reporting of favorable NOM outcomes from smaller case series cannot be ruled out. These results should therefore be interpreted with appropriate caution.

Figure 2. Success Rate of NOM in Splenic Blunt Trauma as compared to OM

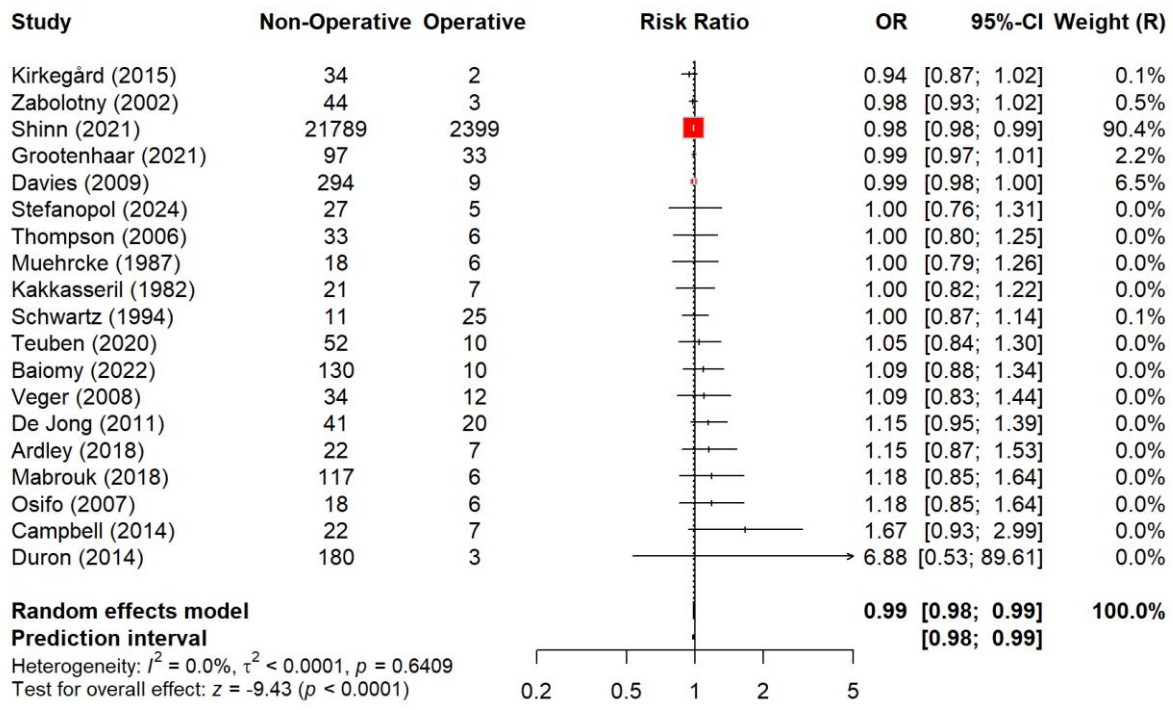


Figure 3. Length of ICU Stay (Days) in Non-Operative Management Patient as compared to Operative Management of Spleen Trauma

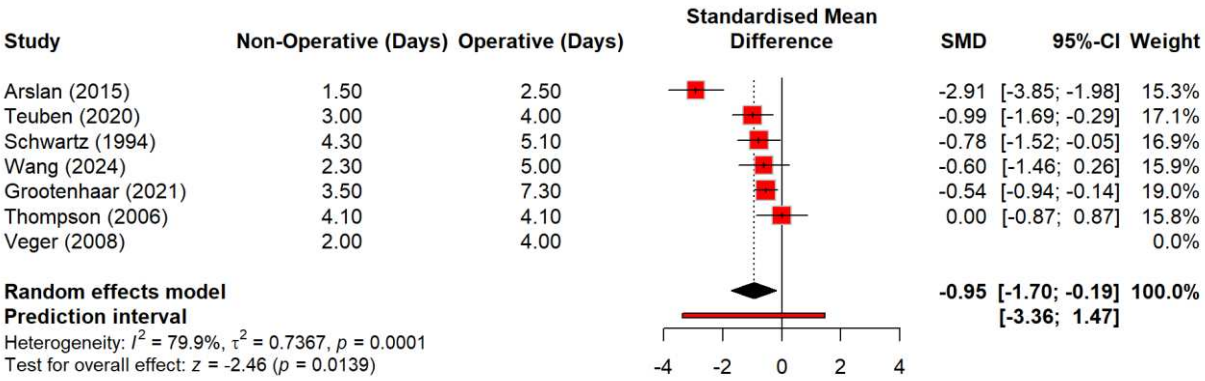


Figure 4. Risk of Complications in Non-Operative Management of Patients as Compared to Operative Management for Spleen Trauma

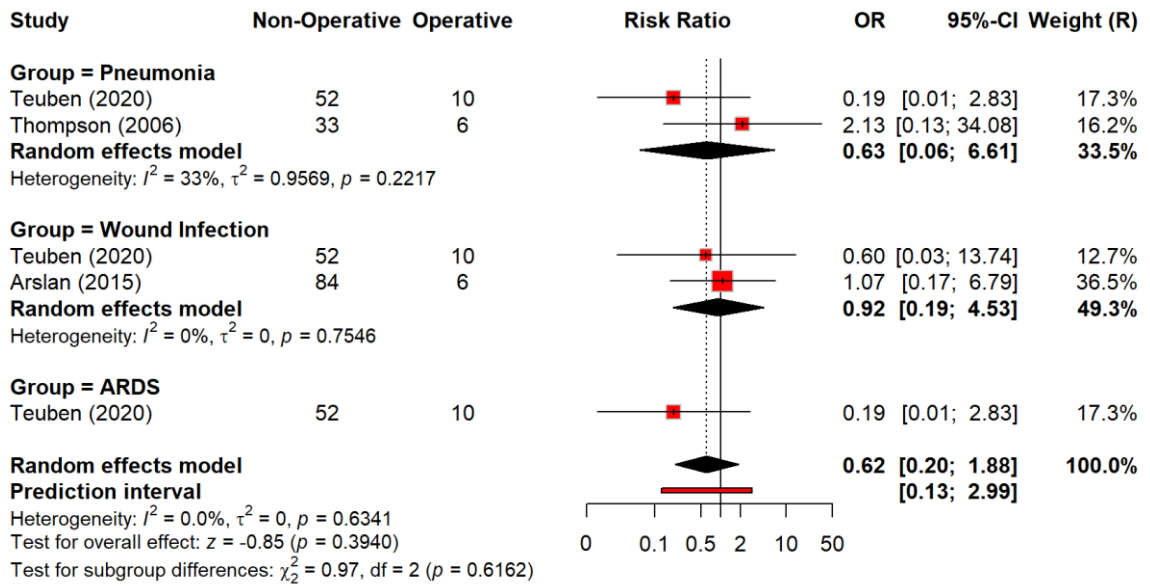


Figure 5. Rate of Blood Transfusion in Non-Operative Management Patients as Compared to Operative Management for Spleen Trauma

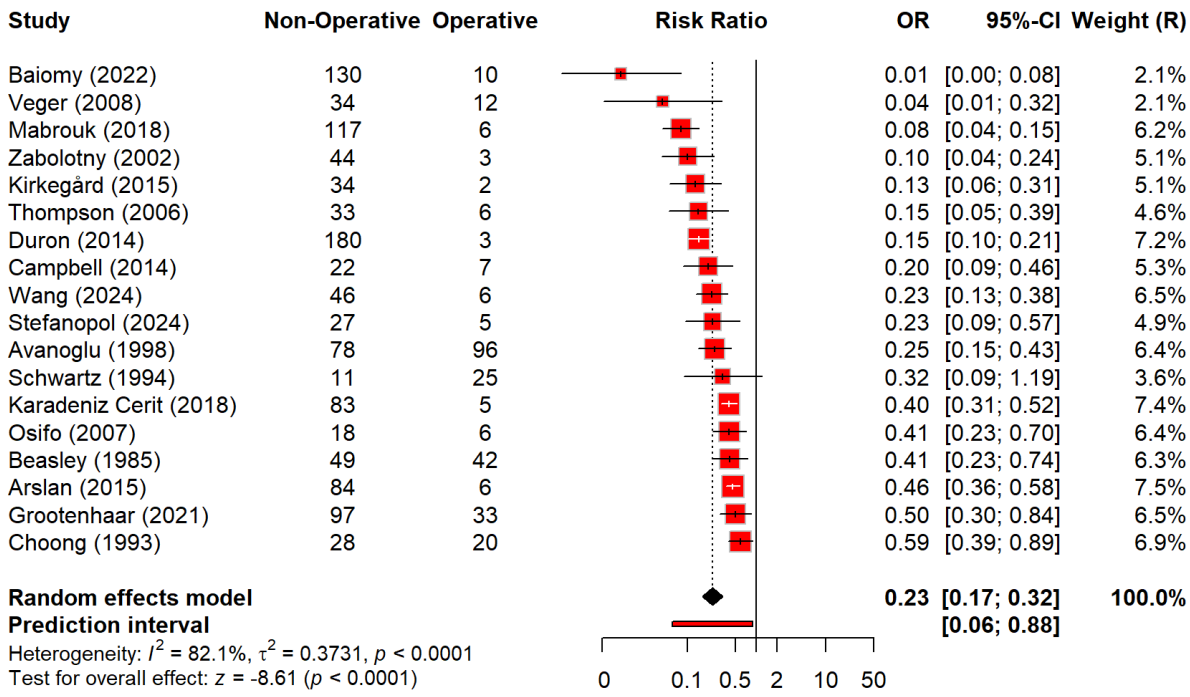


Figure 6. Risk of Mortality in Non-Operative Management Patients as Compared to Operative Management for Spleen Trauma

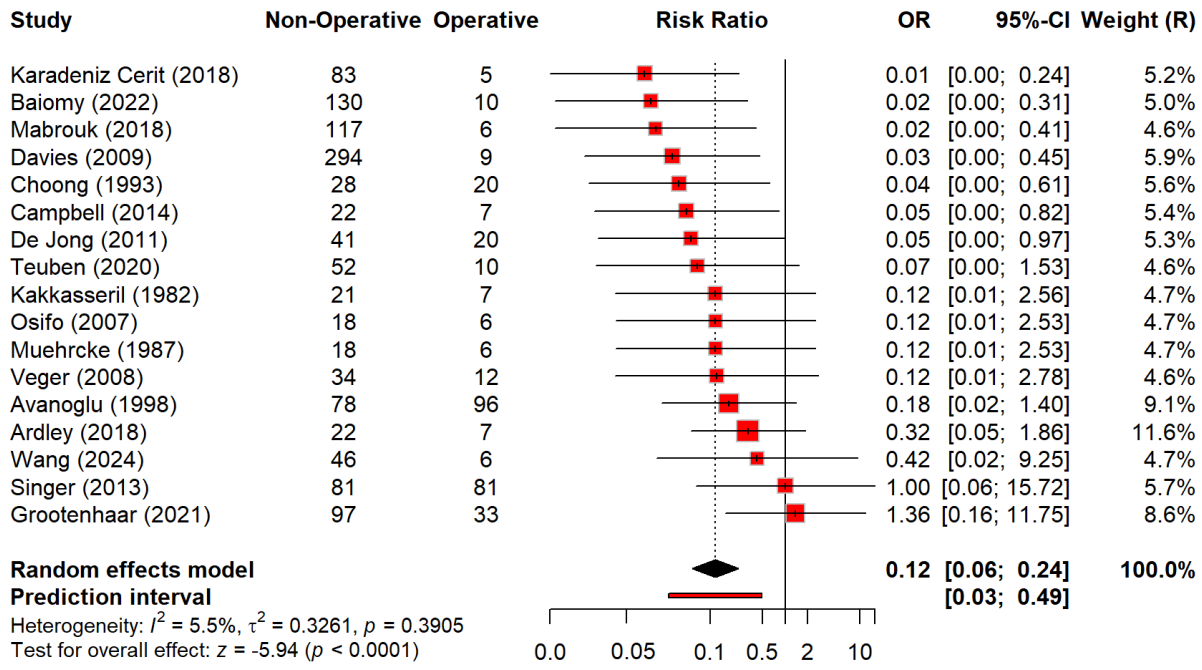
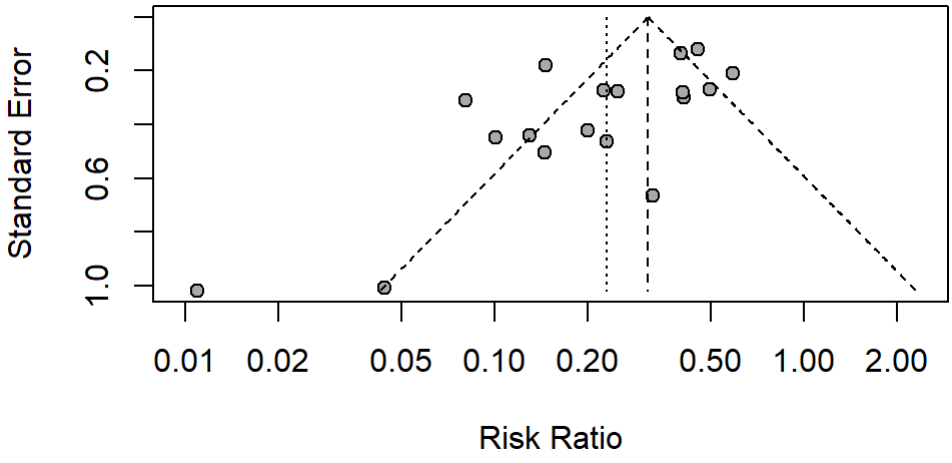


Figure 7. Funnel diagram for evaluating publication bias



Discussion

This systematic review and meta-analysis aim to evaluate the differences in outcomes as well as the safety of nonoperative management (NOM) versus operative management (OM) in pediatrics suffering from blunt splenic injury. The meta-analysis collects data from 33 research studies performed between 1985 and 2024, including more than 43,000 children. The results show that NOM can be effective as well as safe in selected patients. In all trials conducted, the meta-analysis showed the success of NOM was very high, surpassing 95%, in many of which it was 100%. Besides the greater efficacy, the NOM group showed reduced resource use, as there were fewer hospitalizations and ICU admissions and a substantially lower need for blood transfusions. NOM-associated mortality was overall low across the included studies, with the majority reporting zero deaths in the NOM cohort. However, several studies did record NOM deaths — most notably Shinn (2021), which reported 257 deaths in 21,789 NOM patients (1.2%), and Grootenhaar (2021), which reported 4 deaths, predominantly attributable to concomitant injuries rather than splenic injury itself. The rates of mortality in the OM group were comparably higher and correlated with injury severity. Regarding safety, there was no significant disparity between NOM and OM groups regarding the incidence of low rates of complications like wound infection, pneumonia, and ARDS. Overall, NOM appears to be a preferable first line of treatment in pediatric patients with blunt splenic injury, based on its favorable efficacy and safety profile. The results of this systematic review are consistent with the current consensus supporting NOM as the standard approach for pediatric blunt splenic trauma. Early clinical studies demonstrated that children have a greater capacity for spontaneous splenic healing and hemostasis, which justified a shift away from routine operative intervention in stable patients [1,3]. Follow-up studies have confirmed the excellent efficacy of NOM, having a success rate between 95% and 98% in most clinical series, and very low rates of adverse outcomes, such as deferred surgery and in-hospital mortality, in well-selected and adequately monitored cases [5,6]. Notably, more recent studies have emphasized the role of achieving stability over injury severity in the initial management approach, regardless of individual study settings and projects discussed in this paper [13,14,19]. These findings are supported by large population-based studies and registry analyses showing low mortality and complication rates for non-operatively treated children with selected grade V splenic injuries presented to adequately equipped centers for trauma care [17,35]. Similar results have been documented among a broader international community of patients with similar diagnoses, establishing a general ability to apply NOM principles regardless of healthcare systems in place [14,19,36]. Previous studies have shown that NOM is associated with decreased length of hospital stay, intensive care unit use, and blood transfusion need, thereby affirming the benefits of NOM in terms of both clinical and resource considerations [21,25]. It should be noted that there are no higher rates of infectious and pulmonary complications in this review, supporting previous studies that confirm the safety of NOM in pediatric spleen injury [15,40]. Lastly, the existing literature fully supports the findings of this meta-analysis and confirms that NOM is an effective, safe, and efficient method for the treatment of children with blunt splenic injury.

From clinical practice, these findings support non- operative management as the gold standard for pediatric blunt splenic trauma in hemodynamically stable patients. NOM shows a high success rate, lower mortality, lower ICU admissions, and fewer transfusions without raising the

risk of complications. Operative treatment should be preserved for patients who have ongoing hemodynamic instability, those who don't respond to NOM, or those with other injuries that require surgical exploration. In hemodynamically stable patients, non-operative management (NOM) is given priority in the international standard of care for pediatric blunt splenic trauma. This approach is backed by evidence of safety, efficacy, and decreased resource consumption. Our meta-analysis, which shows lower mortality and lower healthcare resource utilization when compared to operative management, validates the suitability of this standard. These results underline the significance of physiologic-based decision-making, where hemodynamic stability is prioritized over injury grade, and support NOM as the prevailing standard of treatment. The continued use of NOM to improve outcomes and resource utilization in pediatric trauma care is supported by this alignment between evidence and best practice.

This review has a number of limitations. The majority of the included studies were observational and retrospective, which made it more difficult to determine the causal relationships between management strategy and results. Heterogeneity may have resulted from differences in injury severity, patient selection, and outcome definitions between studies. Furthermore, the results could have been impacted by insufficient adjustment for confounding variables, especially hemodynamic status and related injuries. Lastly, the inclusion of only English-language studies may have resulted in the exclusion of pertinent non-English research. Based on our findings suggest that future efforts should focus on standardizing guidelines and improving patient selection to optimize non-operative management protocols for pediatric blunt splenic trauma. To reduce needless surgery while guaranteeing prompt intervention when necessary, more clinician awareness and organized trauma pathways are needed. Lastly, more multicenter prospective research is advised to assess long-term results and practice variations.

Conclusion

This moderate -quality systematic review and meta-analysis demonstrates that non-operative management (NOM) of pediatric blunt splenic trauma is a safe and effective treatment strategy. NOM was associated with a high success rate and low mortality, alongside a shorter hospital length of stay compared with operative management. Additionally, patients managed non-operatively showed reduced intensive care unit admissions, lower blood transfusion requirements, and fewer surgical interventions.

These findings support the preferential use of NOM in appropriately selected pediatric patients with blunt splenic injuries. However, further research is warranted, particularly multicenter randomized controlled trials or well-designed standardized cohort studies with extended follow-up, to refine patient selection criteria and to better define long-term outcomes.

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