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Systematic review

## Operative versus imaging-based pathways for penetrating abdominal trauma with hemodynamic instability in the emergency department: a systematic review

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### Abstract

**Background:** Penetrating abdominal trauma (PAT) with hemodynamic instability (HI) requires rapid triage between immediate operative intervention (OI) and imaging-based pathways (IBP). The role of computed tomography (CT) or focused assessment with sonography for trauma in unstable or initially abnormal patients still not determined. **Methods:** This systematic review evaluated original studies reporting OI versus IBPs for patients presenting to the ED with PAT or thoracoabdominal trauma and HI, hypotension, or shock. MEDLINE, Web of Science, Scopus, Embase, and the Cochrane Library were searched, with additional screening of relevant reference lists. Reviews, case reports, editorials, conference abstracts without extractable data, blunt-only studies, and stable-only penetrating trauma studies were excluded. **Results:** We include three retrospective observational studies, one study focused on abdominal gunshot wounds, and two reported extractable PAT subgroups within HI trauma cohorts. CT-based pathways were used selectively, mainly in patients who responded to resuscitation or were considered stable enough for monitored imaging. In the eligible comparative cohorts, CT was not associated with higher mortality, and no deaths occurred in the CT scanner or during intrahospital transfer in one study.

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Imaging-based triage helped avoid OI in some patients and was associated with lower transfusion requirements, shorter hospitalization, or fewer additional procedures in some cohorts. Persistent nonresponse, peritonitis, and suspected major bleeding are indications for OI. Conclusion: CT-based evaluation support triage in selected unstable PAT patients during active resuscitation, and current studies does not justify routine imaging in unselected HI nonresponders.

**Keywords:** Penetrating abdominal trauma; hemodynamic instability; computed tomography; FAST; laparotomy; emergency department; imaging-based triage; operative management; nonoperative management.

## Introduction

Penetrating abdominal trauma (PAT) is a high-risk emergency condition because of the potential involvement of the abdominal wall, diaphragm, solid organs, hollow viscera, retroperitoneum, or major vascular structures. The early ED priority is rapid identification of patients who need immediate hemorrhage control, and avoiding unnecessary OI in patients who can be safely evaluated. Clinical decision-making is affected by mechanism, wound location, projectile energy, physiological response, and the availability of trauma resources [1].

Mandatory laparotomy was used for most PAT because missed bowel, vascular, or diaphragmatic injury sometimes cause severe morbidity and preventable death. This changed with the development of selective NOM for stable and clinically evaluable patients without peritonitis. Selective management does not remove the need for urgent surgery in patients with hemodynamic instability (HI), evisceration, impalement, or generalized peritonitis [2].

Current trauma guidelines show that patient physiology is the central determinant of the initial decision. The Eastern Association for the Surgery of Trauma guideline states that urgent laparotomy is indicated for PAT patients with HI or peritonitis, while selected stable patients observed or investigated further. The same guideline supports abdominopelvic CT in patients chosen for initial NOM, but warns that reducing nontherapeutic

laparotomy must not delay diagnosis or treatment of significant injury [3].

Algorithm-based approaches refine this decision process, and the Western Trauma Association stab wound algorithm supports serial clinical examination, local wound exploration, CT, laparoscopy, or operation according to wound site, examination reliability, and institutional capability [4]. For abdominal gunshot wounds, the Western Trauma Association algorithm supports selective evaluation in appropriate settings, and assumes access to a designated trauma center, trauma-surgeon direction, imaging, blood products, and operative backup [4].

Imaging is central to modern trauma pathways, and its role differs by physiological status. FAST is a bedside, rapid, repeatable tool for detecting hemoperitoneum, hemopericardium, and hemothorax during initial resuscitation [5]. Contrast-enhanced CT provides precise anatomical information about trajectory and organ involvement [6].

Bowel and mesenteric injuries were difficult because clinical signs develop late and CT can miss some injuries. WSES guideline show serial examination, observation, repeat imaging when patient stable, and OI when the case deteriorates [7]. Recent ED study similarly describe management as a physiology-driven pathway integrating ATLS assessment, FAST, CT for stable patients, damage-control surgery, and selective NOM when criteria are met [8].

Studies on abdominal gunshot wounds found that selective NOM reduce unnecessary laparotomy, with low failure-related mortality in pooled data. Most of these studies applies to stable patients and cannot be directly generalized to HI nonresponders [9]. Our systematic review evaluates OI versus IBPs for PAT with HI, focusing on ED triage, imaging use, operative timing, NOM diversion, mortality, transfusion, hospital stay, and procedure-related outcomes.

## Methods

This systematic review was conducted according to PRISMA guidelines (Fig 1) to evaluate OI versus imaging-based pathways for patients presenting to the ED with PAT and HI. The review focused on original studies that reported clinical management pathways, diagnostic imaging use, operative decision-making, and patient outcomes in this trauma population.

A literature search was performed using MEDLINE, Web of Science, Scopus, Embase, and the Cochrane Library. Additional eligible studies were identified by manual screening of the reference lists of relevant articles. The search strategy combined terms related to PAT, HI, ED management, OI, CT, focused assessment with sonography for trauma, and NOM or IBPs. Search terms included combinations of: “penetrating abdominal trauma,” “abdominal gunshot wound,” “stab wound,” “hemodynamic instability,” “unstable trauma,” “computed tomography,” “CT,” “FAST,” “laparotomy,” “operative management,” “damage control surgery,” and “selective nonoperative management.” The search was limited to studies involving human participants. No review articles, editorials, letters, commentaries, or case reports were included.

Studies were considered eligible if they were original research articles that included patients with PAT or thoracoabdominal trauma (TAT) and

reported data relevant to HI, hypotension, shock, or response to resuscitation. Eligible studies had to describe either a direct operative pathway, an IBPs, or both. IBPs included the use of CT or focused assessment with sonography for trauma before definitive OI or NOM. Studies were included when mortality, time to surgery, NOM, therapeutic laparotomy, transfusion requirements, hospital length of stay, complications, or additional procedures were reported.

Studies were excluded if they were reviews, systematic reviews, meta-analyses, case reports, editorials, conference abstracts without extractable data, or studies without original patient-level or cohort-level data. Studies were excluded if they focused only on blunt trauma, elective surgery, non-traumatic abdominal emergencies, or stable PAT without relevant data on HI. Articles that discussed general abdominal trauma patterns without reporting OI versus IBPs were not included in the final result synthesis.

Screening was performed in two stages. First, titles and abstracts were reviewed to remove clearly irrelevant records. Second, full texts were assessed against the eligibility criteria. Only studies that matched the review question and provided extractable data for the target population were included.

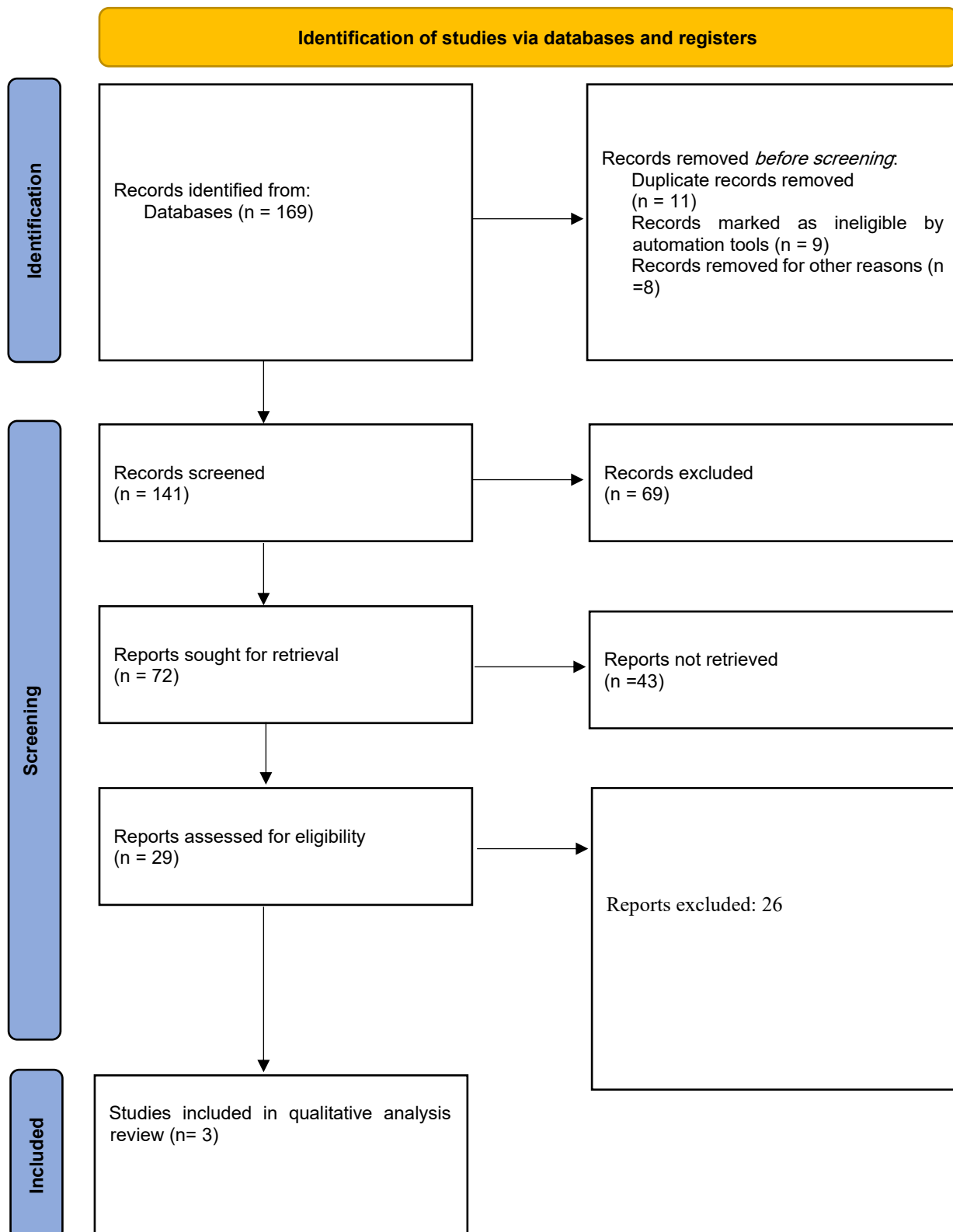
Data were extracted using a structured extraction approach. The extracted variables included author name, publication year, country, study design, study period, sample size, trauma mechanism, hemodynamic definition, imaging modality, operative pathway, NOM rate, time to imaging, time to operation, mortality, transfusion requirements, hospital stay, complications, and need for additional procedures. Because of differences in study design, population definitions, imaging protocols, and reported outcomes, the findings were analyzed qualitatively rather than pooled statistically. ROBINS-I was used for methodological quality assessment of the included

studies because all included studies were non-randomized observational studies comparing imaging-based triage versus direct OI (Table 1).

**Table 1: Methodological quality assessment (ROBINS-I)**

Study	D1: Confounding	D2: Selection of participants	D3: Classification of intervention	D4: Deviations from intended pathway	D5: Missing data	D6: Outcome measurement	D7: Selective reporting	Overall risk of bias
Akin et al., 2026 [10]	Serious	Serious	Moderate	Moderate	Moderate	Low	Moderate	Serious risk of bias
Ordoñez et al., 2016 [11]	Serious	Serious	Low	Moderate	Low to moderate	Low	Moderate	Serious risk of bias
White et al., 2025 [12]	Serious	Serious	Low	Moderate	Moderate	Low	Moderate	Serious risk of bias

Fig 1: PRISMA flow chart



## Results

Three original studies met the eligibility criteria, consisted of one study focused on abdominal gunshot wounds and two studies reported extractable PAT data within HI trauma cohorts. All eligible studies used retrospective observational designs. The studies evaluated OI against CT-based or imaging-assisted triage, but the decision to proceed to CT or directly to surgery was not randomized and was influenced by clinical judgment, response to resuscitation, and institutional trauma workflow.

Akin et al. included 74 patients with abdominal gunshot wounds, of whom 47 were hemodynamically stable and 27 were hemodynamically unstable at presentation. Abdominal CT was performed in 67 patients, with a median time from admission to CT of 28 minutes. The median time to CT was similar between stable and unstable patients, at 28 and 30 minutes, respectively. CT findings supported NOM in 10 patients, and 13.5% of the total cohort. Among HI nonresponders, CT was performed in 7 of 11 patients, and 6 of these patients died. In patients who underwent surgery, the time to operation was shorter in unstable patients than in stable patients, with mean times of  $60.4 \pm 36.7$  and  $93.2 \pm 76.6$  minutes, respectively. The perioperative mortality rate was 9.3%, and all deaths occurred among HI nonresponders [10].

Ordoñez et al. evaluated 171 severely injured HI blunt and PAT patients, including a large PAT subgroup. CT was performed immediately in 80 patients, while 91 patients were transferred directly to the operating room and angiography suite. In the CT group, 43 patients were managed by NOM, 37

underwent surgery after CT, and 2 underwent angiography. No death occurred in the CT scanner or during intrahospital transfer. In the PAT subgroup, 86 patients were managed through the OI pathway and 37 underwent IBPs. Mortality was 15% in the OI group and 5% in the IBPs group, without a statistically significant difference. CT also diverted 38% of PAT patients away from OI and helped define OI, NOM, or angiographic management [11].

White et al. studied 235 initially unstable TAT patients who achieved hemodynamic improvement before definitive triage. 36 patients were triaged directly to the operating room and 199 underwent CT. In the PAT subgroup, mortality was 4.0% in the OI group and 0% in the CT group. Hospital length of stay was shorter in the CT group than in the OI group, at  $10 \pm 1.9$  versus  $19 \pm 4.4$  days. ICU length of stay and ventilator days did not differ significantly between the two groups. CT was associated with lower transfusion requirements, including packed red blood cells, fresh frozen plasma, and platelets, and with fewer additional procedures. The need for additional procedures was 13% after CT compared with 39% after direct operative triage [12].

The included studies showed that IBPs were feasible in selected PAT or TAT patients with HI after response to resuscitation. IBPs was not associated with higher mortality in the eligible comparative cohorts and was associated with reduced NOM diversion, lower transfusion burden, shorter hospitalization, or fewer additional procedures in selected patients [10–12]. Characteristics of the included studies and main findings presented in Table (2 & 3) respectively.

Table 2. Characteristics of included studies

Study	Country and setting	Design and period	Eligible population for this review	Hemodynamic definition	Pathway comparison
Akın et al., 2026 [10]	Türkiye, tertiary university hospital	Retrospective study, January 2013–January 2023	74 patients with abdominal gunshot wounds; 27 were hemodynamically unstable	Patients classified as stable or unstable according to admission parameters and response to resuscitation	Abdominal CT use versus OI timing and decision-making
Ordoñez et al., 2016 [11]	Colombia, Level I trauma center	Retrospective cross-sectional study, 2012–2013	171 severely injured hemodynamically unstable trauma patients; 123/171 had PAT	SBP <100 mmHg and/or HR >100 bpm and/or ≥4 units PRBC transfused in trauma bay	Immediate CT versus direct OR and angio suite
White et al., 2025 [12]	USA, Level I trauma center	Retrospective study, 2015–2022	235 hemodynamically abnormal TAT patients; PAT subgroup had 66 patients	HR ≥120 bpm and/or SBP <90 mmHg, then included if SBP improved to ≥90 mmHg	ER-to-CT versus ER-to-definitive therapy/OR

Table 3. main findings of the included studies

Study	Imaging-based pathway findings	Direct OI and definitive pathway findings	Main outcomes
Akın et al., 2026 [10]	Abdominal CT was performed in 67/74 patients. Median time to CT was 28 minutes overall, with similar time in stable and unstable patients: 28 vs 30 minutes. CT findings supported NOM in 10 patients (13.5%).	Among operated patients, mean time to operation was shorter in unstable than stable patients: 60.4±36.7 vs 93.2±76.6 minutes. Mean time to surgery was 73.4 minutes overall and 44.7 minutes in nonresponders.	Perioperative mortality was 9.3%, and all deaths occurred in hemodynamically unstable nonresponders. CT use was feasible in selected unstable patients.
Ordoñez et al., 2016 [11]	CT was performed immediately in 80/171 unstable patients. In the CT group, 43/80 were managed by NOM and 37/80 underwent surgery after CT. CT diverted 38% of PAT patients away from OI.	91/171 patients went directly to operating room and angio suite; procedures included 63 laparotomies and 20 thoracotomies.	PAT subgroup mortality was 5% in CT patients versus 15% in direct OR/angio patients, not statistically significant. No patient died or arrested in the CT scanner or during intrahospital transfer.
White et al., 2025 [12]	In the PAT subgroup, 40 patients underwent CT before definitive therapy. CT patients had lower transfusion burden: PRBC 1.3±0.4 vs 4.5±0.9 units, FFP 0.8±0.3 vs 2.2±0.7 units, and fewer additional procedures: 13% vs 39%.	In the PAT subgroup, 26 patients went directly to OR/definitive therapy.	Mortality was 0% in CT patients versus 4.0% in operating room patients; hospital length of stay was shorter with CT: 10±1.9 vs 19±4.4 days. No mortality advantage was proven. Hospitalization and intervention burden were lower in the CT pathway.

## Discussion

The findings of this review indicate that CT-based triage is not equivalent to routine CT for all unstable PAT patients. According to the included studies, imaging was used in selected patients whose physiology allowed transfer, monitoring, and continued resuscitation. The apparent safety of CT was observed in responders or abnormal patients who improved after resuscitation [10]. The results support a balanced pathway between immediate OI and diagnostic precision. In abdominal gunshot wounds, CT was obtained rapidly and helped identify patients suitable for NOM or better planned surgery, but deaths clustered among unstable nonresponders [10]. Immediate CT in severely injured unstable trauma patients was feasible in a high-resource trauma system where the scanner was close to the trauma bay and resuscitation continued during imaging [11]. White et al. supported CT after hemodynamic improvement, with lower transfusion requirements and fewer additional procedures in scanned patients, but the authors emphasized caution in PAT transient responders, especially when thoracic or cardiac injury is likely [12].

These findings are consistent with trauma studies showing that imaging reduce unnecessary OI but must not delay hemorrhage control. Cook et al. found that CT in initially hypotensive patients with a positive FAST was associated with lower odds of urgent operation and higher odds of angiographic intervention, without a significant difference in 30-day mortality [13]. This supports the concept that CT redirect management when physiology permits safe scanning. FAST alone is insufficient as a rule-out test in hypotensive trauma. Rowell et al. showed that FAST had limited sensitivity for therapeutic laparotomy and that a negative FAST did not exclude significant abdominal hemorrhage in PAT [14].

The regional studies from Saudi Arabia, Qatar, Oman, and the United Arab Emirates did not directly

answer this review question. They show the continuing relevance of selective management, negative laparotomy avoidance, trauma-system resources, and damage control surgery in abdominal trauma care [15–17]. Al-Ozaibi et al. emphasized that shock, evisceration, and generalized peritonitis warrant immediate laparotomy after penetrating stab wounds, while stable patients can be considered for selective observation or CT-based evaluation [16].

This review is limited by retrospective designs, small eligible PAT subgroups, variable definitions of HI, and selection bias. No included study randomized unstable PAT patients to CT or immediate OI. Direct OI are appropriate for nonresponders, peritonitis, evisceration, or suspected major TAT bleeding, while CT may be reasonable for monitored responders in trauma systems able to provide rapid imaging, immediate surgical backup, and uninterrupted resuscitation.

## Conclusion

CT was feasible when patients responded to resuscitation, imaging was rapidly accessible, and trauma teams maintained close monitoring. The findings do not support routine CT for unstable nonresponders or patients with peritonitis, evisceration, or suspected uncontrolled hemorrhage. Direct OI is the safest pathway for patients requiring immediate source control. Future prospective studies should define clear physiologic thresholds, timing limits, and institutional requirements for safe imaging before definitive intervention in this population.

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