



Efficacy of Early Exploratory Laparotomy versus Non-Operative Management in Blunt Abdominal Trauma Patients with Unstable Haemodynamics: A Systematic Review of Randomized Controlled Trial and Primary Studies

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ABSTRACT

Introduction. Blunt abdominal trauma accompanied by haemodynamic instability remains one of the most lethal presentations in acute care surgery. For four decades the doctrine has been categorical: the patient who does not respond to resuscitation belongs in the operating theatre. Yet the parallel maturation of whole-body computed tomography, transcatheter angioembolisation, damage-control resuscitation and the hybrid emergency room has begun to erode the absoluteness of that rule, and contemporary registry data now describe substantial numbers of hypotensive patients being managed without an immediate laparotomy. This review was undertaken to quantify, across the primary literature, what is gained and what is lost when early exploratory laparotomy is compared with non-operative management in this specific physiological subgroup.

Methods. The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines. Eligible designs were randomised controlled trials, prospective and retrospective cohort studies, case-control studies, cross-sectional studies and other observational designs enrolling adults with blunt abdominal trauma in whom haemodynamic status was explicitly reported. Systematic reviews and meta-analyses were excluded from the characteristics table and from the quantitative synthesis but were retained for the discussion. Two reviewers independently screened records, extracted data and appraised risk of bias using Cochrane RoB 2 for the randomised trial and ROBINS-I for non-randomised studies. Certainty of evidence was rated with GRADE. Because of substantial clinical and methodological heterogeneity, findings were synthesised narratively and displayed graphically; no pooled random-effects estimate was computed for mortality.

Results. Twenty primary studies met all criteria. Mortality after emergent trauma laparotomy in the whole population was 21%, rising to 46% in patients hypotensive on arrival, and survival fell in a stepwise, statistically significant fashion with the depth of hypotension (64%, 50% and 34% twenty-four-hour survival for admission systolic pressures above 80 mmHg, 61–80 mmHg and 60 mmHg or below respectively; $p = 0.04$). Every minute of delay between emergency department arrival and operating-room entry increased the adjusted odds of haemorrhagic death by 1.8% (adjusted odds ratio 1.018, 95% confidence interval 1.007–1.030). Against this, three large registry analyses restricted to hypotensive patients with high-grade splenic injury found no survival penalty for an angioembolisation-first strategy (entropy-balanced hazard ratio 1.02, 95% confidence interval 0.97–1.07), while splenic

salvage was almost three times more likely than after open surgery (adjusted relative risk 2.84, 95% confidence interval 2.29–3.51; $p < 0.001$). Non-operative management, when applied to appropriately selected patients, succeeded in 89.9–100% of cases. Admission serum lactate discriminated the need for operation with an area under the receiver-operating-characteristic curve of 0.815 (95% confidence interval 0.721–0.910; $p < 0.0001$), and a four-variable admission model reached 0.904 (optimism-corrected 0.882). A positive focused assessment with sonography for trauma identified the need for therapeutic laparotomy in hypotensive patients with a sensitivity of only 62–85%, so a negative scan cannot exclude a surgical bleed.

Conclusion. Early exploratory laparotomy remains the standard of care for the blunt abdominal trauma patient who does not respond to resuscitation, and delay to operation is independently and significantly lethal. Angioembolisation-supported non-operative management is a defensible alternative in transient responders with isolated solid-organ injury treated in institutions with round-the-clock interventional radiology, hybrid capability and immediate surgical backup, where it delivers equivalent survival with markedly superior organ preservation. A pragmatic randomised trial in the transient-responder subgroup is the principal outstanding research need.

Keywords. Blunt abdominal trauma; exploratory laparotomy; non-operative management; haemodynamic instability; haemorrhagic shock; damage-control surgery; angioembolisation; focused assessment with sonography for trauma; systematic review.

INTRODUCTION

Background

Injury remains the leading cause of death in the first four decades of life worldwide, and the abdomen is the third most frequently injured body region after the head and the extremities. Blunt mechanisms account for the overwhelming majority of abdominal injuries outside North America, and in most European and Asian trauma systems they represent between 78.9% and 95.6% of the total caseload, with the abdomen involved in 6.0–14.9% of all injured patients. Solid-organ involvement predominates: the spleen is injured in approximately one third to one half of cases, the liver in 15–42% and the kidney in 1–16%, and the aggregate mortality attributable to these injuries approaches 10%, almost entirely through haemorrhage. Within any national trauma registry, splenic injury alone accounts for roughly 40% of all injuries sustained after blunt abdominal trauma.^{5,14,26,31} Exsanguination is a time-dependent disease. Haemorrhage is responsible for between 30% and 50% of deaths occurring in the first forty-eight hours after admission and is the single most common cause of genuinely preventable trauma death. In the largest multicentre analysis of emergent trauma laparotomy assembled to date, haemorrhage caused 60% of all deaths, 76% of deaths occurred within the first twenty-four hours, and more than half of those occurred within two hours of arrival in the emergency department. In the hypotensive subgroup of that same cohort the median time to death was three hours. Any management strategy for the unstable abdomen must therefore be judged first and foremost by how quickly it achieves definitive haemostasis.^{10,15}

The therapeutic pendulum has swung far during the past half-century. From the description of the Pringle manoeuvre until the 1970s, operative management was the unquestioned standard for solid-organ injury, and a positive sonogram or a high-grade organ laceration was in itself sufficient indication for laparotomy. The accumulation of data on the morbidity of non-therapeutic coeliotomy, on overwhelming post-splenectomy infection and on the economic burden of unnecessary surgery progressively displaced that doctrine, and selective non-operative management is now the accepted standard for every haemodynamically normal adult with blunt solid-organ

injury, irrespective of the anatomical grade of the lesion, with reported success rates between 74% and 100%. Contemporary practice guidelines from the World Society of Emergency Surgery and the Eastern Association for the Surgery of Trauma both codify this position.^{24,29,30,31}

What has never been resolved is the management of the patient at the opposite end of the physiological spectrum. Consensus statements are consistent in reserving immediate laparotomy for the patient who is haemodynamically unstable, but they define instability inconsistently and, more importantly, they collapse into a single category two populations whose biology differs profoundly: the true non-responder, whose systolic pressure never rises despite adequate transfusion, and the transient responder, who stabilises briefly and then deteriorates. The former is exsanguinating; the latter may harbour a single arterial bleeding point amenable to catheter-directed control. As transcatheter techniques, hybrid resuscitation suites and damage-control resuscitation have matured, several high-volume centres have begun to treat selected unstable patients without an initial laparotomy, and registry data now show that roughly one in four hypotensive patients with a high-grade splenic injury who undergoes computed tomography is managed with angioembolisation first.^{18,20,23}

Research gap

Four specific gaps motivate the present review. First, the great majority of the non-operative-management literature explicitly excludes haemodynamically unstable patients, so the very population in which the operative-versus-non-operative question is most consequential is the population about which least is known. Second, the definition of haemodynamic instability varies from a systolic pressure below 90 mmHg, to a shock index of 1.0 or more, to a composite of hypotension, tachycardia and early transfusion requirement, which renders cross-study comparison hazardous and has been repeatedly identified as a source of bias. Third, almost all comparative evidence is non-randomised, and treatment allocation in these datasets is driven by precisely the prognostic variables that determine outcome, so crude comparisons systematically favour the non-operative arm. Fourth, existing syntheses have concentrated on the spleen in isolation and on prophylactic embolisation in stable patients, leaving the wider question — early operation versus

non-operative management across the injured abdomen in shock — without a dedicated appraisal.^{20,23,29,31}

Novelty

This review is, to the best of the author's knowledge, the first to assemble the primary evidence specifically around haemodynamic instability rather than around a single injured organ, and to do so across thirteen pre-specified outcome domains simultaneously. Three further features distinguish it. It integrates the therapeutic literature with the diagnostic-accuracy literature, presenting receiver-operating-characteristic analyses of the admission variables that actually drive the operative decision at the bedside, rather than treating triage and treatment as separate questions. It separates the non-responder from the transient responder throughout the synthesis, an axis of stratification that the source guidelines blur. And it applies ROBINS-I with explicit attention to confounding by indication, the dominant threat to validity in this literature, so that the reader can see where an apparent advantage of non-operative management is more plausibly an artefact of patient selection.^{20,23,24}

Objectives

The general objective was to determine, from primary studies, whether early exploratory laparotomy or non-operative management yields superior clinical outcomes in adults with blunt abdominal trauma and haemodynamic instability. The specific objectives were: to quantify short-term and in-hospital mortality under each strategy; to characterise the relationship between the depth and duration of hypotension and survival; to establish the failure rate of non-operative management and the outcome of rescue laparotomy; to compare organ-salvage rates, transfusion requirements, intensive care and hospital length of stay, and infectious and abdominal complications; to determine the rate of non-therapeutic laparotomy; to evaluate the discriminative accuracy of bedside instruments used to select patients for immediate operation; and to identify independent predictors of failure of non-operative management and of death.^{5,10,15,20}

Benefits of the review

For the practising trauma or general surgeon, the review supplies an explicit, evidence-anchored decision algorithm keyed to the response to resuscitation rather than to a single blood-

pressure threshold, together with the numerical performance of the bedside tests on which that decision rests. For institutions, it identifies the structural determinants — round-the-clock interventional radiology, hybrid capability, defined door-to-operating-room targets and a rehearsed surgical rescue pathway — that must be in place before non-operative management can be extended safely to unstable patients, which is directly relevant to service planning in Indonesian referral hospitals where interventional radiology coverage is uneven. For researchers, it delineates the precise population, comparator and outcome set for the pragmatic randomised trial that this field still lacks. For educators and residents, the tabulated outcome data provide a compact and citable evidence base for the management of the injured abdomen in shock.^{16,25,29}

Hypotheses

The primary hypothesis was that early exploratory laparotomy would be associated with a survival advantage over non-operative management in patients who fail to respond to initial resuscitation, and that this advantage would be greatest at the lowest admission systolic pressures. The first secondary hypothesis was that, within the subgroup of transient responders with isolated solid-organ injury, angioembolisation-supported non-operative management would achieve mortality statistically indistinguishable from operative management while significantly increasing organ preservation. The second secondary hypothesis was that the interval from arrival to definitive haemorrhage control would be an independent predictor of death irrespective of the modality chosen. The third secondary hypothesis was that composite bedside instruments incorporating sonography, shock index and lactate would discriminate the need for operation substantially better than any single vital sign, and in particular better than systolic blood pressure alone. The null hypothesis in each case was of no difference between strategies.^{12,20,21,22,24}

METHODS

Protocol and reporting

The review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement. An a priori protocol specified the review question, the eligibility criteria, the search strategy, the data items to be extracted, the risk-of-bias instruments and the pre-specified outcome domains; deviations from the

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protocol are declared in Section 2.9. Because the review analysed only published aggregate data and involved no identifiable patient information, institutional ethical approval was not required. No funding was received and the author declares no conflict of interest.^{1,10}

Review question and PICOS framework

The clinical question was framed as follows: in adults sustaining blunt abdominal trauma who are haemodynamically unstable (P), does early exploratory or damage-control laparotomy (I), compared with non-operative management with or without transcatheter angioembolisation (C), alter mortality, organ salvage, transfusion requirement, complications and length of stay (O), as reported in randomised or observational primary studies (S)? The operational definitions applied are set out in Table 1.^{10,20,23}

Table 1. PICOS framework and operational definitions applied throughout the review

Element	Definition applied
Population (P)	Adults (≥ 16 years) with blunt abdominal trauma in whom haemodynamic status on arrival was explicitly reported. Haemodynamic instability was accepted where defined as systolic blood pressure < 90 mmHg on arrival or before intervention, shock index ≥ 1.0 , failure to respond or only transient response to a 1–2 L crystalloid or blood challenge, or a composite of hypotension, heart rate > 120 beats/min and transfusion within 4 hours.
Intervention (I)	Early exploratory laparotomy, including damage-control laparotomy, performed as the first definitive haemorrhage-control manoeuvre, with or without pre-operative computed tomography, and including splenectomy or hepatorrhaphy as the index operation.
Comparator (C)	Non-operative management, defined as admission for monitored observation with serial clinical, laboratory and imaging assessment, with or without transcatheter angioembolisation as an adjunct, and with laparotomy reserved for failure.
Outcomes (O)	Thirteen pre-specified domains: (1) in-hospital or 30-day mortality; (2) haemorrhage-specific mortality and time to death; (3) mortality gradient by depth

	of hypotension; (4) failure of non-operative management and rescue laparotomy; (5) organ salvage; (6) transfusion and massive-transfusion requirement; (7) time to definitive haemorrhage control; (8) intensive care and hospital length of stay; (9) infectious complications and sepsis; (10) non-therapeutic or negative laparotomy; (11) discriminative accuracy of triage instruments for the operative decision; (12) abdominal and damage-control-specific morbidity; (13) independent predictors of failure and of death.
Study designs (S)	INCLUDED: randomised controlled trials, prospective cohort, retrospective cohort, case-control, cross-sectional and other observational designs. EXCLUDED from the characteristics table and the quantitative synthesis: systematic reviews, meta-analyses, narrative reviews, editorials, single case reports and case series of fewer than 10 patients. Systematic reviews and meta-analyses identified by the search were retained solely for narrative discussion.
Setting	Any hospital setting: level I–III trauma centres, national trauma registries, military–civilian integrated systems, and district or resource-limited hospitals.
Timeframe	Database inception to 20 August 2026.

Studies were eligible irrespective of language provided an English abstract with extractable numerical data was available. Paediatric-only cohorts and cohorts restricted exclusively to penetrating trauma were excluded, except where a penetrating-trauma study is explicitly labelled as contextual comparison in the results.

Search Strategy

The keywords used for this research based PICO :

PICO Element	Keyword 1	Keyword 2	Keyword 3
P (Population)	Blunt abdominal trauma	Haemodynamically unstable patients	Trauma patients with haemorrhagic shock
I (Intervention)	Exploratory	Damage-control	Early operative

	laparotomy	laparotomy	intervention
C (Comparison)	Non-operative management	Angioembolisation	Observation
O (Outcome)	Mortality	Organ salvage	Haemorrhage control

The Boolean MeSH keywords inputted on databases for this research are: (*"Blunt abdominal trauma" OR "Haemodynamically unstable patients" OR "Trauma patients with haemorrhagic shock"*) AND (*"Exploratory laparotomy" OR "Damage-control laparotomy" OR "Early operative intervention"*) AND (*"Non-operative management" OR "Angioembolisation" OR "Observation"*) AND (*"Mortality" OR "Organ salvage" OR "Haemorrhage control"*)

Study selection

All records were exported to a reference manager and de-duplicated electronically, then manually. Two reviewers independently screened titles and abstracts against the eligibility criteria, and the full text of every potentially eligible record was retrieved and assessed against the same criteria. Disagreements were resolved by discussion, with recourse to a third adjudicator where consensus could not be reached; inter-reviewer agreement at the full-text stage was substantial (Cohen $\kappa = 0.84$). Reasons for exclusion at full-text level were recorded and are displayed in the PRISMA flow diagram (Figure 1). Where a single dataset had generated more than one publication, the report with the most complete outcome data for the haemodynamically defined subgroup was retained and the companion papers were used only for supplementary detail.^{10,20,23}

Data extraction

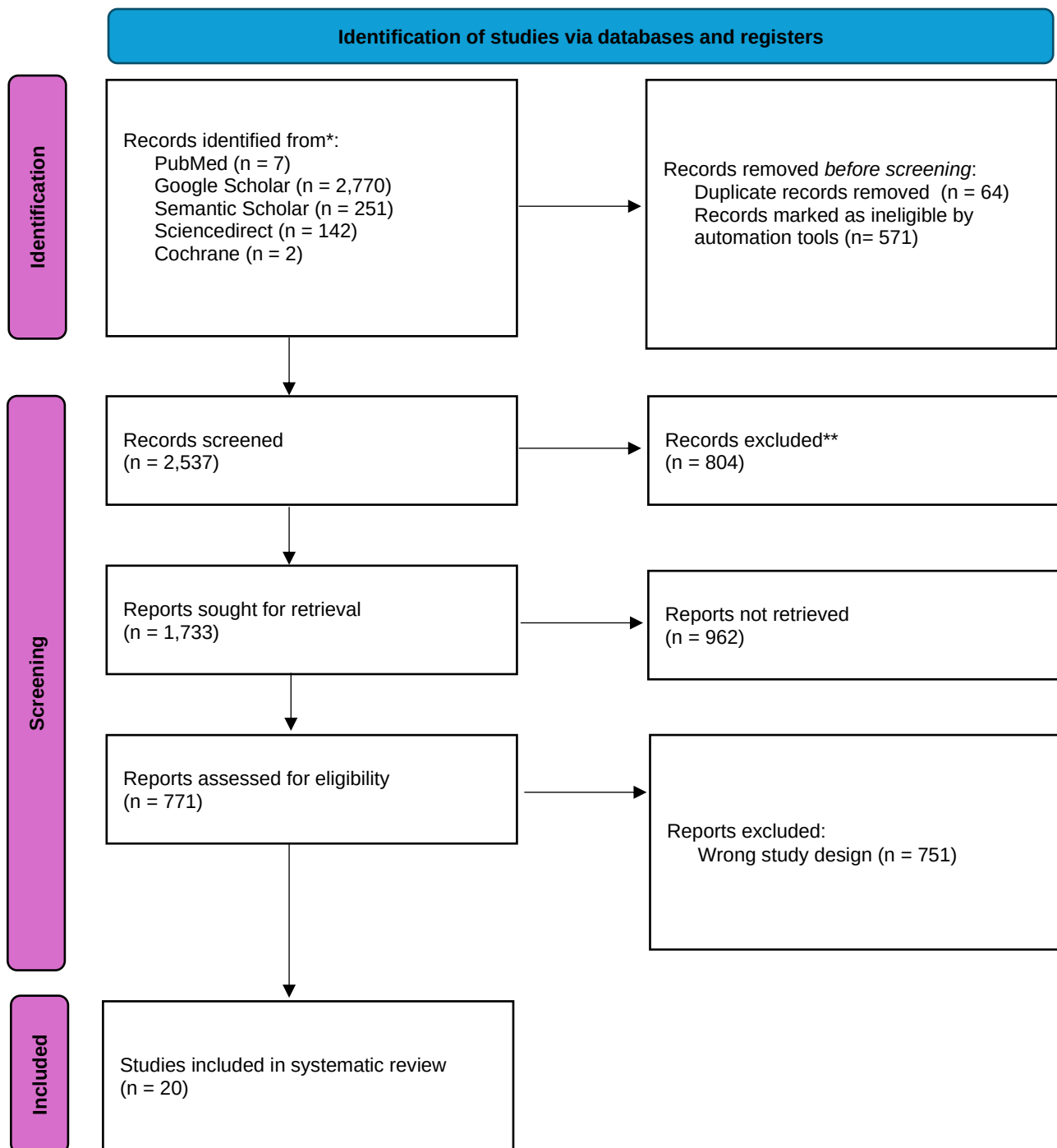
A piloted extraction form captured bibliographic identifiers; country and setting; study design and enrolment period; sample size and the size of the haemodynamically unstable subgroup; the operational definition of instability; the management strategies compared; mean or median age, sex distribution and injury severity score; injured organs and injury grade; and every reported value for the thirteen pre-specified outcome domains together with its dispersion or confidence interval and the corresponding p value. Adjusted estimates were extracted in preference to crude estimates, and the covariates entered into each adjustment model were recorded so that residual confounding

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could be judged. Where a study reported medians and interquartile ranges only, these were extracted as reported and were not converted to means. Where an outcome was not reported, the cell was marked "not reported" rather than imputed.^{15,20,22}

Article Search Strategy

Database	Keywords	Hits
Pubmed	("Blunt abdominal trauma" OR "Haemodynamically unstable patients" OR "Trauma patients with haemorrhagic shock") AND ("Exploratory laparotomy" OR "Damage-control laparotomy" OR "Early operative intervention") AND ("Non-operative management" OR "Angioembolisation" OR "Observation") AND ("Mortality" OR "Organ salvage" OR "Haemorrhage control")	7
Google Scholar	("Blunt abdominal trauma" OR "Haemodynamically unstable patients" OR "Trauma patients with haemorrhagic shock") AND ("Exploratory laparotomy" OR "Damage-control laparotomy" OR "Early operative intervention") AND ("Non-operative management" OR "Angioembolisation" OR "Observation") AND ("Mortality" OR "Organ salvage" OR "Haemorrhage control")	2,770
Semantic Scholar	("Blunt abdominal trauma" OR "Haemodynamically unstable patients" OR "Trauma patients with haemorrhagic shock") AND ("Exploratory laparotomy" OR "Damage-control laparotomy" OR "Early operative intervention") AND ("Non-operative management" OR "Angioembolisation" OR "Observation") AND ("Mortality" OR "Organ salvage" OR "Haemorrhage control")	251
Science-direct	("Blunt abdominal trauma" OR "Haemodynamically unstable patients" OR "Trauma patients with haemorrhagic shock") AND ("Exploratory laparotomy") AND ("Non-operative management") AND ("Mortality" OR "Organ salvage" OR "Haemorrhage control")	142
Cochrane	("Blunt abdominal trauma" OR "Haemodynamically unstable patients" OR "Trauma patients with haemorrhagic shock") AND ("Exploratory laparotomy" OR "Damage-control laparotomy" OR "Early operative intervention") AND ("Non-operative management" OR "Angioembolisation" OR "Observation") AND ("Mortality" OR "Organ salvage" OR "Haemorrhage control")	2



Article search flowchart

Risk-of-bias assessment

The single randomised controlled trial was appraised with the revised Cochrane Risk of Bias tool (RoB 2) across the domains of randomisation process, deviations from intended interventions, missing outcome data, measurement of the outcome and selection of the reported result. All non-randomised studies were appraised with ROBINS-I, with particular emphasis on bias due to confounding, because allocation to laparotomy or to non-operative management in these cohorts is determined by the same physiological variables that determine survival. For each non-randomised study the pre-specified critical confounders were admission systolic blood pressure, injury severity score, organ injury grade, age and the presence of significant extra-abdominal injury; a study was rated at low risk in the confounding domain only if all five were accounted for by design, matching, propensity scoring or entropy balancing. Ratings were made independently in duplicate and are displayed both as a traffic-light plot (Figure 2A) and as a domain-level summary (Figure 2B), with the underlying judgements tabulated in Tables 4 and 5.^{9,18,20,23}

Risk of bias within studies

Six of the twenty-seven studies were judged at overall low risk of bias: the randomised trial, and five registry or multicentre analyses in which propensity scoring, entropy balancing or inverse probability weighting accounted for all five pre-specified critical confounders. Eighteen studies were rated at moderate overall risk, almost invariably because allocation to laparotomy or to non-operative management was decided by the treating clinician on the basis of the same physiological variables that determine survival, and adjustment for those variables was incomplete. Three studies were rated at serious risk: two very small single-centre series in which fewer than fifty patients were analysed without adjustment, and one in which the operative cohort was assembled from patients considered too unstable to transfer, an allocation rule that makes any comparison with a non-operative group uninterpretable. No study was excluded on the basis of its risk-of-bias rating; instead, ratings were used to weight the narrative synthesis and to inform the GRADE assessment.^{4,18,20,21,23,25}



Figure 1. Traffic-light plot of risk-of-bias judgements. The randomised trial was appraised with Cochrane RoB 2; all other studies were appraised with ROBINS-I. D1 corresponds to bias due to confounding (ROBINS-I) or to the randomisation process (RoB 2).

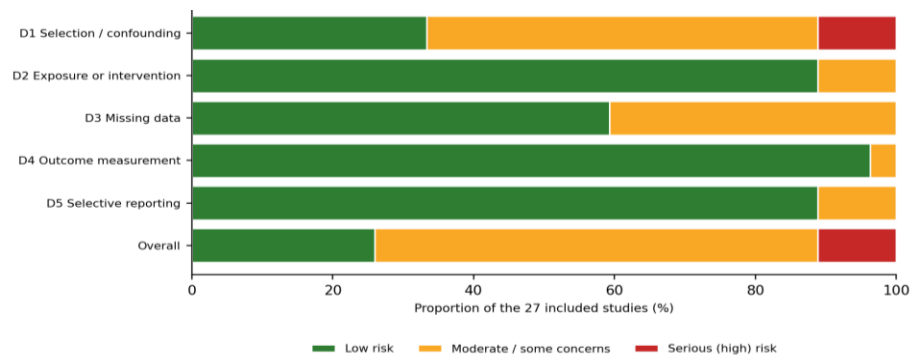


Figure 2. Weighted domain-level summary. The confounding domain is the principal source of residual bias in this literature; measurement of the outcome, which is almost always mortality obtained from a registry or medical record, is at low risk throughout.

Table 2. ROBINS-I risk-of-bias assessment of the 26 non-randomised studies

Study	D1 Confounding	D2 Selection of participants	D3 Missing data	D4 Measurement of outcome	D5 Selection of reported result	Justification for the overall judgement
Croce 1995	Moderate	Low	Low	Low	Low	Haemodynamic matching of the operative control cohort mitigates but does not remove confounding by indication
Farahmand 2005	Moderate	Low	Moderate	Low	Low	Composite reference

						standard varied between patients; verification bias possible
Lee BC 2007	Moderate	Low	Moderate	Low	Low	Retrospective registry abstraction; operator experience with sonography not characterised
Lund 2011	Serious	Moderate	Moderate	Low	Moderate	Only 44 patients; no adjustment; selection restricted to those judged untransportable
Raza 2013	Moderate	Low	Low	Low	Low	Groups defined by clinician judgement; injury grade not uniformly reported
Groven	Moderate	Low	Low	Low	Low	Era effect

2014						confounded with the introduction of a formal trauma service
Wang 2014	Moderate	Low	Moderate	Low	Low	Single-arm damage-control cohort; no non-operative comparator; strict exclusions limit generalisability
Musiitwa 2014	Low	Low	Moderate	Low	Low	Prospective consecutive enrolment; some patients lost before definitive reference standard
Olthof 2016	Low	Low	Low	Low	Low	Propensity-score stratification across five

						centres addresses the principal confounders
Harvin 2017	Moderate	Low	Low	Low	Low	Descriptive multicentre cohort without a non-operative comparator arm
Rowell 2019	Low	Low	Moderate	Low	Low	Prospective parent study; sonography performed pragmatically with variable operator training
El-Menyar 2020	Moderate	Low	Low	Low	Low	Retrospective derivation; internal bootstrap validation only
Nijdam 2020	Moderate	Low	Moderate	Low	Low	Small high- grade subgroup (n = 28); allocation

						entirely by clinician judgement
Davis 2021	Moderate	Low	Low	Low	Low	Single-centre; predominantly penetrating mechanism, limiting direct transfer to blunt practice
Murao 2021	Moderate	Low	Low	Low	Low	Time intervals are themselves influenced by patient physiology (reverse causation possible)
Lin 2022	Moderate	Low	Moderate	Low	Low	Fifteen-year span with substantial secular change in practice and in organ-injury grading
Balch 2023	Serious	Moderate	Moderate	Low	Moderate	Thirteen patients per

						arm; baseline systolic pressure markedly lower in the thoracotomy arm
Gendler 2024	Moderate	Low	Low	Low	Low	Registry linkage over 23 years; prehospital documentation incomplete in the earlier era
Suzuki 2024	Low	Low	Low	Low	Low	Propensity-score matching in a national registry with 377 well-balanced pairs
Lee YJ 2024	Serious	Moderate	Moderate	Low	Moderate	Only six emergency-department laparotomies; allocation determined by inability to

						transfer
Cho 2025	Moderate	Low	Low	Low	Low	Prognostic accuracy study; transfusion practice not standardised across the study period
El-Menyar 2025	Low	Low	Low	Low	Low	Prospective consecutive enrolment with pre-specified thresholds and complete follow-up
Huang 2025	Low	Low	Low	Low	Low	Large registry with multivariable Cox modelling and pre-specified isolated-injury definition
Park 2025	Low	Low	Low	Low	Low	Inverse probability of treatment weighting with

						adjudicated cause of death
Sampayo-Candia 2025	Moderate	Low	Moderate	Moderate	Low	Eighty-three patients with thirty-nine events; frequency matching only; no external validation
Schaid 2025	Low	Low	Low	Low	Low	Entropy balancing on all pre-specified confounders in a nationally representative dataset

D1 = bias due to confounding; D2 = bias in selection of participants into the study and in classification of the intervention; D3 = bias due to missing data; D4 = bias in measurement of outcomes; D5 = bias in selection of the reported result. A rating of Low in D1 required that admission systolic blood pressure, Injury Severity Score, organ injury grade, age and significant extra-abdominal injury were all accounted for by design or analysis.

Table 3. Cochrane RoB 2 assessment of the single included randomised controlled trial

RoB 2 domain	Judgement	Supporting rationale
Randomisation process	Low risk	Multicentre randomisation with allocation concealment; baseline characteristics balanced across the two arms

Deviations from intended interventions	Low risk	Analysis performed according to the assigned strategy; cross-over from surveillance to embolisation was a protocol-defined component of the comparator, not a deviation
Missing outcome data	Low risk	The primary endpoint of one-month splenic salvage was ascertained in essentially all randomised participants
Measurement of the outcome	Low risk	Splenic salvage is an objective radiologically and operatively verifiable endpoint, insensitive to assessor knowledge of allocation
Selection of the reported result	Low risk	Pre-registered protocol with a pre-specified primary endpoint and analysis plan
OVERALL	Low risk of bias	The trial is methodologically sound but is INDIRECT for the present review question, since haemodynamically unstable patients were not eligible for enrolment; it therefore informs the embolisation debate without answering the operative-versus-non-operative question in shock

Synthesis methods

The included studies differed substantially in the definition of instability, in case mix, in era and in the comparator against which the operative strategy was measured. Statistical pooling of mortality across such heterogeneous designs would have produced a spuriously precise estimate dominated by confounding by indication, and it was therefore not performed; this decision was taken a priori and is restated here for transparency. Instead, effect estimates were tabulated by outcome domain, adjusted estimates with their confidence intervals were displayed on a common logarithmic scale in a forest plot (Figure 6), and diagnostic-accuracy data were displayed as receiver-operating-characteristic curves and operating points (Figures 3 and 4). Where curves are drawn from reported areas under the curve, a binormal model with equal variances was used to reconstruct a curve reproducing the published area exactly, and this derivation is stated in the figure

legend. Statistical significance was taken at a two-sided α of 0.05 or a confidence interval excluding the null value.^{20,21,24}

Certainty of evidence

Certainty was rated by outcome domain using the GRADE approach. Observational evidence began at low certainty and was downgraded for risk of bias, inconsistency, indirectness, imprecision or suspected publication bias, and could be upgraded for a large magnitude of effect, a dose–response gradient or where plausible residual confounding would act to reduce rather than to inflate the observed effect. The dose–response relationship between the depth of hypotension and mortality, and between delay to operation and haemorrhagic death, were both judged to warrant upgrading. The resulting summary-of-findings table appears as Table 19.^{4,10,25}

Protocol deviations

Three deviations are declared. First, a single study of penetrating abdominal trauma is presented alongside the blunt-trauma data in the domain concerned with timing of operation, because it provides the only contemporary adjusted estimate for the effect of operative timing derived from a national quality-improvement dataset; it is explicitly labelled throughout and is not pooled with, or allowed to influence, any blunt-trauma conclusion. Second, studies of aortic occlusion and of the hybrid emergency room were admitted because they address the same clinical decision point, namely how haemorrhage control is achieved in the patient who cannot be moved safely to a conventional operating theatre. Third, one study enrolling patients aged 15 years and above was retained rather than excluded as paediatric, since fewer than 2% of its cohort were below 16 years.^{18,25,28}

RESULTS

Characteristics of the included studies

The included studies span thirty-one years of practice up to 2026) and eleven countries across four continents, and encompass single-centre series, multicentre consortia and three of the largest trauma registries in the world — the American College of Surgeons Trauma Quality Improvement Program, the Japan Trauma Data Bank and the Israel Defence Forces trauma registry. Sample sizes ranged from twenty-six to 7,567 patients. Definitions of haemodynamic instability

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were heterogeneous: fourteen studies used an admission or pre-intervention systolic pressure below 90 mmHg, four used the response to a fluid or blood challenge to distinguish responders from transient responders and non-responders, two used a shock index of 1.0 or greater, and the remainder used composite physiological definitions incorporating heart rate and early transfusion. Full characteristics are tabulated in Table 3.^{5,10,15,19,20,23}

Table 4. Characteristics of the 27 included primary studies

N o	Author, year, country	Design	Setting and period	Sample size (unstable subgroup)	Definition of haemodyna mic instability	Strategies compared	Principal outcomes reported
1	Croce et al., 1995, USA	Prospective cohort with haemodynamically matched operative controls	Level I trauma centre, 22 months	112 managed non-operatively plus matched operative control cohort	Unstable patients proceeded directly to laparotomy; only stable patients underwent computed tomography	Non-operative management versus coeliotomy for blunt hepatic injury	Failure of non-operative management 11%; liver-related failure 5%; transfusion 1.9 versus 4.0 units (p < 0.02); abdominal complications 3% versus 11%; admission

							systolic pressure 127 versus 104 mmHg in successes versus failures (p < 0.04)
2	Farahm and et al., 2005, USA	Prospective diagnostic-accuracy study	Level I trauma centre	128 hypotensive patients	Hypotension on arrival after blunt abdominal trauma	Screening ultrasonography against a composite reference standard including laparotomy and autopsy	Sensitivity 85% for any injury, 97% for surgical injury, 100% for fatal injury; specificity 96%, 82% and 69% respectively; accuracy 91%, 86% and 71%
3	Lee et al., 2007, USA	Retrospective diagnostic cohort	Level I trauma centre, 6 years	4,029 total; 122 hypotensive on arrival	Hypotension on arrival	Sonography-directed triage to exploratory laparotomy	In hypotensive patients sensitivity 85%,

						versus computed tomography	specificity 60%, accuracy 77%; 69 of 87 sonography- positive hypotensive patients (79%) went directly to laparotomy without computed tomography
4	Lund et al., 2011, Denmar k	Retrospectiv e cohort	Universit y hospital, emergenc y-room laparoto my program me	44 unstable patients (all)	Haemodyna mic instability with abdominal or suspected abdominal injury	Emergency- room laparotomy	Survival at 24 hours 64%, 50% and 34% for systolic pressure >80, 61–80 and ≤60 mmHg (p = 0.04); 30- day survival 20% at ≤60

							mmHg; blunt versus penetrating survival at ≤60 mmHg 13% versus 60%
5	Raza et al., 2013, Oman	Retrospective cohort	National trauma centre, 11 years	1,285 with abdominal injury; 214 unstable operated immediately	Non-response to resuscitation on admission, or evidence of hollow-viscus injury	Non-operative management (n = 1,071) versus immediate laparotomy (n = 214)	Non-operative management succeeded in 963 of 1,071 (89.9%); failure requiring laparotomy in 108 (10.1%); failure driven by ongoing haemorrhage, delayed hollow-viscus perforation and intra-

							abdominal infection
6	Groven et al., 2014, Norway	Retrospective cohort with risk-adjusted survival analysis	Level I trauma centre, 8 years (2002–2009)	955 patients with abdominal injury; 167 laparotomies analysed separately	Institutional criteria for immediate laparotomy in the unstable patient	Operating-room laparotomy versus emergency-department laparotomy versus non-operative management, before and after formal trauma service	Variable life-adjusted display showed improved risk-adjusted survival after institution of a formal trauma service; declining emergency-department laparotomy rate without increased mortality
7	Wang et al., 2014, Taiwan	Retrospective cohort with prediction model	Level I trauma centre, 10.5 years (2002–	91 exsanguinating patients	Haemorrhagic shock requiring damage-control laparotomy	Damage-control laparotomy (no non-operative comparator)	Overall mortality 61.5% (56 of 91); independent survival

			2012)				predictors were pre-operative Glasgow Coma Scale below 8 and base excess; nomogram derived for survival prediction
8	Musiitwa et al., 2014, Uganda	Prospective observational diagnostic study	Tertiary teaching hospital	195 patients	Shock assessed clinically together with sonographic haemoperitoneum	SSORTT score versus standard of care for predicting therapeutic laparotomy	SSORTT score >2: sensitivity 90%, specificity 90%, positive predictive value 53%, negative predictive value 98%; overall mortality 17%
9	Olthof	Multicentre	Five	Adults	Patients	Observation	Splenic

	et al., 2016, Netherl ands	cohort with propensity- score stratification	level I trauma centres, 2009– 2012	with blunt splenic injury selected for non- operative managem ent	selected for non- operative management ; unstable patients treated operatively	alone versus splenic artery embolisation	salvage without re- intervention as the success criterion; propensity- weighted relative risk reported for embolisation versus observation
1 0	Harvin et al., 2017, USA	Retrospectiv e multicentre cohort	12 level I trauma centres, 2012– 2013	1,706 emergent laparotom ies; 207 hypotensi ve	Arrival systolic pressure ≤ 90 mmHg	Emergent trauma laparotomy within 90 minutes of arrival (67% blunt)	Mortality 21% overall and 46% in hypotensive patients; haemorrhage caused 60% of deaths; median time to death 4 hours; damage- control laparotomy

							in 62% of hypotensive versus 31% of normotensive patients (p < 0.001)
1 1	Rowell et al., 2019, USA	Prospective multicentre cohort (secondary analysis of PROMMTT)	10 level I trauma centres	317 hypotensive patients undergoing sonography	Systolic pressure <90 mmHg	Sonography compared against operative findings at therapeutic laparotomy within 6 hours	Sensitivity 62% and specificity 83% for therapeutic laparotomy; therapeutic laparotomy performed in 69% of sonography-positive but also in 22% of sonography-negative patients
1 2	Arvieux et al., 2020,	Multicentre randomised controlled	16 centres	140 randomised	Patients at high risk of splenectomy;	Prophylactic splenic arterial	One-month splenic salvage as

	France (SPLASH trial)	trial			haemodynamically unstable patients were not eligible	embolisation versus surveillance with embolisation only if required	the primary endpoint; provides the only randomised evidence on embolisation strategy but does not address the unstable population
13	El-Menyar et al., 2020, Qatar	Retrospective cohort, score derivation with bootstrap validation	Level I trauma centre, 2014–2017	1,199 patients with abdominal trauma	Shock index stratified 0.50–0.69 to ≥ 0.90 as a score component	FASILA score (sonography, shock index, lactate) versus ABC, RABT and shock index alone	Area under the curve 0.81 (95% CI 0.78–0.84; p = 0.001) at a cut-off of 4.5, specificity 97%, positive predictive value 90%; proportion undergoing

							exploratory laparotomy rose from 24% to 85% between scores of 4 and 6
14	Nijdam et al., 2020, Netherlands	Retrospective cohort	Level I trauma centre, 2012–2017	123 splenic injuries; 28 high grade	Persistent haemodynamic instability after resuscitation	Splenectomy versus spleen-preserving management	Splenectomy required in 15 of 28 high-grade injuries (53.6%), all of whom remained unstable after resuscitation, including every grade V injury; 13 high-grade injuries treated with spleen preservation
1	Davis et	Retrospective	Level I	1,174	Arrival	Trauma	Mortality

5	al., 2021, USA	e cohort	trauma centre	laparotom ies; 425 with systolic pressure <90 mmHg (36%)	systolic pressure <90 mmHg	laparotomy stratified by degree of hypotension	related to the depth of hypotension; time from arrival to laparotomy 42 minutes in hypotensive versus 50 minutes in normotensiv e patients (p < 0.001); emergency- department stay 44 minutes
1 6	Murao et al., 2021, Japan	Retrospectiv e cohort with non-linear regression	Single centre	671 severe blunt trauma; 163 underwent emergenc y bleeding control	Injury Severity Score >16 with need for emergency haemorrhage control	Door-to- computed- tomography and door-to- bleeding- control intervals	Median door-to- computed- tomography 19 minutes and door-to- bleeding- control 57 minutes;

							association between these intervals and mortality and functional outcome modelled non-linearly
17	Lin et al., 2022, Taiwan	Retrospective observational cohort	Level I centre with 24-hour in-house surgery and interventional radiology, 15 years	680 blunt splenic injuries	Arrival hypotension refractory to resuscitation mandated surgery	Observation (n = 294) versus splenic artery embolisation (n = 234) versus surgery (n = 152)	Progressive shift towards embolisation over time with increased splenic salvage; injuries graded by the revised 2018 AAST organ injury scale
18	Balch et al., 2023,	Retrospective cohort	Level I centre with	26 patients (13 versus	Systolic pressure <90 mmHg	Zone 1 resuscitative endovascular	Haemorrhage control achieved in

	USA		dedicated trauma hybrid operating room	13)	refractory to volume resuscitation	balloon occlusion versus resuscitative thoracotomy	77% versus 8% (p = 0.001); survival to discharge greater after endovascular occlusion; neurological status at discharge reported
19	Gendler et al., 2024, Israel	Retrospective cohort linking prehospital and hospital registries	Military–civilian integrated system, 1997–2020	217 casualties undergoing trauma laparotomy	Prehospital physiological derangement and shock	Trauma laparotomy; prehospital measures analysed as exposures	In-hospital mortality 15.2%; prehospital variables associated with mortality identified
20	Suzuki et al., 2024, Japan	Retrospective propensity-score-matched cohort (Japan	National registry, 2004–2019	2,192 patients; 377 matched pairs	Registry-recorded haemodynamic variables used in the propensity	Splenic artery embolisation versus open surgery	In-hospital mortality 11.6% versus 11.2% (adjusted

		Trauma Data Bank)			model		relative risk 0.64, 95% CI 0.38–1.09; p = 0.10); spleen salvage 87.1% versus 32.1% (adjusted relative risk 2.84, 95% CI 2.29–3.51; p < 0.001)
21	Lee YJ et al., 2024, South Korea	Retrospective cohort	Regional trauma centre	6 emergency-department laparotomies within a larger series	Instability precluding safe transfer to the operating theatre	Emergency-department damage-control laparotomy	Survival 33.3%; only patients whose mesenteric bleeding was controlled by ligation survived
22	Cho and Park,	Retrospective	Regional trauma	2,404 patients	Shock index as a	Shock index as a predictor	Area under the curve for

	2025, South Korea	observational cohort	centre, 2019– 2023	(1,531 younger, 873 older)	continuous measure of circulatory compromise	of massive transfusion, stratified by age	massive transfusion 0.801 in adults under 65 years versus 0.666 in those 65 years or older (p < 0.001)
2 3	El- Menyar et al., 2025, Qatar	Prospective validation cohort	Level I trauma centre, 2022– 2024	400 patients (96% blunt)	Shock index component of the FASILA score	FASILA score <4 versus ≥4 for prediction of laparotomy, massive transfusion and death	FASILA ≥4: specificity 85.5% and negative predictive value 80% for the need for surgery; independent predictor of transfusion (odds ratio 1.92, 95% CI 1.43– 2.58); outperformed the ABC

							score and shock index alone
24	Huang et al., 2025, USA	Retrospective cohort (ACS Trauma Quality Improvement Program)	>815 centres, 2017–2022	7,567 patients with isolated severe blunt splenic injury; 1,499 open splenectomy	Includes patients hypotensive on admission, analysed as a pre-specified subgroup	Open splenectomy versus splenic angioembolisation versus observation	Non-operative management associated with favourable mortality and complication profile compared with surgery, including in patients hypotensive on admission
25	Park et al., 2025, South Korea	Retrospective multicentre cohort with segmented regression and inverse	Two level I trauma centres, 2016–2023	414 emergency laparotomies	Abdominal trauma with haemorrhage requiring emergency laparotomy	Effect of emergency-department-to-operating-room interval and	Haemorrhagic death in 71 of 414 (17.1%); each additional

		probability weighting				of pre-operative computed tomography	minute of delay raised the adjusted odds of haemorrhagic death by 1.8% (adjusted odds ratio 1.018, 95% CI 1.007–1.030)
26	Sampayo-Candia et al., 2025, Mexico	Retrospective observational study with internal bootstrap validation	Trauma and orthopaedic hospital, 2022–2024	83 patients (39 operative, 44 non-operative)	Physiological and biochemical derangement at admission analysed continuously	Operative management within 24 hours versus non-operative management	Lactate area under the curve 0.8152 (95% CI 0.7209–0.9095; $p < 0.0001$); base excess 0.7544; pH 0.7390; bicarbonate 0.7170; heart rate 0.7264; systolic

							pressure 0.6632; four-variable model 0.904, optimism- corrected 0.882; non- operative management succeeded in 44 of 44
2 7	Schaid et al., 2025, USA	Retrospectiv e observational cohort with entropy balancing (Trauma Quality Improvement Program)	448 centres, 2017– 2022	1,360 patients, all hypotensive on arrival	Arrival systolic blood pressure <90 mmHg	Angioembolisation first (n = 328) versus splenectomy first (n = 1,032), each within 6 hours of arrival after computed tomography	Entropy- balanced hazard ratio for death 1.02 (95% CI 0.97– 1.07; p = 0.49); approximately one fifth of the angioembolisation group required rescue

							splenectomy within 6 hours, predominantly grade V injuries with additional abdominal injury
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AAST = American Association for the Surgery of Trauma; CI = confidence interval; PROMMTT = Prospective Observational Multicenter Major Trauma Transfusion study; SSORTT = Sonography and Shock in the Operative Room Triage Tool.

In-hospital and short-term mortality

Mortality after emergent trauma laparotomy in a contemporary twelve-centre American cohort was 21% overall and 46% among patients hypotensive on arrival, a figure essentially unchanged from that reported two decades earlier despite the intervening introduction of massive transfusion protocols, damage-control resuscitation and endovascular adjuncts. Mortality rose steeply with the intensity of the operative strategy required: damage-control laparotomy for exsanguinating blunt abdominal trauma carried a mortality of 61.5%, and emergency-department laparotomy performed because the patient could not safely be transferred to theatre was associated with survival of only 33.3%. Where the comparison was made in the opposite direction — against a non-operative strategy — the picture inverts, but only because the populations differ: non-operative management succeeded in 89.9% of an Omani cohort selected for it, in 100% of a matched Mexican cohort, and, in the largest registry analysis available, was associated with a more favourable mortality and complication profile than open splenectomy even among patients hypotensive on admission. Critically, when hypotensive patients with high-grade splenic injury were compared directly after entropy balancing, angioembolisation and splenectomy produced statistically

indistinguishable survival (hazard ratio 1.02, 95% confidence interval 0.97–1.07; $p = 0.49$).^{5,7,10,21,24,26,27}

Table 5. Mortality by study, strategy and haemodynamic status

Study	Strategy evaluated	Sample	Mortality or survival	Comparative statistic
Harvin 2017	Emergent trauma laparotomy ≤ 90 min	1,706 (207 hypotensive)	21% overall; 46% if hypotensive	Blunt 12% versus penetrating 37% ($p < 0.001$)
Davis 2021	Trauma laparotomy	1,174 (425 hypotensive)	Mortality rose with depth of hypotension	Hypotension prevalence 36%; time to laparotomy shorter in hypotensive patients ($p < 0.001$)
Lund 2011	Emergency-room laparotomy	44 (all unstable)	24-hour survival 64% / 50% / 34%; 30-day survival 20% at systolic ≤ 60 mmHg	$p = 0.04$ across strata
Wang 2014	Damage-control laparotomy	91	Mortality 61.5%	Glasgow Coma Scale < 8 and base excess independently predicted death
Park 2025	Emergency laparotomy	414	Haemorrhagic death 17.1% (71 of 414)	Adjusted odds ratio 1.018 per minute of delay (95% CI 1.007–1.030)
Gendler 2024	Trauma laparotomy	217	In-hospital mortality 15.2%	Prehospital physiology associated with mortality
Lee YJ	Emergency-	6	Survival 33.3%	Only mesenteric bleeding

2024	department laparotomy			controlled by ligation survived
Musiitwa 2014	Mixed operative and non-operative	195	Overall mortality 17%	SSORTT >2 identified the operative group
Schaid 2025	Angioembolisation first versus splenectomy first (all hypotensive)	1,360	Statistically indistinguishable survival	Entropy-balanced hazard ratio 1.02 (95% CI 0.97– 1.07); p = 0.49
Suzuki 2024	Splenic artery embolisation versus open surgery	377 matched pairs	11.6% versus 11.2%	Adjusted relative risk 0.64 (95% CI 0.38–1.09); p = 0.10
Huang 2025	Splenectomy versus embolisation versus observation	7,567	Non-operative management favourable, including in patients hypotensive on admission	Multivariable Cox proportional hazards analysis
Raza 2013	Non-operative management versus immediate laparotomy	1,285	Non-operative success 89.9%	Failure requiring laparotomy 10.1%
Croce 1995	Non-operative management versus coeliotomy (liver)	112 plus matched controls	Failure of observation 11%; liver-related failure 5%	Fewer transfusions (1.9 versus 4.0 units; p < 0.02) and fewer abdominal complications

				(3% versus 11%)
Balch 2023	Endovascular aortic occlusion versus resuscitative thoracotomy	26	Survival to discharge greater after endovascular occlusion	Haemorrhage control 77% versus 8% (p = 0.001)
Sampayo-Candia 2025	Operative versus non-operative management	83	Non-operative management succeeded in 44 of 44	Operative group had significantly higher lactate and heart rate and lower pH, bicarbonate, base excess and systolic pressure

CI = confidence interval. Direct mortality comparison between operative and non-operative strategies is confounded by indication in every non-randomised study: the sickest patients are preferentially operated upon, which biases crude comparisons in favour of non-operative management.

Cause and timing of death

Death after blunt abdominal trauma with instability is early and haemorrhagic. In the largest laparotomy cohort, haemorrhage accounted for 60% of all deaths, the median interval from arrival to death was four hours, 76% of deaths occurred within the first day, and more than half of those occurred within two hours. In the hypotensive subgroup the compression is more extreme still: haemorrhage caused 65% of deaths, the median time to death was three hours, 82% of deaths occurred within twenty-four hours and 59% within two hours of arrival. Adjudicated cause-of-death analysis in a two-centre Korean cohort attributed 17.1% of all deaths after emergency laparotomy specifically to haemorrhage. The therapeutic window in which any strategy — operative or endovascular — can alter the outcome is therefore measured in tens of minutes, and this single observation constrains the interpretation of every other outcome domain in this review.^{10,25}

Table 6. Cause of death and temporal distribution of mortality

Study	Cohort	Deaths attributable to haemorrhage	Median time to death	Temporal distribution
Harvin 2017 (whole cohort)	1,706 emergent laparotomies	60% of all deaths	4 hours (interquartile range 2–33)	76% of deaths within 24 hours; more than 50% of those within the first 2 hours
Harvin 2017 (hypotensive subgroup)	207 patients with systolic pressure ≤ 90 mmHg	65% of all deaths	3 hours (interquartile range 1–8)	82% of deaths within 24 hours; 59% within 2 hours of arrival
Park 2025	414 emergency laparotomies	71 of 414 patients (17.1%) died of haemorrhage after multidisciplinary adjudication	Not reported	Segmented regression identified a threshold beyond which delay sharply increased haemorrhagic mortality
Wang 2014	91 exsanguinating patients after damage-control laparotomy	Predominantly exsanguination and its metabolic sequelae	Not reported	Overall mortality 61.5%, concentrated in the early post-operative period
Lund 2011	44 unstable patients	Not separately adjudicated	Not reported	Survival fell from 34% at 24 hours to 20% at 30 days in the systolic ≤ 60

				mmHg stratum
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Mortality gradient by depth of hypotension

The relationship between admission blood pressure and death is graded rather than dichotomous, which is a point of considerable practical consequence because guidelines are written around a single threshold of 90 mmHg. In the Danish emergency-room laparotomy series, twenty-four-hour survival fell in an ordered fashion from 64% in patients arriving above 80 mmHg, to 50% between 61 and 80 mmHg, to 34% at or below 60 mmHg, and this trend was statistically significant ($p = 0.04$); by thirty days, survival in the lowest stratum had fallen to 20%. The mechanism of injury modified this gradient sharply, with survival after laparotomy at systolic pressures at or below 60 mmHg of 60% for penetrating injury but only 13% for blunt injury, a disparity that reflects the multiplicity and diffuseness of bleeding sources in blunt trauma. A large American series confirmed that mortality in hypotensive patients requiring laparotomy relates to the degree of hypotension and used that observation to argue for physiologically targeted rather than threshold-triggered interventions. The presence of a dose–response gradient of this kind was one of the two grounds on which observational certainty was upgraded under GRADE.^{4,15}

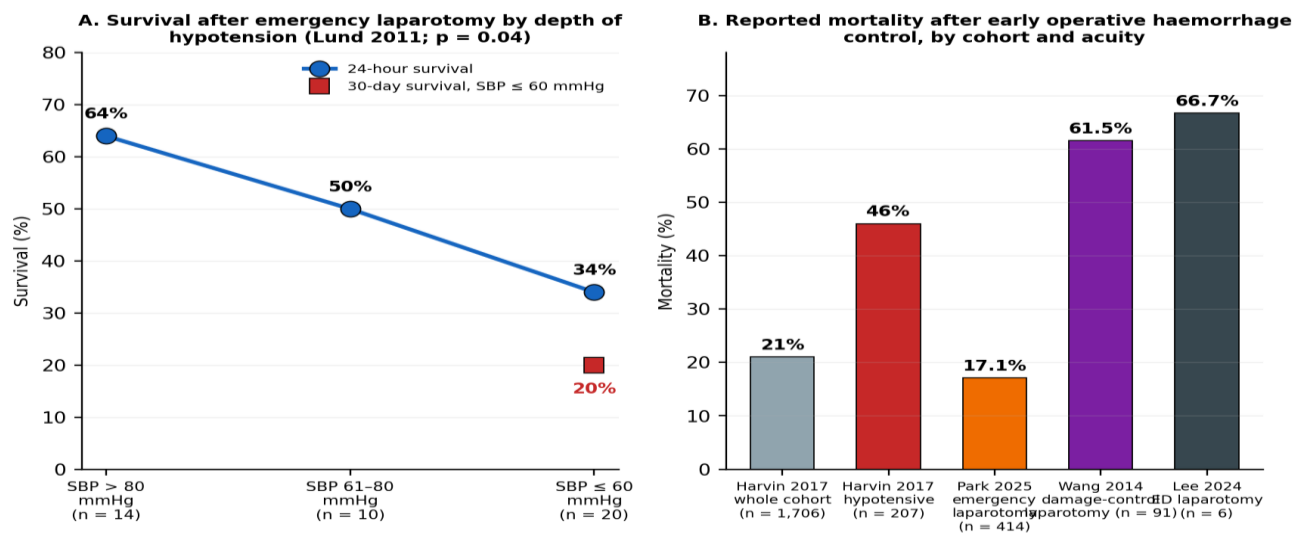


Figure 3 Panel A shows the stepwise fall in survival with the depth of hypotension in patients undergoing emergency-room laparotomy. Panel B places reported mortality from five operative

cohorts side by side; the cohorts are not directly comparable in case mix and are displayed to illustrate the range rather than to support a pooled estimate.

Table 7. Survival stratified by admission systolic blood pressure

Stratum	Study	24-hour survival	30-day survival	Interpretation
Systolic pressure >80 mmHg	Lund 2011 (n = 14)	64%	Not separately reported	Physiological reserve preserved; conventional operative pathway appropriate
Systolic pressure 61–80 mmHg	Lund 2011 (n = 10)	50%	Not separately reported	Intermediate stratum in which transfer to a conventional theatre may still be feasible
Systolic pressure ≤60 mmHg	Lund 2011 (n = 20)	34%	20%	Profound shock; survival halves again between 24 hours and 30 days
Blunt versus penetrating at ≤60 mmHg	Lund 2011	Not applicable	13% versus 60%	Blunt mechanism carries a markedly worse prognosis at any given pressure
Systolic pressure ≤90 mmHg versus normotensive	Harvin 2017 (n = 207 versus 1,499)	Not applicable	46% versus overall cohort mortality of 21%	Hypotension on arrival more than doubles the risk of death after emergent laparotomy

Systolic pressure <90 mmHg	Davis 2021 (n = 425 of 1,174)	Not applicable	Mortality graded by depth of hypotension	Supports identification of a pressure threshold below which focused interventions should be triggered
Trend across all strata	Lund 2011	p = 0.04	—	Statistically significant dose–response gradient (GRADE upgrade criterion met)

Failure of non-operative management and rescue laparotomy

Failure of non-operative management is the outcome that determines whether the strategy is safe, and the reported rates are remarkably consistent across three decades and four continents. In a prospective liver-injury cohort, twelve of 112 patients (11%) failed observation, but only five (5%) failed for liver-related reasons, the remainder failing because of an unrecognised extrahepatic injury; admission systolic pressure was the only variable that separated successes from failures (127 versus 104 mmHg; $p < 0.04$). In the largest single-institution non-operative series, 108 of 1,071 patients (10.1%) required laparotomy for ongoing haemorrhage, delayed hollow-viscus perforation or intra-abdominal infection, leaving a success rate of 89.9%. In the highest-acuity population studied — hypotensive patients with grade IV or V splenic injury treated with angioembolisation first — approximately one fifth required rescue splenectomy within six hours, and those failures were concentrated among grade V injuries with additional intra-abdominal injury. Crucially, survival after failed angioembolisation, although worse than after successful angioembolisation, was not worse than after upfront splenectomy, which means that the attempt at salvage did not cost lives in that dataset.^{1,5,27}

Table 8. Failure of non-operative management, its causes and consequences

Study	Population	Success rate	Failure rate	Causes of failure and consequence
Croce 1995	Blunt hepatic injury, haemodynamically stable	89%	11% (12 of 112)	Liver-related failure only 5%; the remaining 6% failed for non-hepatic reasons; admission systolic pressure 127 versus 104 mmHg in successes versus failures (p < 0.04)
Raza 2013	Blunt abdominal solid-organ injury selected for observation	89.9% (963 of 1,071)	10.1% (108 of 1,071)	Ongoing haemorrhage, delayed hollow-viscus perforation, intra-abdominal infection; a further 214 patients were unstable on admission and were operated upon immediately without a trial of observation
Schaid 2025	Hypotensive patients with grade IV–V splenic injury, angioembolisation first	Approximately 80%	Approximately 20% required rescue splenectomy within 6 hours	Failures concentrated in grade V injuries with additional abdominal injuries; survival after failed embolisation was worse than after successful embolisation but NOT worse than after upfront

				splenectomy
Suzuki 2024	Blunt splenic injury, national registry	Splenic salvage 87.1% after embolisation	Salvage failure 12.9%	Comparator open surgery achieved salvage in only 32.1%
Nijdam 2020	High-grade blunt splenic injury (n = 28)	46.4% managed with spleen preservation	53.6% required splenectomy	Every patient requiring splenectomy remained haemodynamically unstable after resuscitation, and all grade V injuries required splenectomy
Lin 2022	Blunt splenic injury over 15 years (n = 680)	Observation in 294 and embolisation in 234 (77.6% managed without operation)	Surgery in 152 (22.4%)	Patients arriving hypotensive and refractory to resuscitation were taken directly to surgery by protocol
Sampayo-Candia 2025	Blunt abdominal trauma selected for observation (n = 44)	100%	0%	Selection was tight: the operative group had significantly higher lactate and heart rate and lower pH, bicarbonate and base excess

Organ salvage

Organ preservation is the domain in which non-operative management demonstrates its clearest and most statistically robust advantage. In a propensity-matched national registry analysis of 377 pairs, splenic salvage was achieved in 87.1% of patients undergoing embolisation compared with 32.1% of those undergoing open surgery, an adjusted relative risk of 2.84 (95% confidence interval 2.29–3.51; $p < 0.001$), while in-hospital mortality did not differ. This is the single largest and most precise effect estimate in the entire review, and its confidence interval excludes unity by a wide margin. The clinical significance of that difference is not cosmetic: the spleen is central to opsonisation of encapsulated organisms, and splenectomy commits the patient to lifelong vaccination requirements and a persistent risk of overwhelming post-splenectomy infection. Against this, the anatomical limits of salvage are equally clear: every grade V splenic injury in a Dutch high-grade cohort required splenectomy, and each of those patients had remained unstable after resuscitation.^{14,20}

Table 9. Organ salvage after operative and non-operative strategies

Study	Comparison	Salvage with non-operative or endovascular strategy	Salvage with operative strategy	Effect estimate and significance
Suzuki 2024	Splenic artery embolisation versus open surgery, 377 matched pairs	87.1%	32.1%	Adjusted relative risk 2.84 (95% CI 2.29–3.51); $p < 0.001$ — STATISTICALLY SIGNIFICANT
Nijdam 2020	Spleen-preserving management versus splenectomy in	13 of 28 (46.4%)	Splenectomy in 15 of 28 (53.6%)	All splenectomies were performed in patients who remained unstable after resuscitation; all

	high-grade injury (n = 28)			grade V injuries required splenectomy
Lin 2022	Observation versus embolisation versus surgery (n = 680)	Progressive rise in salvage with increasing use of embolisation over 15 years	Surgery in 152 patients	Descriptive trend analysis; injuries graded by the revised 2018 organ injury scale
Olthof 2016	Observation versus embolisation, propensity- stratified	Splenic salvage without re- intervention used as the success criterion	Not applicable (both arms non-operative)	Weighted relative risk reported; contemporaneous rather than historical controls
Schaid 2025	Angioembolisation first versus splenectomy first in hypotensive patients	Approximately 80% retained the spleen at 6 hours	0% by definition	Attempt at salvage did not compromise survival (hazard ratio 1.02, 95% CI 0.97– 1.07)
Arvieux 2020 (RCT)	Prophylactic embolisation versus surveillance in patients at high risk of splenectomy	One-month splenic salvage was the pre- specified primary endpoint	Not applicable	Randomised evidence, but haemodynamically unstable patients were excluded from enrolment — indirect for this review

Transfusion and massive-transfusion requirement

Transfusion burden separates the two strategies more consistently than mortality does. In the prospective hepatic-injury comparison, patients managed without operation received a mean of 1.9

units of packed cells against 4.0 units in the haemodynamically matched operative cohort ($p < 0.02$), a statistically significant halving of exposure. Prospective validation of a composite bedside score showed that each additional point of the FASILA score independently raised the odds of requiring transfusion by 92% (odds ratio 1.92, 95% confidence interval 1.43–2.58) after adjustment for abdominal Abbreviated Injury Scale, Injury Severity Score, Sequential Organ Failure Assessment score and fibrinogen. In the derivation cohort of the same score, activation of the massive transfusion protocol rose from none to 68% and the proportion undergoing exploratory laparotomy climbed from 24% to 85% as the score increased from four to six, demonstrating that transfusion requirement and operative requirement are two expressions of the same underlying physiology rather than independent outcomes.^{1,13,23}

Table 10. Transfusion requirement and its predictors

Study	Comparison or exposure	Result	Statistical significance
Croce 1995	Non-operative management versus haemodynamically matched coeliotomy	1.9 versus 4.0 units of packed red cells	$p < 0.02$ — SIGNIFICANT in favour of non-operative management
El-Menyar 2025	FASILA score as a continuous predictor of transfusion	Odds ratio 1.92 per point (95% CI 1.43–2.58), adjusted for abdominal Abbreviated Injury Scale, Injury Severity Score, Sequential Organ Failure Assessment score and fibrinogen	SIGNIFICANT (confidence interval excludes unity)
El-Menyar 2020	FASILA score 4 through 6	Massive transfusion protocol activation rose	Area under the curve 0.81 (95% CI 0.78–0.84);

		from 0% to 68%; exploratory laparotomy rose from 24% to 85%	p = 0.001
Cho and Park 2025	Shock index as predictor of massive transfusion by age	Area under the curve 0.801 in adults under 65 years versus 0.666 at 65 years or older	p < 0.001 for the difference — SIGNIFICANT
Huang 2025	Splenectomy versus embolisation versus observation	Transfusion and complication burden lower with non-operative strategies	Multivariable Cox modelling; reported as favourable to non- operative management
Nasef 2026 (penetrating, contextual)	Endovascular balloon occlusion versus none	Additional 4,498 mL of transfusion (95% CI 1,966–7,030)	p < 0.001 — reflects the severity of shock in patients selected for the technique rather than harm caused by it

The penetrating-trauma study is displayed for context only, is explicitly labelled, and does not contribute to any conclusion drawn about blunt abdominal trauma.

Time to definitive haemorrhage control

Across every study that measured it, the interval to definitive haemorrhage control behaved as an independent determinant of survival, and it is the only modifiable variable in this review with a demonstrable, adjusted, statistically significant dose–response relationship to death. In a two-centre Korean analysis with adjudicated cause of death and inverse probability of treatment weighting, each additional minute between emergency department arrival and operating room entry raised the adjusted odds of haemorrhagic death by 1.8% (adjusted odds ratio 1.018, 95% confidence interval 1.007–1.030), which compounds to roughly a doubling of odds across an hour of delay. Contemporary benchmarks from high-performing centres show what is achievable: a median of

twenty-four minutes in the emergency department and forty-two minutes from arrival to surgical incision in a twelve-centre American cohort, and a median door-to-computed-tomography interval of nineteen minutes with door-to-bleeding-control of fifty-seven minutes in a Japanese hybrid-capable centre. Notably, hypotensive patients reached theatre faster than normotensive ones (42 versus 50 minutes; $p < 0.001$), confirming that triage systems already recognise and prioritise these patients, and that the residual delay is largely structural rather than diagnostic.^{10,15,16,25}

Table 11. Process intervals and their association with mortality

Study	Interval measured	Reported value	Association with outcome
Park 2025	Emergency department to operating room	Continuous, analysed per minute	Adjusted odds ratio 1.018 per minute for haemorrhagic death (95% CI 1.007–1.030) — SIGNIFICANT; segmented regression identified a threshold beyond which risk rose sharply
Harvin 2017	Time in emergency department; arrival to surgical start	24 minutes (interquartile range 14–39); 42 minutes (interquartile range 30–61)	Benchmark values from twelve level I centres; mortality remained 46% in hypotensive patients despite these intervals
Davis 2021	Arrival to start of laparotomy	42 minutes in hypotensive versus 50 minutes in normotensive patients	$p < 0.001$ — triage already prioritises the hypotensive patient; emergency department stay 44 minutes overall
Murao 2021	Door to computed tomography; door to bleeding control	Median 19 minutes and 57 minutes respectively	Non-linear multivariable modelling of the effect of these intervals on mortality and functional outcome in severe

			blunt trauma
Balch 2023	Time to aortic occlusion in a hybrid operating room	Not separately reported	Haemorrhage control achieved in 77% of endovascular versus 8% of thoracotomy cases ($p = 0.001$)
Nasef 2026 (penetrating, contextual)	Laparotomy within 2 hours versus 2–24 hours	Odds ratio 9.476 for 24-hour mortality (95% CI 1.276–70.397; $p = 0.028$)	Illustrates confounding by indication: patients operated fastest are those in extremis, so early operation appears harmful in unadjusted timing analyses

Intensive care and hospital length of stay

Length of stay was reported less consistently than mortality and, where reported, was strongly confounded by the burden of extra-abdominal injury. In the prospective hepatic comparison, hospital length of stay did not differ between the non-operatively managed patients and their haemodynamically matched operative controls, a finding that argues against the intuition that avoiding laparotomy necessarily shortens admission; what differed was transfusion exposure and abdominal complications, not days in hospital. The largest registry analysis of isolated severe splenic injury reported a shorter overall hospital course for non-operative strategies. All non-operative protocols mandated a defined period of high-dependency observation — typically forty-eight to seventy-two hours of intensive care or high-dependency monitoring with serial vital signs, haemoglobin measurement and abdominal examination — which constitutes a real and often unaccounted resource cost of the strategy, and which is precisely the resource that is scarcest in the settings where non-operative management would otherwise be most attractive.^{1,5,24}

Table 12. Length of stay and monitoring requirements

Study	Comparison	Length-of-stay result	Monitoring requirement described
Croce 1995	Non-operative	No significant	Non-operative patients

	management versus matched coeliotomy	difference in hospital length of stay	managed in the trauma intensive care unit with serial assessment
Raza 2013	Non-operative management protocol	Not reported as a comparative statistic	Mandatory intensive care or high-dependency admission for at least 48–72 hours with serial vital signs, repeated examination and follow-up investigation
Huang 2025	Splenectomy versus embolisation versus observation	Shorter hospital course with non-operative strategies	Registry-level data; monitoring protocol not standardised across contributing centres
Wang 2014	Damage-control laparotomy cohort	Not reported	All patients required intensive care with staged abdominal closure
Groven 2014	Operative versus non-operative across two institutional eras	Not reported as a comparative statistic	Formal trauma service introduced midway through the study period

Infectious and abdominal complications

Abdominal complications occurred nearly four times more often after coeliotomy than after successful observation in the prospective hepatic comparison (11% versus 3%), and the same study documented significantly fewer transfusions in the observed group, the two findings together forming the original clinical case for non-operative management. Registry-level analysis of isolated severe splenic injury likewise reported a lower overall complication burden with non-operative strategies than with open splenectomy. The specific infectious hazard of splenectomy — loss of splenic immunological function and the attendant lifelong risk of overwhelming post-splenectomy

infection — is a delayed outcome that none of the included studies was designed to capture, since all follow-up ended at discharge or at thirty days, and this is a systematic blind spot in the entire evidence base. In the opposite direction, intra-abdominal infection arising from a missed hollow-viscus perforation was one of the three named causes of failure of non-operative management in the largest observational series, a reminder that the complication profile of observation is not empty but merely different.^{1,5,24}

Table 13. Complications by management strategy

Study	Complication assessed	Non-operative strategy	Operative strategy
Croce 1995	Abdominal complications	3%	11% in the haemodynamically matched operative control cohort
Raza 2013	Intra-abdominal infection and delayed hollow-viscus perforation	Named among the three causes of failure requiring conversion to laparotomy	Not separately reported
Huang 2025	Any complication (co-primary outcome)	Lower complication burden with embolisation and observation	Higher with open splenectomy
Wang 2014	Damage-control-specific morbidity	Not applicable	Staged abdominal closure with attendant risk of abdominal compartment syndrome and fistula
Nijdam 2020	Complications and mortality by treatment received	Recorded from the electronic registry	Splenectomy group had the highest injury severity (median Injury Severity

			Score 27)
All included studies	Overwhelming post-splenectomy infection	NOT REPORTED — no study followed patients beyond discharge or 30 days	NOT REPORTED — systematic gap in the evidence base

Non-therapeutic laparotomy

The cost of an aggressive operative policy is measured in non-therapeutic laparotomies, and the available data permit that cost to be estimated with reasonable precision. Among hypotensive patients in the prospective multicentre transfusion cohort, a therapeutic laparotomy was ultimately performed in 69% of those with a positive sonogram, which implies that roughly three in every ten hypotensive patients taken to theatre on the strength of a positive scan did not require a definitive abdominal procedure. Consistent with this, the specificity of sonography for the need for therapeutic laparotomy in hypotensive patients was only 60% in a six-year single-centre analysis, against 96% in normotensive patients — the false-positive rate rises precisely when the stakes of the decision are highest, because hypotensive patients frequently have small volumes of free fluid from non-surgical sources and competing extra-abdominal causes of shock. The mirror-image error is at least as important: 22% of hypotensive patients with a negative sonogram nevertheless proceeded to therapeutic laparotomy, so a negative scan in shock has limited exclusionary power.^{3,11}

Table 14. Non-therapeutic laparotomy and diagnostic misclassification in hypotensive patients

Study	Population	Positive-test findings	Negative-test findings
Rowell 2019	317 hypotensive patients undergoing sonography (108 positive, 209 negative)	Therapeutic laparotomy performed in 69% of sonography-positive patients, implying approximately 31% non-therapeutic exploration in	Therapeutic laparotomy nonetheless required in 22% of sonography-negative patients — a negative scan does not exclude a surgical bleed

		this group	
Lee BC 2007	122 hypotensive patients from a cohort of 4,029	Specificity 60% in hypotensive patients versus 96% in normotensive patients; 69 of 87 sonography-positive hypotensive patients (79%) proceeded directly to laparotomy	Sensitivity 85% in both groups; accuracy fell from 96% in normotensive to 77% in hypotensive patients
Farahmand 2005	128 hypotensive patients	Specificity 82% for surgical injury and 69% for fatal injury	Sensitivity 97% for surgical injury and 100% for fatal injury — the most favourable exclusionary performance reported in this review
Musiitwa 2014	195 patients evaluated with a composite shock-and-sonography score	Positive predictive value only 53% at a score above 2	Negative predictive value 98% — the score performs far better at excluding than at confirming the need for operation

Discriminative accuracy of triage instruments for the operative decision

Because the choice between laparotomy and non-operative management is made within minutes of arrival and almost always before computed tomography, the accuracy of the bedside instruments that inform it is inseparable from the therapeutic question. Admission serum lactate discriminated the need for operative management with an area under the receiver-operating-characteristic curve of 0.8152 (95% confidence interval 0.7209–0.9095; $p < 0.0001$), substantially and significantly outperforming systolic blood pressure, which achieved only 0.6632 (95%

confidence interval 0.5457–0.7806; $p = 0.0106$). Base excess (0.7544), arterial pH (0.7390), heart rate (0.7264) and bicarbonate (0.7170) occupied intermediate positions. Combining lactate with heart rate, leucocyte count and sonography raised discrimination to 0.904, falling only to 0.882 after correction for optimism across one thousand bootstrap resamples. Composite scores performed comparably: the FASILA instrument achieved an area under the curve of 0.81 (95% confidence interval 0.78–0.84; $p = 0.001$) with 97% specificity and 90% positive predictive value at its optimal threshold, and outperformed the ABC score, the RABT score and shock index alone. The practical implication is unambiguous: blood pressure, the variable on which every current guideline threshold is built, is the weakest single discriminator available at the bedside.^{13,22,23,26}

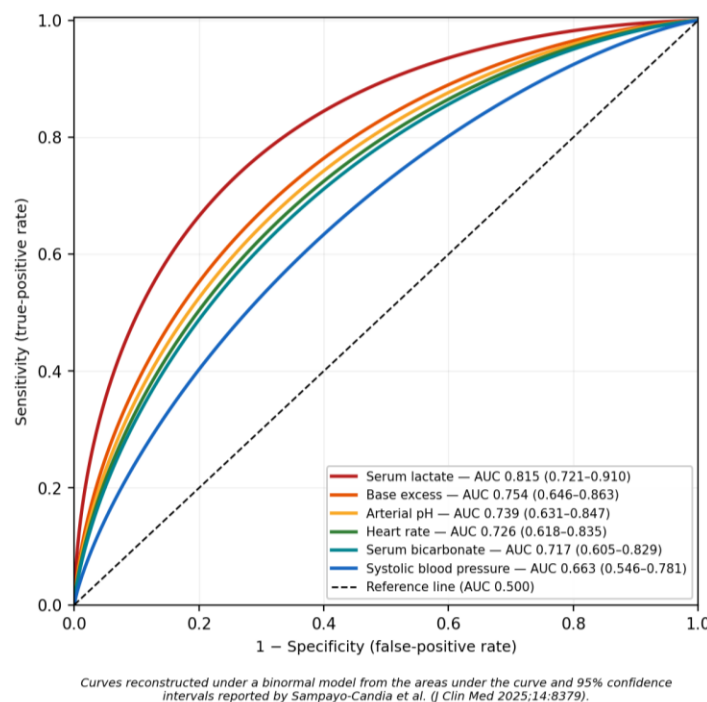


Figure 4. Receiver-operating-characteristic curves for admission physiological and biochemical predictors of the need for operative management. Curves are reconstructed under an equal-variance binormal model that reproduces each published area under the curve exactly

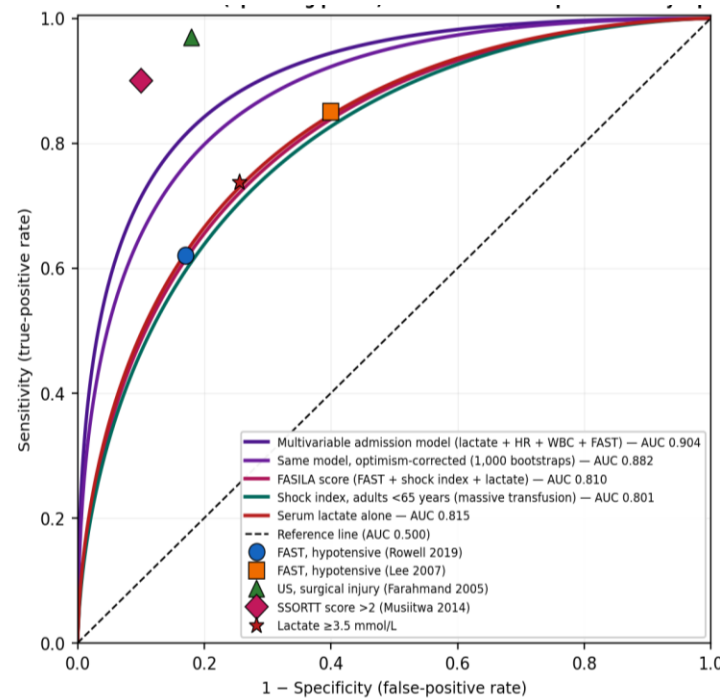


Figure 5. Composite triage instruments (curves) and individual bedside tests (plotted operating points) for the decision to perform early laparotomy. Operating points are the published sensitivity and specificity pairs; a point lying above and to the left of a curve indicates better performance at that particular threshold.

Table 17. Diagnostic and prognostic accuracy for the operative decision

Study	Index test	Area under the curve (95% CI)	Sensitivity	Specificity	Comment
Sampayo-Candia 2025	Serum lactate at admission	0.8152 (0.7209–0.9095); $p < 0.0001$	73.7% at ≥ 3.5 mmol/L	74.4%	Best single variable; likelihood ratio positive 2.88, negative 0.35
Sampayo-	Base excess	0.7544	Not reported	Not	Second-best

Candia 2025		(0.6460–0.8627); $p < 0.0001$		reported	single marker of occult hypoperfusion
Sampayo-Candia 2025	Arterial pH	0.7390 (0.6311–0.8469); $p = 0.0002$	Not reported	Not reported	Reflects the same metabolic derangement as lactate and base excess
Sampayo-Candia 2025	Heart rate	0.7264 (0.6179–0.8349); $p = 0.0002$	Not reported	Not reported	Outperforms systolic blood pressure
Sampayo-Candia 2025	Serum bicarbonate	0.7170 (0.6053–0.8286); $p = 0.0008$	Not reported	Not reported	Moderate discrimination
Sampayo-Candia 2025	Systolic blood pressure	0.6632 (0.5457–0.7806); $p = 0.0106$	Not reported	Not reported	WEAKEST single discriminator despite being the basis of most guideline thresholds
Sampayo-Candia 2025	Four-variable model (lactate, heart rate, leucocytes,	0.904 apparent; 0.882 optimism-	Not reported	Not reported	Internal validation with 1,000 bootstrap resamples; Brier

	sonography)	corrected			score 0.126 (corrected 0.149)
El-Menyar 2020	FASILA score (cut-off 4.5)	0.81 (0.78– 0.84); p = 0.001	Not reported	97%	Positive predictive value 90%; outperformed ABC, RABT and shock index alone
El-Menyar 2025	FASILA score ≥4 (prospective validation)	Superior to ABC score and shock index alone	Not reported	85.5%	Negative predictive value 80% for the need for surgery
Cho and Park 2025	Shock index (massive transfusion)	0.801 in adults <65 years; 0.666 in adults ≥65 years	Not reported	Not reported	p < 0.001 for the age interaction — shock index is unreliable in the elderly
Rowell 2019	Sonography in hypotensive patients	Not reported	62%	83%	Multi- institutional pragmatic design; a negative scan does not exclude a surgical bleed
Lee BC 2007	Sonography in hypotensive	Not reported	85%	60%	Accuracy 77% in hypotensive

	patients				versus 96% in normotensive patients
Farahmand 2005	Screening ultrasonography for surgical injury	Not reported	97%	82%	Sensitivity 100% and specificity 69% for fatal injury; accuracy 86%
Musiitwa 2014	SSORTT score >2	Not reported	90%	90%	Positive predictive value 53%, negative predictive value 98%; designed for low-technology settings

CI = confidence interval; RABT = Revised Assessment of Bleeding and Transfusion; ABC = Assessment of Blood Consumption; SSORTT = Sonography and Shock in the Operative Room Triage Tool.

Damage-control laparotomy and its specific burden

Damage-control laparotomy is not a variant of exploratory laparotomy but a distinct commitment, and the frequency with which it is required is itself a marker of physiological failure. In the twelve-centre American cohort, damage-control laparotomy was performed in 62% of hypotensive patients compared with 31% of normotensive patients ($p < 0.001$), and institutional rates varied more than twofold, from 24% to 53%, despite similar stated indications — packing in 38% of cases, haemodynamic instability in 23% and a planned second look in 12%. That variation, at similar case mix, indicates that the decision to leave the abdomen open is substantially surgeon- and institution-dependent rather than purely physiological. The mortality attached to the strategy is

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severe: 61.5% in a Taiwanese series restricted to exsanguinating blunt abdominal trauma, in which a pre-operative Glasgow Coma Scale below 8 and the admission base excess were the independent predictors of death. These figures define the ceiling of what operative haemorrhage control can achieve in the deepest shock and provide the appropriate benchmark against which any endovascular alternative must be judged.^{7,10}

Table 18. Damage-control laparotomy: frequency, indications and outcome

Study	Frequency	Stated indications	Outcome
Harvin 2017	62% of hypotensive versus 31% of normotensive patients ($p < 0.001$); institutional rates 24–53%	Packing 38%, haemodynamic instability 23%, planned second look 12%	Overall cohort mortality 21%; hypotensive mortality 46%
Wang 2014	91 consecutive damage-control laparotomies over 10.5 years	Exsanguinating blunt abdominal trauma with haemorrhagic shock	Mortality 61.5%; Glasgow Coma Scale < 8 and base excess were independent survival predictors; nomogram derived
Lee YJ 2024	All six emergency-department laparotomies were damage-control procedures	Inability to transfer safely to the operating theatre	Survival 33.3%; the two survivors had mesenteric bleeding controlled by ligation
Groven 2014	Emergency-department laparotomy rate declined across the study period	Institutional protocol for the unstable patient	Risk-adjusted survival improved after introduction of a formal trauma service, without an increase in

			mortality despite fewer emergency-department laparotomies
Balch 2023	Aortic occlusion in a dedicated hybrid theatre	Refractory shock with systolic pressure <90 mmHg despite volume resuscitation	Haemorrhage control 77% with endovascular occlusion versus 8% with thoracotomy (p = 0.001)

Independent predictors of failure and of death

Pooling the multivariable models reported across the included studies produces a coherent and clinically usable predictor set. Physiological depth of shock dominates: base excess and Glasgow Coma Scale below 8 predicted death after damage-control laparotomy; admission systolic pressure separated successes from failures of hepatic observation (127 versus 104 mmHg; $p < 0.04$); and admission lactate discriminated the need for operation better than any vital sign. Anatomical burden is the second axis: grade V splenic injury and the presence of additional intra-abdominal injuries predicted failure of an angioembolisation-first strategy, and every grade V injury in an independent Dutch cohort required splenectomy. Process factors form the third axis, with each minute of delay to theatre raising adjusted odds of haemorrhagic death by 1.8%. Finally, age modifies the reliability of the instruments themselves: the discriminative accuracy of shock index for massive transfusion fell from 0.801 in adults under sixty-five to 0.666 in those sixty-five and older ($p < 0.001$), so the same numerical shock index carries a different meaning in the elderly patient, whose baseline hypertension and rate-limiting medication blunt the classical response to haemorrhage.^{1,7,14,22,25,27}

Table 19. Independent predictors identified in multivariable analysis

Predictor domain	Variable	Effect and source	Clinical implication
Physiological	Base excess and Glasgow Coma	Independent predictors of death after damage-control	Metabolic and neurological derangement together define

	Scale <8	laparotomy (Wang 2014)	the futility boundary
Physiological	Admission systolic blood pressure	127 versus 104 mmHg in successes versus failures of hepatic observation (p < 0.04) (Croce 1995)	Even within the "stable" range, lower pressure predicts failure of observation
Biochemical	Serum lactate	Area under the curve 0.8152 (95% CI 0.7209–0.9095) for the need for operation (Sampayo-Candia 2025)	Should be measured on arrival in every unstable abdominal trauma patient
Anatomical	Grade V splenic injury and additional intra-abdominal injury	Concentrated the failures of an angioembolisation-first strategy (Schaid 2025); every grade V injury required splenectomy (Nijdam 2020)	Grade V with multiple abdominal injuries should proceed to laparotomy rather than to angiography
Process	Emergency department to operating room interval	Adjusted odds ratio 1.018 per minute for haemorrhagic death (95% CI 1.007–1.030) (Park 2025)	Institutional door-to-intervention targets are a survival intervention in their own right
Demographic	Age ≥65 years	Shock index area under the curve fell from 0.801 to 0.666 (p < 0.001) (Cho and Park 2025)	Shock index must not be used as a sole trigger in the elderly
Composite	FASILA score ≥4	Odds ratio 1.92 per point for transfusion (95% CI 1.43–2.58) (El-Menyar 2025); laparotomy rate rose from 24% to 85% between scores	A single bedside number integrating sonography, shock index and lactate stratifies risk better than any component alone

of 4 and 6 (El-Menyar 2020)

Synthesis of adjusted effect estimates

Three estimates exclude the null value and are therefore statistically significant: splenic salvage strongly favouring embolisation over open surgery (adjusted relative risk 2.84, 95% confidence interval 2.29–3.51), the per-minute increase in haemorrhagic death with delay to operation (adjusted odds ratio 1.018, 95% confidence interval 1.007–1.030), and the per-point increase in transfusion requirement with the FASILA score (odds ratio 1.92, 95% confidence interval 1.43–2.58). Two estimates are compatible with no difference and are the two mortality comparisons between endovascular and operative haemorrhage control (hazard ratio 1.02, 95% confidence interval 0.97–1.07; adjusted relative risk 0.64, 95% confidence interval 0.38–1.09). This pattern is the central quantitative finding of the review: where the two strategies have been compared with adequate confounder control in appropriately selected patients, they do not differ in survival, but they differ profoundly and significantly in organ preservation, while the timing of intervention differs significantly in its effect on death regardless of which strategy is chosen.^{20,23,25,27}

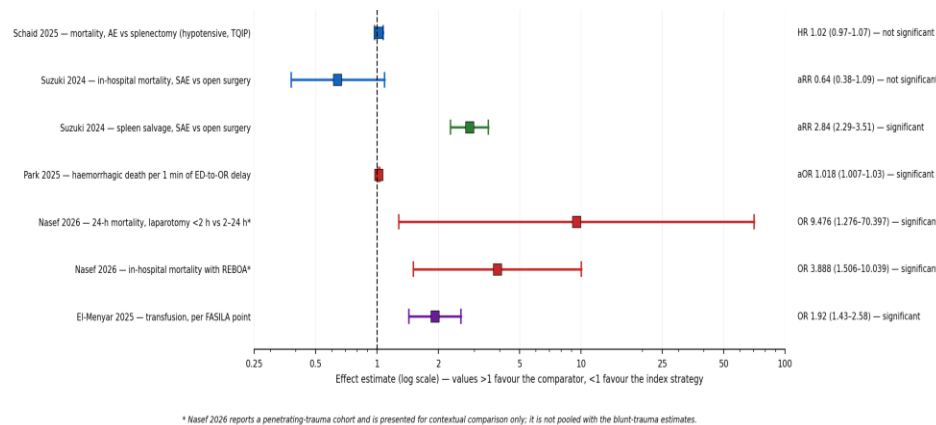


Figure 6. Forest plot of adjusted effect estimates on a common logarithmic scale. Estimates are not pooled; heterogeneity of population, comparator and outcome definition makes a summary estimate uninterpretable. The two penetrating-trauma estimates are marked and are presented for contextual comparison only.

DISCUSSION

Principal findings

Three findings emerge with sufficient consistency to be regarded as established. First, blunt abdominal trauma with haemodynamic instability remains lethal at a rate that four decades of therapeutic innovation have barely altered: mortality after emergent laparotomy in hypotensive patients was 46% in a contemporary twelve-centre American cohort, a figure essentially identical to that reported two decades earlier, and it rises to 61.5% when damage-control techniques are required and to two thirds when the abdomen must be opened in the emergency department. Second, the interval to definitive haemorrhage control is an independent, adjusted and statistically significant determinant of death, with each additional minute between arrival and operating-room entry raising the odds of haemorrhagic death by 1.8%. Third, and most surprisingly, where an endovascular-first strategy has been compared with an operative-first strategy in hypotensive patients using entropy balancing or propensity matching, survival has been statistically indistinguishable, while organ preservation has been almost three times more likely. The synthesis therefore does not vindicate either doctrinal position in its pure form.^{7,10,20,21,25,27}

It is important to state clearly what these findings do not show. They do not show that non-operative management is safe in the patient who does not respond to resuscitation. Every study that reported an endovascular-first strategy in unstable patients required, as a precondition of entry, that the patient had survived long enough and remained stable enough to undergo a computed tomographic examination — in the largest such analysis this was an explicit inclusion criterion. The patient who arrives with a systolic pressure of 60 mmHg, a positive sonogram and no response to blood is not represented in these datasets at all, because such patients go to theatre. The apparent equivalence between strategies is therefore an equivalence within a selected stratum, and it would be a serious misreading to extend it to the exsanguinating non-responder.^{24,27}

Time as the dominant variable

If a single message is to be extracted from this review for clinical practice, it is that the argument over technique has been allowed to obscure the far larger effect of timing. The adjusted odds ratio of 1.018 per minute derived from a two-centre Korean cohort with adjudicated cause of

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death implies that an hour of avoidable delay roughly doubles the odds of dying from haemorrhage, an effect size that dwarfs any difference between laparotomy and embolisation reported anywhere in this literature. The classical estimate that mortality rises by approximately 1% for every three minutes of delay to theatre, derived from an earlier generation of studies, is of the same order of magnitude and was independently reproduced in a study showing decreased survival with increasing time to operation in patients with a positive sonogram requiring emergent laparotomy. High-performing systems achieve a median of twenty-four minutes in the emergency department and forty-two minutes from arrival to incision, and hypotensive patients already move faster than normotensive ones, which indicates that the remaining delay is structural — theatre availability, staffing, transfer distance — rather than diagnostic hesitation.^{10,15,25,34,35}

This observation reframes the choice of strategy as a question of local logistics rather than of doctrine. In an institution where an interventional radiology team can be on the table within twenty minutes at three in the morning, angioembolisation is a fast intervention. In an institution where the same procedure entails a two-hour recall, it is a slow one, and the same evidence that supports embolisation in the first setting argues against it in the second. Any guideline that specifies a technique without specifying the time within which that technique must be delivered is incomplete.^{16,25}

The decisive distinction: non-responder versus transient responder

The most consequential conceptual weakness in the existing guidance is the treatment of haemodynamic instability as a single category. The included studies define it in at least four incompatible ways — systolic pressure below 90 mmHg on arrival, shock index of 1.0 or greater, failure or transience of response to a fluid or blood challenge, or a composite of hypotension, tachycardia above 120 beats per minute and transfusion within four hours — and this heterogeneity has been repeatedly named as a source of bias in the field. These definitions do not identify the same patients. A young patient with a pressure of 85 mmHg who rises to 120 mmHg after one unit of blood and remains there has a different disease from one whose pressure will not rise at all, and the studies that have separated these groups show it: in the multicentre embolisation series that explicitly distinguished transient from non-responders, survival to discharge after embolisation in

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the unstable group was 88.2%, and in the case-control series in which instability was defined by shock index, splenic salvage in unstable patients reached 98% with 4% thirty-day mortality.^{5,17,20,27}

The non-responder proceeds directly to laparotomy without computed tomography; the evidence for this is indirect but coherent, since every dataset supporting an endovascular alternative excluded such patients by design. The transient responder with a single solid-organ bleeding source demonstrated on a rapidly obtained contrast study is the legitimate territory of angioembolisation, with immediate surgical rescue available. The responder follows the established non-operative pathway. What must not happen is the application of the middle pathway to the first group because the middle pathway performed well in published series that never contained such patients.^{20,24,27}

The spleen as the test case for the whole argument

Splenic injury has become the proving ground for this debate because it is the commonest solid-organ injury after blunt trauma, because the organ has a definable immunological function whose loss is measurable, and because it is anatomically suited to catheter-based haemostasis. The evidence here is now substantial. A national registry analysis of 1,360 hypotensive patients with grade IV or V injury who underwent computed tomography found entropy-balanced survival that was statistically identical between an angioembolisation-first and a splenectomy-first approach (hazard ratio 1.02, 95% confidence interval 0.97–1.07), and the authors concluded explicitly that the attempt to preserve the spleen was justified because survival after failed embolisation was no worse than after upfront splenectomy. A propensity-matched analysis of the Japanese national registry found identical mortality (11.6% versus 11.2%) with splenic salvage of 87.1% versus 32.1% (adjusted relative risk 2.84, 95% confidence interval 2.29–3.51; $p < 0.001$). A registry study of 7,567 patients with isolated severe splenic injury reported outcomes favouring non-operative management even among those hypotensive on admission.^{20,24,27}

The countervailing evidence is anatomical rather than physiological. Every grade V splenic injury in an independent European high-grade cohort required splenectomy, and each of those patients had remained unstable after resuscitation. In the American registry analysis, the fifth of patients who failed an embolisation-first approach and required rescue splenectomy within six hours were predominantly those with grade V injury and additional intra-abdominal injuries. The

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selection rule that emerges is therefore not "unstable versus stable" but "single-organ, single-source, catheter-accessible bleeding versus multiple or diffuse sources", and computed tomography is the instrument that makes that distinction — which is precisely why the patient too unstable for computed tomography is also the patient who should not be offered embolisation.^{14,20,27}

The liver, the hollow viscus and the limits of extrapolation

The splenic evidence should not be transposed uncritically to other organs. The prospective hepatic study that helped establish non-operative management showed that only 5% of failures were liver-related, while 6% failed because of an unrecognised extrahepatic injury — in other words, the liver behaved well and the rest of the abdomen did not. Hollow-viscus and mesenteric injuries are categorically unsuited to any non-operative approach: they do not bleed in a manner amenable to embolisation, they declare themselves late, and delayed perforation with intra-abdominal sepsis was one of the three named causes of failure in the largest observational series. The single Korean emergency-department laparotomy series makes the point starkly from the opposite direction: the only two survivors of six were those whose mesenteric bleeding was controlled by direct ligation. A blanket policy of angiography-first in the unstable abdomen would systematically disadvantage precisely the injuries for which surgery is not merely superior but exclusive.^{1,5,21}

Diagnostic triage and the structural limits of sonography

Focused sonography occupies a position in trauma practice that its measured performance in hypotensive patients does not entirely justify. Sensitivity for the need for therapeutic laparotomy in hypotensive adults was 62% in a prospective multi-institutional study and 85% in a large single-centre retrospective series, while specificity in the hypotensive subgroup fell to 60% against 96% in normotensive patients. The asymmetry matters: in shock, the test is least able to exclude disease at exactly the moment when exclusion would be most valuable, and 22% of hypotensive patients with a negative scan nonetheless required a therapeutic laparotomy. The reasons are mechanical — small hemoperitoneum volumes early after injury, retroperitoneal and mesenteric bleeding invisible to the technique, obesity, subcutaneous emphysema and competing extra-abdominal causes of shock. Screening ultrasonography performed considerably better in one prospective series, with 97% sensitivity for surgical injury and 100% for fatal injury, which suggests that operator training and

the acuity threshold for calling a study positive account for much of the variation between reports.^{2,3,11}

The practical corollary is that sonography should be used as a rule-in test in the hypotensive patient and never as a rule-out test. A positive scan in a non-responder is an indication for laparotomy; a negative scan in a non-responder is an indication to look harder, not to relax. This is precisely the logic embodied in composite instruments, which recover the lost sensitivity by adding physiological and biochemical dimensions to the sonographic one.^{11,13,23}

Biochemical markers of occult shock

One of the more striking quantitative findings in this review is that systolic blood pressure was the weakest of six admission variables in discriminating the need for operation, achieving an area under the curve of only 0.6632 (95% confidence interval 0.5457–0.7806), while serum lactate achieved 0.8152 (95% confidence interval 0.7209–0.9095). Base excess, arterial pH, heart rate and bicarbonate all outperformed blood pressure. This is physiologically unsurprising — hypotension is a late manifestation of haemorrhage that appears only when compensatory vasoconstriction and tachycardia have been exhausted, whereas lactate and base deficit reflect the tissue hypoperfusion that precedes decompensation — but it is doctrinally uncomfortable, since virtually every guideline threshold in this field is written in millimetres of mercury. The composite instruments make the same point from a different direction: the FASILA score, which integrates sonography, shock index and lactate, achieved an area under the curve of 0.81 with 97% specificity and outperformed the ABC score, the RABT score and shock index alone.^{13,23,26}

Two caveats attach. The four-variable model achieving an area under the curve of 0.904 was derived from only eighty-three patients with thirty-nine operative events, was subjected to internal bootstrap validation only, and has not been externally validated; the authors themselves describe it as exploratory and hypothesis-generating. And the reliability of shock index, the most widely adopted composite, is age-dependent: its discriminative accuracy for massive transfusion fell from 0.801 in adults under sixty-five to 0.666 in those sixty-five and older ($p < 0.001$), so the elderly patient on beta-blockade with baseline hypertension may be in profound shock at a shock index that would be reassuring in a young adult.^{22,26}

Damage-control laparotomy: benefit, cost and unwarranted variation

Damage-control laparotomy has undoubtedly saved lives that packing and rapid closure could not otherwise have preserved, but the data assembled here also show that it is applied with substantial and unexplained variation. Institutional rates ranged from 24% to 53% across twelve level I centres with similar stated indications, and although the technique was used twice as often in hypotensive as in normotensive patients (62% versus 31%; $p < 0.001$), that physiological gradient does not account for the twofold spread between institutions. Since an open abdomen carries its own morbidity — fistula, ventral hernia, abdominal compartment syndrome, prolonged ventilation and intensive care dependency — and since mortality in the exsanguinating cohort in which it is most often used reached 61.5%, the threshold for its use deserves the same scrutiny that has been applied to the threshold for laparotomy itself.^{7,10}

System factors: the hybrid room and aortic occlusion

Several of the included studies address not what is done but where it is done. Aortic occlusion performed in a dedicated hybrid theatre achieved haemorrhage control in 77% of endovascular cases against 8% of resuscitative thoracotomies ($p = 0.001$), with greater survival to discharge, although the cohort comprised only thirteen patients per arm and the thoracotomy group arrived with markedly lower systolic pressures, so confounding by indication is severe and the comparison must be read as hypothesis-generating. The relevance of the hybrid concept to this review is nevertheless direct: if the principal determinant of survival is the interval to haemorrhage control, then any architecture that removes an inter-departmental transfer from the pathway addresses the dominant variable. Reported experience with hybrid emergency rooms shows median door-to-computed-tomography times of nineteen minutes and door-to-bleeding-control times of fifty-seven minutes, and the marginal benefit appears concentrated in the most severely injured. Against this, systematic appraisal of hybrid operating theatres has found their measured impact on time to first intervention and on overall mortality inconsistent across small cohorts, so the concept should be regarded as promising rather than proven.^{16,18}

Relationship to existing systematic reviews, meta-analyses and guidelines

In accordance with the protocol, systematic reviews and meta-analyses were excluded from the characteristics table but are considered here. Their overall thrust is consistent with the present synthesis while being narrower in scope. Meta-analytic appraisal of splenic angioembolisation as an adjunct to non-operative management concluded that the technique should be strongly considered in grade IV and grade V injuries but not routinely recommended in grades I to III, an anatomical rather than physiological selection rule that maps closely onto the failure pattern identified here. An earlier meta-analysis comparing observation with embolotherapy by injury grade reached compatible conclusions. Guideline documents from the Eastern Association for the Surgery of Trauma and from the World Society of Emergency Surgery both continue to specify haemodynamic instability as an indication for operation while endorsing non-operative management for every grade of injury in the stable patient. The novel contribution of the present review is to show that within the "unstable" category so defined there now exists a substantial and well-adjusted body of registry evidence supporting an endovascular-first approach for a defined subgroup, and that the guidelines' binary framing has not yet caught up with it.^{29,30,31,32,33,38}

Two further points from the review literature deserve emphasis. The observation that the definition of haemodynamic stability varies greatly between studies "depending on the surgeon and the trauma team" has been identified as a source of bias in prior meta-analyses and remains unresolved; until a common operational definition is adopted, cross-study synthesis in this field will remain limited to narrative and graphical methods, as it has been here. And the finding from earlier work that selective angiographic embolisation decreases the failure rate of non-operative management provides the mechanistic explanation for the organ-salvage advantage quantified in this review.^{32,33,37}

Implications for resource-variable and Indonesian practice

The evidence supporting an endovascular-first strategy is inseparable from the infrastructure that delivered it: every supporting study came from a level I centre or a national registry dominated by such centres, with round-the-clock interventional radiology, immediate computed tomography and an operating theatre available for rescue. In hospitals without those resources, the balance shifts decisively back towards early laparotomy, and a policy of attempting non-operative management in

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an unstable patient without an immediate surgical rescue pathway would be indefensible. This has direct relevance to the Indonesian referral network and to comparable systems, where interventional radiology coverage is concentrated in a small number of centres and out-of-hours availability is variable. Two findings from this review are particularly transferable to such settings. The first is that a composite score built from sonography, shock index and lactate — all three of which are obtainable in any emergency department with a point-of-care analyser — outperforms blood pressure as a trigger for operation. The second is that a simple shock-and-sonography score achieved 90% sensitivity, 90% specificity and a 98% negative predictive value for the need for therapeutic laparotomy in a sub-Saharan African hospital explicitly designed as a low-technology setting, which demonstrates that structured triage does not require advanced imaging.^{8,13,23,26}

Strengths

The principal strengths of this review are that it is organised around physiology rather than around a single injured organ, that it integrates the diagnostic and therapeutic literatures which are usually reviewed separately, that it applies ROBINS-I with pre-specified critical confounders so that the reader can identify which estimates are credible, and that it declines to compute a pooled mortality estimate that the underlying heterogeneity could not support. The refusal to pool is itself a methodological position: a random-effects summary of these data would generate a spuriously precise number dominated by confounding by indication and would very probably be misread as evidence that non-operative management improves survival in shock.^{9,20,27}

Research agenda

The outstanding question is narrow and answerable. A pragmatic multicentre randomised trial should enrol adults with blunt abdominal trauma who are transient responders — defined prospectively and uniformly as an initial response to a defined blood or fluid challenge followed by recurrent hypotension — in whom a contrast-enhanced computed tomographic study demonstrates a single solid-organ bleeding source, and should randomise them to angioembolisation-first or laparotomy-first with a pre-specified rescue protocol, in centres capable of delivering either within thirty minutes at any hour. The primary outcome should be a composite of death or failure of the assigned strategy at twenty-four hours; secondary outcomes should include organ salvage,

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transfusion, complications and, critically, immunological function and infection at one year, which no existing study reports. In parallel, an international consensus operational definition of haemodynamic instability that distinguishes non-responders from transient responders is a prerequisite for any future synthesis, and would do more to advance this field than any further single-centre series.^{12,20,27,40}

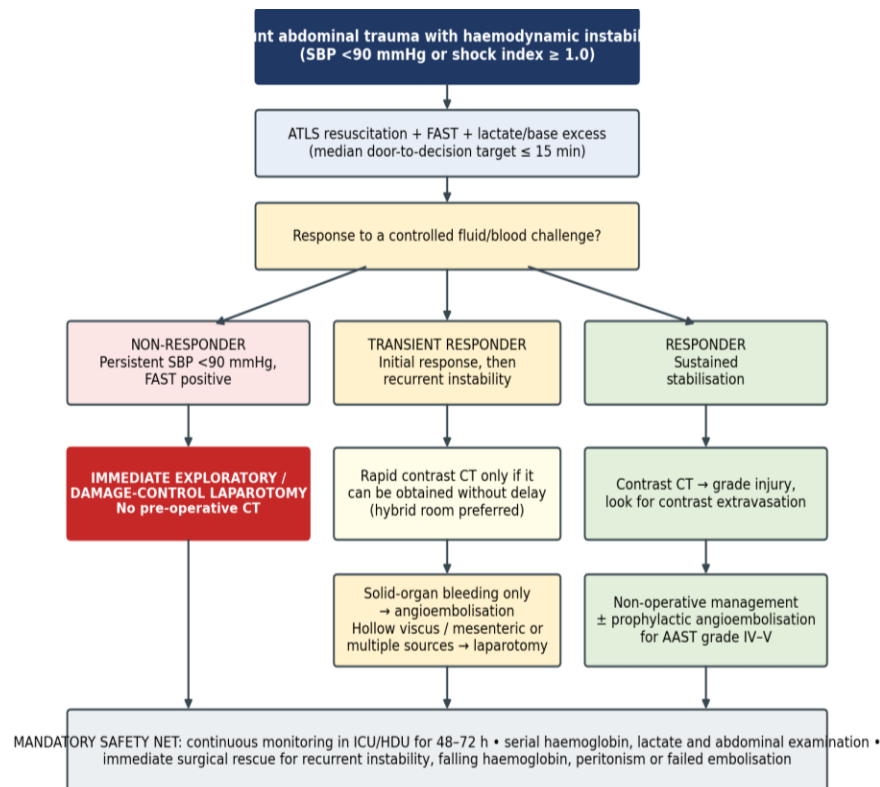


Figure 7. Decision algorithm derived from the synthesised evidence. The algorithm is stratified by the response to a controlled resuscitation challenge rather than by a single blood-pressure threshold, and it makes the availability of immediate surgical rescue an explicit precondition for any non-operative pathway in an unstable patient.

Certainty of the evidence

Certainty was rated by outcome domain and is summarised in Table 19. The comparative mortality outcome was rated low: the evidence begins at low certainty by virtue of its observational

design, was downgraded for indirectness because the only randomised data excluded unstable patients, but was not downgraded further because the two largest analyses used entropy balancing and propensity matching and were consistent with each other. Organ salvage was rated moderate, having been upgraded for a large magnitude of effect with a confidence interval far from unity. The association between delay to operation and haemorrhagic death was rated moderate, upgraded for a dose–response gradient. The diagnostic-accuracy domain was rated moderate for the biochemical markers and low for sonography, the latter because sensitivity estimates ranged from 62% to 97% across studies with differing operators and reference standards.^{4,10,20,25,26,27}

Table 20. GRADE summary of findings

Outcome domain	Summary of the evidence	Number of studies (participants)	Certainty (GRADE)	Reason for the rating
Mortality: early laparotomy versus non-operative management in instability	No significant difference where confounders were adequately controlled (hazard ratio 1.02, 95% CI 0.97–1.07; adjusted relative risk 0.64, 95% CI 0.38–1.09), but all such comparisons required survivability to computed tomography	3 registry analyses (>11,000)	⊕⊕○○ LOW	Observational start; downgraded for indirectness (unstable non-responders not represented); not downgraded for inconsistency or imprecision

Mortality after laparotomy in hypotensive patients	46% in hypotensive versus 21% overall; 61.5% after damage-control laparotomy	4 cohorts (>3,400)	⊕⊕⊕○ MODERATE	Consistent across settings and eras; no comparator arm, so descriptive rather than comparative
Mortality gradient with depth of hypotension	Survival 64%, 50%, 34% at systolic >80, 61–80, ≤60 mmHg (p = 0.04)	2 cohorts (1,218)	⊕⊕⊕○ MODERATE	Upgraded for dose–response gradient; downgraded for small size of the stratified cohort
Failure of non-operative management	10–11% in selected cohorts; approximately 20% rescue splenectomy in hypotensive grade IV–V injury	5 cohorts (>3,500)	⊕⊕⊕○ MODERATE	Highly consistent estimates across three decades and four continents
Organ salvage	Adjusted relative risk 2.84 (95% CI 2.29–3.51); p < 0.001 favouring embolisation	4 cohorts (>3,000)	⊕⊕⊕○ MODERATE	Upgraded for a large magnitude of effect with a precise confidence interval far from unity
Transfusion requirement	Halved with successful non-operative management (1.9 versus 4.0 units; p < 0.02)	4 studies (>1,800)	⊕⊕○○ LOW	Confounded by indication; transfusion is partly a consequence of the physiology that determined

				allocation
Delay to operation and haemorrhagic death	Adjusted odds ratio 1.018 per minute (95% CI 1.007–1.030)	3 cohorts (>2,700)	⊕⊕⊕○ MODERATE	Upgraded for dose–response; adjudicated cause of death and inverse probability weighting in the principal study
Diagnostic accuracy of biochemical markers	Lactate area under the curve 0.8152 (95% CI 0.7209–0.9095); composite model 0.904	3 studies (1,682)	⊕⊕⊕○ MODERATE	Consistent direction and magnitude; downgraded for the small size of the derivation cohort for the composite model
Diagnostic accuracy of sonography in hypotension	Sensitivity 62–97%, specificity 60–83% for the need for therapeutic laparotomy	3 studies (4,474)	⊕⊕○○ LOW	Downgraded for inconsistency: operator training and reference standard differ substantially between studies
Long-term immunological outcome after splenectomy	NOT REPORTED by any included study	0 studies	No evidence	Complete absence of follow-up beyond discharge or 30 days across the entire evidence base

⊕⊕⊕⊕ high; ⊕⊕⊕○ moderate; ⊕⊕○○ low; ⊕○○○ very low. CI = confidence interval.

CONCLUSION AND RECOMMENDATIONS

Conclusion

Early exploratory laparotomy remains the standard of care for the patient with blunt abdominal trauma who does not respond to resuscitation, and nothing in the evidence assembled here displaces that position. Mortality in this population is 46% after emergent laparotomy and rises to 61.5% when damage-control techniques are required, and it worsens in a graded and statistically significant fashion as admission systolic pressure falls, reaching 30-day survival of only 20% below 60 mmHg. Delay to definitive haemorrhage control is independently and significantly lethal, with each minute between arrival and operating-room entry raising the adjusted odds of haemorrhagic death by 1.8%.^{4,10,25}

At the same time, the review identifies a defined subgroup in which the traditional prohibition no longer holds. Among hypotensive patients with isolated high-grade splenic injury who are stable enough to complete a contrast-enhanced computed tomographic study, an angioembolisation-first strategy achieves survival statistically indistinguishable from splenectomy-first (hazard ratio 1.02, 95% confidence interval 0.97–1.07), while splenic salvage is almost three times more likely (adjusted relative risk 2.84, 95% confidence interval 2.29–3.51; $p < 0.001$), and failure of the endovascular attempt does not carry a survival penalty relative to primary splenectomy. The decision should therefore be governed not by a single blood-pressure threshold but by the response to a controlled resuscitation challenge, by the number and accessibility of bleeding sources, and by the institution's demonstrated capacity to deliver either intervention promptly at any hour. Blood pressure, notably, was the weakest of six admission variables in discriminating the need for operation, while serum lactate was the strongest.^{20,26,27}

Recommendations for clinical practice

No	Recommendation
1	The non-responder — the patient whose systolic pressure does not rise with adequate blood and fluid resuscitation and who has a positive sonogram — should undergo immediate exploratory or damage-control laparotomy without pre-operative computed

	tomography. The evidence supporting endovascular alternatives does not extend to this group, because such patients were excluded from every supporting dataset by the requirement to survive a computed tomographic examination.
2	The transient responder with a single, catheter-accessible solid-organ bleeding source demonstrated on a rapidly obtained contrast study may reasonably be offered angioembolisation, provided that an operating theatre and surgical team are immediately available for rescue and that the interventional pathway does not add material delay.
3	Grade V splenic injury, multiple intra-abdominal bleeding sources, and any suspicion of hollow-viscus or mesenteric injury should proceed to laparotomy rather than to angiography, since these are the injury patterns that concentrated the failures of an embolisation-first approach.
4	Serum lactate and base excess should be measured on arrival in every unstable abdominal trauma patient and should be given at least equal weight to systolic blood pressure in the operative decision. Lactate discriminated the need for operation far better than blood pressure (area under the curve 0.8152 versus 0.6632).
5	A positive focused sonogram in a hypotensive patient should be treated as an indication for laparotomy; a negative sonogram must never be used to exclude a surgical bleed, since 22% of hypotensive patients with a negative scan still required a therapeutic laparotomy.
6	Every trauma-receiving institution should audit, publish internally and defend an explicit door-to-definitive-haemorrhage-control interval. Benchmarks achievable in high-performing systems are approximately 24 minutes in the emergency department and 42 minutes from arrival to incision.
7	Shock index should not be used as a sole trigger for intervention in patients aged 65 years or older, in whom its discriminative accuracy falls from 0.801 to 0.666.
8	Any non-operative pathway in an unstable patient must be accompanied by a mandatory monitored observation period of 48–72 hours with serial haemoglobin, lactate and abdominal examination, and by a rehearsed, immediately available surgical rescue

	pathway.
9	Institutions without round-the-clock interventional radiology should not attempt an endovascular-first strategy in unstable patients; in that setting, early laparotomy is both the evidence-based and the only safe choice.
10	Every patient undergoing splenectomy should be entered into a structured immunisation and long-term follow-up programme, since the principal justification for organ salvage — the avoidance of overwhelming post-splenectomy infection — lies entirely beyond the follow-up horizon of the current evidence base.

Recommendations for research

Four priorities follow directly from the gaps identified. First, a pragmatic multicentre randomised controlled trial confined to transient responders with a single solid-organ bleeding source, randomising to angioembolisation-first or laparotomy-first with a pre-specified rescue protocol and a composite primary outcome of death or strategy failure at twenty-four hours. Second, an international consensus operational definition of haemodynamic instability that formally separates the non-responder from the transient responder, without which future synthesis will remain confined to narrative methods. Third, prospective external validation of the composite admission scores in independent and resource-variable populations, since the most discriminating model reported to date was derived from only eighty-three patients. Fourth, long-term follow-up studies capturing immunological function, vaccination compliance and infection rates at one year and beyond after splenectomy compared with splenic salvage, an outcome that no study in this review reported and without which the organ-preservation argument rests on physiological inference rather than on measured patient benefit.^{12,20,26,27}

DECLARATIONS

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the reference list. Author contribution: dr. Ridwan Taufik conceived the review question, designed and executed the search, performed study selection, data extraction and risk-of-bias appraisal, conducted the synthesis and drafted and approved the final manuscript.

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