Patient Safety in Surgery

RESEARCH

Open Access

Evolution of management strategies for unstable pelvic ring injuries over the past 40 years: a systematic review

Kenichi Sawauchi[1,2,3*], Luca Esposito[2], Yannik Kalbas[1,2], Zygimantas Alasauskas[1,2], Valentin Neuhaus[1,2], Hans-Christoph Pape[1,2], Felix Karl-Ludwig Klingebiel[1,2†] and Roman Pfeifer[1,2†]

Abstract

Background Hemodynamically unstable pelvic ring fractures from high-energy trauma are critical injuries in trauma care, requiring urgent intervention and precise diagnostics. With ongoing advancements in trauma management, treatment strategies have evolved, with some techniques becoming obsolete as new ones emerge. This study aimed to evaluate changes and trends in treatment algorithms for these injuries over approximately 40 years.

Methods A systematic review of PubMed and EMBASE was conducted to include articles published over roughly four decades that presented visual treatment algorithms or workflows for managing unstable pelvic ring fractures. Identified algorithms were categorized by publication period and analyzed by initial assessment, diagnostic methods, pelvic stabilization, and hemorrhage control interventions.

Results The search identified 5,434 publications, of which 32 met the inclusion criteria. 75% of these studies were published between 2011 and 2022, reflecting a growing focus on standardization, particularly in Europe, North America, and Asia. Physiological assessment remains essential in the initial management of hemodynamically unstable pelvic ring fractures, guiding resuscitation and influencing the selection of intervention and imaging. The use of pelvic binders or sheets has risen steadily, highlighting their role in hemorrhage control and temporary stabilization. CT scans and angiography have largely replaced pelvic X-rays in diagnostic protocols, becoming preferred radiological methods alongside focused assessment with sonography for trauma (FAST). Pelvic stabilization remains critical, with external fixation being the most commonly used technique, showing an upward trend in recent years. Laparotomy, pelvic packing, and angioembolization continue to play vital roles in hemorrhage management. Emerging techniques, such as resuscitative endovascular balloon occlusion of the aorta (REBOA), anterior subcutaneous internal fixation (INFIX), and rescue screws, are increasingly included in treatment algorithms, while diagnostic peritoneal lavage (DPL) has become obsolete and is no longer listed in these algorithms.

Conclusions This review provides foundational insights toward the standardization of initial treatment for hemodynamically unstable pelvic ring fractures and holds significant importance in enhancing the consistency and efficiency of treatment. Future research should focus on accumulating higher-quality evidence to evaluate the effectiveness of standardized protocols and explore the applicability of new treatment methods.

†Felix Karl-Ludwig Klingebiel and Roman Pfeifer contributed equally to this work.

*Correspondence:
Kenichi Sawauchi
kenichi519jp@gmail.com
Full list of author information is available at the end of the article

Keywords Pelvic ring fracture, Hemodynamically unstable pelvic fracture, Treatment algorithms for pelvic trauma, Emergency trauma management, Trauma care standardization, Pelvic hemorrhage management, Pelvic stabilization techniques, Systematic review

Background

Hemodynamically unstable pelvic ring fractures from high-energy trauma are among the most severe cases in trauma surgery, posing significant risks to patient survival due to massive hemorrhage from major pelvic vessels, which requires prompt and appropriate intervention in the acute phase [1, 2]. It is recommended that each patient with a pelvic ring injury is considered as a potential candidate for a "hidden shock" symptomatic until further diagnostics can disprove the possibility of retroperitoneal blood loss, which can initially be masked by the patient's compensation mechanism [3]. While timely initial management has been shown to improve survival rates [4], treating these fractures remains complex, involving multiple diagnostic and therapeutic steps that demand swift and accurate decision-making in clinical settings.

Despite the critical nature of this management, the standardization of initial treatment procedures and approaches remains insufficient, and treatment often depends on individual clinician judgment [5]. To address these inconsistencies, various medical facilities have implemented flowcharts designed to standardize initial treatment approaches, aiming to streamline decision-making and improve patient outcomes in emergency settings [6]. These structured pathways not only enhance transparency and care quality by reducing variability but also promote consistent adherence to essential steps.

However, research indicates substantial differences in flowchart content and structure across institutions, potentially affecting treatment uniformity [7]. The ongoing evolution of treatment techniques and diagnostic tools further complicates standardization, as newer flowcharts may lack clear criteria or sufficient supporting evidence, suggesting a need for continual refinement [8].

This systematic review aims to evaluate the development of initial treatment flowcharts for hemodynamically unstable pelvic ring fractures, analyzing variations over time to support future standardization efforts. By synthesizing current practices, this review seeks to lay the groundwork for a standardized approach, ultimately enhancing trauma care decision-making and clinical guidelines.

Methods

The reporting of this systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (http://www.prisma-statement.org/).

Eligibility criteria

A systematic review was conducted to identify all relevant publications regarding the initial management of patients with pelvic ring fractures associated with hemodynamic instability due to trauma. Only original articles written in English, German, or Japanese were included, that present flowcharts or visual treatment algorithms for the emergency management of unstable pelvic ring injuries. Exclusion criteria included studies on pediatric patients, isolated sacral fractures, military-related fractures, case reports, case series, reviews, editorials, studies without a clear description of treatment timing, studies not focused on emergency care, low-quality studies, and studies involving navigated or robotic-assisted procedures (as these are not applicable to emergency settings). In cases where multiple studies with flowcharts were published by the same institution or hospital, only the most recent publication was included in the analysis, and earlier studies from the same institution were excluded.

Information sources and search strategy

The Medline and EMBASE databases were searched to cover the period from January 1, 1980, to December 31, 2022. The final search was performed on February 25, 2023. The search strategy included a combination of controlled vocabulary terms (MeSH/Emtree terms) and regular search terms, connected using Boolean operators. Truncation was applied to account for plural forms and alternate spellings, and careful attention was paid to include all relevant synonyms. Filters were applied to exclude inappropriate article types. The full list of search terms is provided in Supplementary File 1. In addition, the reference lists of selected studies and relevant reviews were screened to identify additional sources. The search results were organized and deduplicated using Clarivate™ EndNote™ version 20.

Study selection

Titles and abstracts of the identified articles were independently screened by KS, FKLK, and LE. KS and FKLK cross-checked the extracted data, and any disagreements were resolved through personal discussion. Full texts of potentially eligible studies were retrieved through the university's central library via respective publishers.

Data extraction

Data extraction was conducted solely from the figures in the flowcharts/algorithms presented in the papers, and no data were extracted from the main text of the articles. The extracted items were categorized into five major areas: "Paper Information," "Initial Management," "Diagnostic Methods," "Pelvic Stabilization," and "Interventions for Hemorrhage Control."

For "Paper Information," the author names, paper title, journal name, year of publication, and country were extracted. Temporal trends in publication were also evaluated. Specifically, articles were stratified according to their publishing dates as follows: 1980 to 1985, each subsequent 5-year period after 1986, and the period from 2021 to 2022. This resulted in a 6-year period for 1980–1985 and a 2-year period for 2021–2022. The average number of publications per year for each period was assessed. The number of publications by region was also analyzed. For "Initial Management", "Diagnostic Methods", "Pelvic Stabilization", and "Interventions for Hemorrhage Control", the presence of each respective procedure or method in the flowcharts was evaluated. The presence or absence of these elements was recorded as "Yes," "No," or "UNK = Unknown", "NA = Not Applicable". The results were further analyzed by dividing them into four periods: 1980–2010, 2011–2015, 2016–2020, and 2021–2022, and the proportions for each response were calculated for these time frames.

The specific items extracted for "Initial Management" included:

- Was the stability of the fracture assessed?
- Was the patient's physiology taken into account?
- Were other sources of bleeding (from other body regions/injuries) ruled out?
- Was a pelvic binder or sheet applied?
- Were resuscitation efforts described?

For "Diagnostic Methods", the following items were evaluated:

- Focused Assessment with Sonography for Trauma (FAST).
- Diagnostic Peritoneal Lavage (DPL).
- X-ray of the pelvis.
- Computed Tomography scan (CT-scan).
- Angiography.

For "Pelvic Stabilization", the following items were included:

- Was any form of pelvic fixation/stabilization was performed (excluding pelvic binders or sheets)?
- External fixation.
- C-clamp.
- Anterior subcutaneous internal fixation (INFIX).
- Rescue screws.
- Open reduction and internal fixation (Definitive fixation) (ORIF).

For "Interventions for Hemorrhage Control", the following items were extracted:

- Laparotomy.
- Pelvic packing.
- Angioembolization.
- Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA).

Results

Study selection

The flowchart detailing the study selection process is presented in Fig. 1. A systematic search of the Medline database yielded 1,932 results, and an additional 3,465 records were identified through EMBASE. Furthermore, 37 additional records were identified from other sources. After removing 1,213 duplicates, 4,221 records were screened, with 3,811 records excluded. Of the remaining 410 full-text articles assessed, 369 were excluded due to the absence of flowcharts addressing initial treatment or early management. Of the 41 remaining studies, 9 duplicate studies from the same institution were excluded, leaving 32 studies that were ultimately included in this review [9–40].

Paper information

Information regarding all included studies is provided in Table 2 in Appendix. A total of 32 studies published between 1980 and 2022 met the inclusion criteria and were included in this review. The number of studies incorporating flowcharts for initial treatment and management has increased in recent years, with 24 studies published between 2011 and 2022, accounting for 75% of the total. The number of publications during the four time periods used in subsequent evaluations—1980–2010, 2011–2015, 2016–2020, and 2021–2022—were 8, 7, 10, and 7, respectively. Moreover, the trend of increasing publications per year has become more pronounced in recent years, with an average of 3.5 studies published annually in the 2021–2022

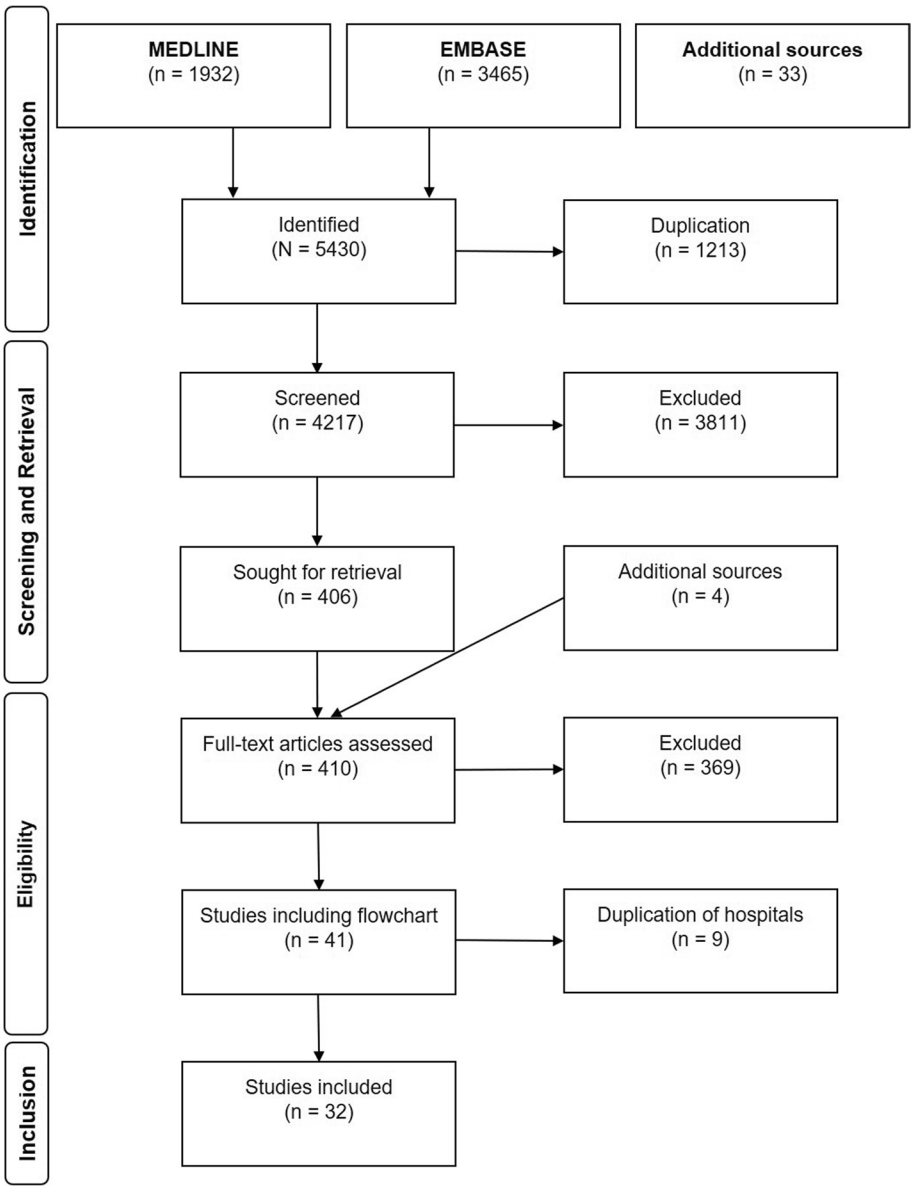

Fig. 1 Flowchart of this systematic review

period (Fig. 2). Additionally, when categorizing the institutions where treatments were conducted by region, Europe accounted for 14 studies, followed by North America with 8, Asia with 7, the Middle East with 2, and South America with 1 (Table 1).

Initial management

The results of the evaluation items related to initial management are presented in Table 3 in Appendix; Fig. 3. Fracture stability assessment was documented in 50.0% (16/32), physiological assessment in 100% (32/32), ruling out other bleeding sources in 31.3% (10/32), pelvic binder or sheet application in 68.8% (22/32), and resuscitation measures in 53.1% (17/32).

Regarding fracture stability assessment, no marked changes were observed across different time periods. Physiological assessment was consistently included in all flowcharts across all time periods. In contrast, exclusion of other bleeding sources exhibited considerable variation between time periods, with no clear trend observed. The use of pelvic binders or sheets showed a steady increase over time, reaching 100%

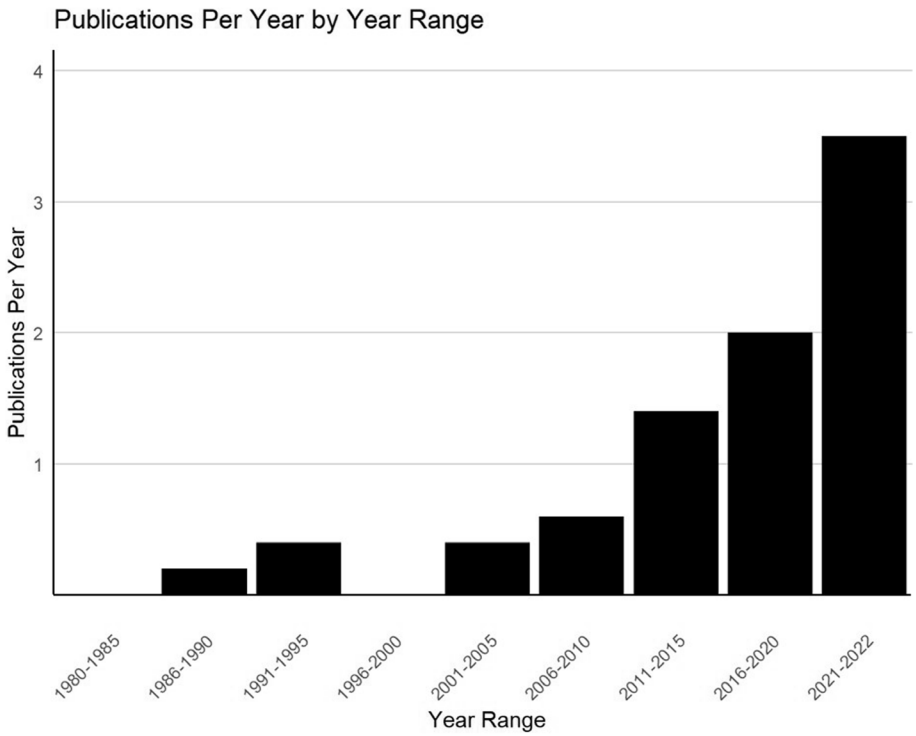

Fig. 2 Annual number of publications featuring flowcharts on initial management, assessment, and treatment

Table 1 Regional distribution of treatment institutions

Region	Papers	Details
Asia	7	Hong Kong (2), Japan (1), South Korea (2), Taiwan (2)
Europe	14	Austria (1), France (1), Germany (1), Italy (4), Netherlands (2), Norway (2), Switzerland (2), UK (1)
Middle East	2	Israel (2)
North America	8	USA (8)
South America	1	Brazil (1)

(7/7) in the 2021–2022 period. Documentation of resuscitation efforts also saw a notable increase after 2011.

Diagnostic method

The results related to diagnostic methods are presented in Table 4 in Appendix; Fig. 4. FAST was used in 81.2% of the studies (26/32), DPL in 15.6% (5/32), pelvic X-ray in 56.3% (18/32), CT scan in 74.2% (23/31), and angiography in 87.1% (27/31).

FAST was consistently used across all time periods, with a particularly notable increase after 2011. DPL was used to some extent in the early stages, but it was no longer included in flowcharts after 2016. Regarding radiological diagnostics, until 2015, there was no marked difference in the usage rates between pelvic X-ray and CT scan; however, after 2016, the use of CT scan increased. Angiography maintained a high usage rate across all time periods, and in the 2021–2022 period, both CT scan and angiography were included in 100% of the flowcharts (6/6).

Pelvic stabilization

The results related to pelvic stabilization are presented in Table 5 Appendix; Fig. 5. Including papers where details were not explicitly mentioned, some form of pelvic fixation was documented in 78.1% (25/32) of the flowcharts. Specifically, external fixation was noted in 56.3% (18/32), C-Clamp in 9.4% (3/32), INFIX in 6.3% (2/32), rescue screws in 3.1% (1/32), and ORIF in 25.0% (8/32). External fixation was the most frequently documented method of fixation. Additionally, there was a tendency for the usage of external fixation to increase over time.

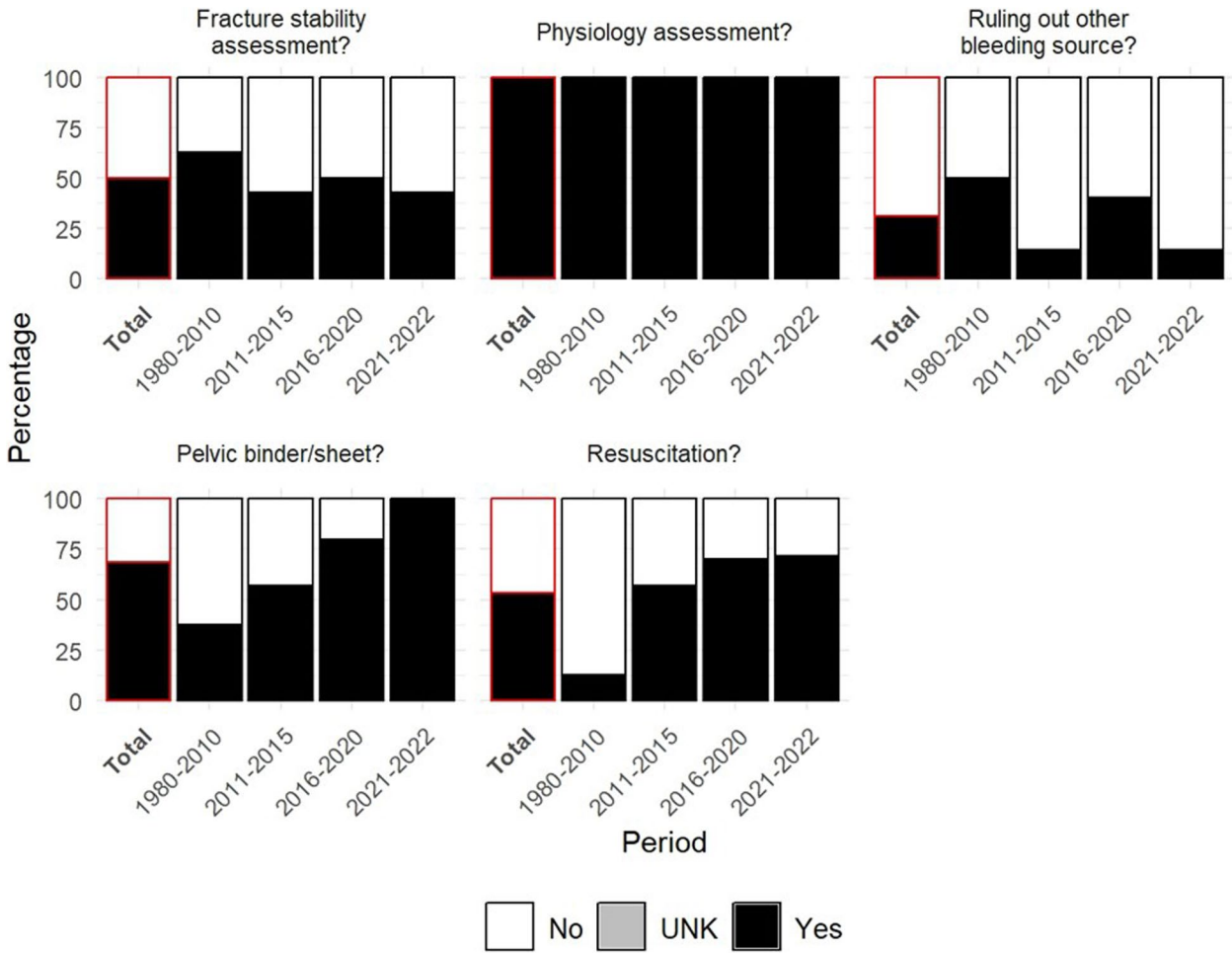

Fig. 3 Initial management

Interventions for hemorrhage control

The results related to interventions for hemorrhage control are presented in Table 6 Appendix; Fig. 6. Laparotomy was documented in 78.1% (25/32) of the studies, pelvic packing in 62.5% (20/32), angioembolization in 56.3% (18/32), and REBOA in 18.8% (6/32). Laparotomy showed relatively high usage rates across all time periods. Although some cases of pelvic packing were categorized as "UNK," its documentation has markedly increased since 2011. The use of angioembolization showed no evident variation across the different periods. REBOA was first documented after 2016, and its use has been increasing in recent years.

Discussion

Based on this systematic review of treatment algorithms for pelvic ring injuries we conclude the following main findings:

- The number of publications featuring initial treatment flowcharts for hemodynamically unstable pelvic ring fractures has risen in recent years, reflecting a growing interest in standardization, primarily from institutions in Europe, North America, and Asia.
- Physiological assessment remains essential in the initial management of hemodynamically unstable pelvic ring fractures, as it guides the decision-making process for resuscitation measures.
- The recommendation for the use of pelvic binders or sheets has progressively increased over recent years, underscoring their perceived value in flowcharts for hemorrhage control and temporary pelvic stabilization.
- CT scans and angiography have increasingly replaced pelvic X-rays in diagnostic protocols, ultimately becoming more commonly radiological method alongside FAST, while pelvic X-rays remain

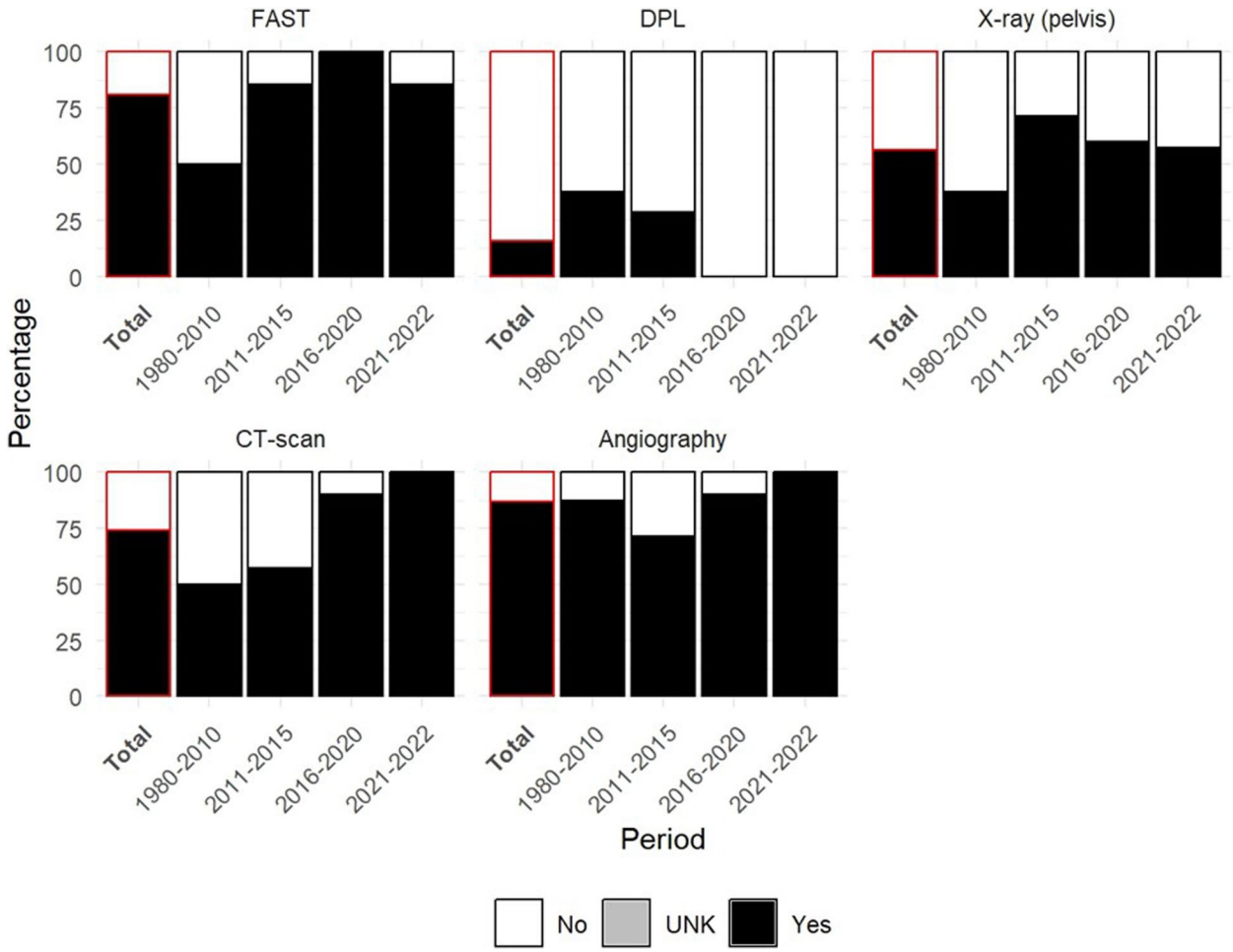

Fig. 4 Diagnostics methods

an important tool for assessing patients with unstable conditions.

- Pelvic stabilization remains a critical aspect of trauma management, with various methods reported; however, external fixation continues to be the most frequently utilized technique, showing an increasing trend in usage in recent years.
- Laparotomy, pelvic packing, and angioembolization continue to play essential roles in managing hemorrhage in hemodynamically unstable patients with pelvic fractures, while the use of REBOA has notably increased in recent years.

Initial management

The assessment of fracture stability is included in approximately half of the flowcharts across all periods. In contrast, physiological assessment appears in 100% of the flowcharts, as understanding vital signs and levels of consciousness is essential for determining emergency severity and stabilizing hemodynamics, and plays a critical role in establishing the initial treatment plan. Similarly to the assessment of fracture stability, the exclusion of other bleeding sources is not frequently included in flowcharts during any period. This pattern may suggest that such evaluations are commonly performed by clinicians without requiring explicit mention in the flowcharts. Including too many details in the flowchart risks complicating it and potentially delaying the primary objectives of rapid initial management and treatment. However, in life-threatening conditions, even basic evaluations like fracture stability and the exclusion of bleeding from other sources might be overlooked. According to Pfeifer et al., the clearance process for fracture fixation in polytrauma patients prioritizes initial physiological stabilization but also

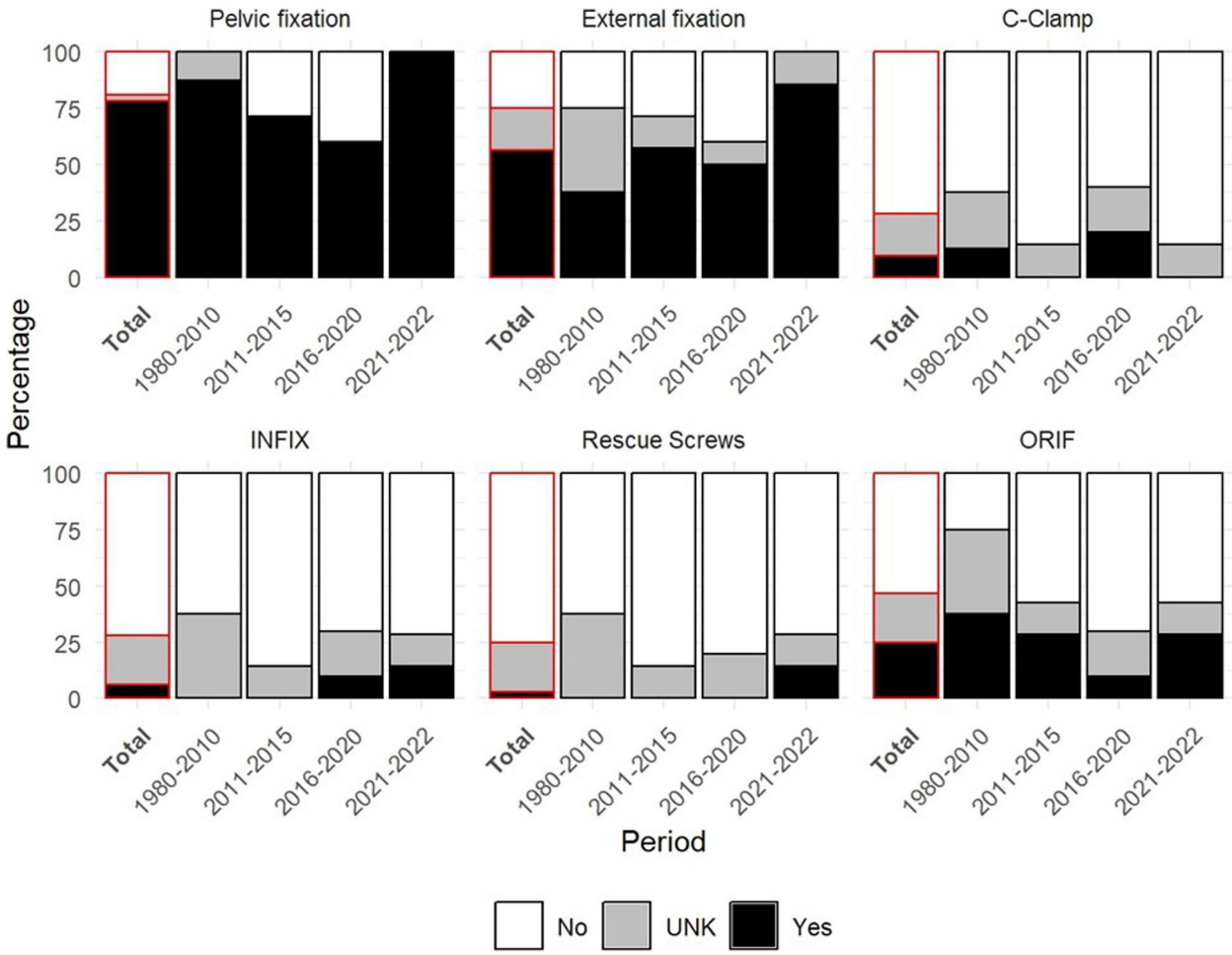

Fig. 5 Pelvic stabilization

necessitates a rapid assessment of fracture and other organ status as part of a comprehensive evaluation [41]. Therefore, the inclusion of elements such as fracture stability assessment and the exclusion of other bleeding sources within the flowcharts may be worth considering, provided they do not lead to overcomplication or confusion.

The use of pelvic binders and sheets has been on the rise, with every flowchart in the literature from 2021 to 2022 including references to them. Research on cadavers has suggested that pelvic binders significantly increase intrapelvic pressure, which helps minimize venous bleeding [42]. While improper placement has been reported as an issue [43], including them in flowcharts is considered beneficial for hemorrhage control and temporary pelvic stabilization [44]. Documentation on resuscitation has notably increased since 2011, and similar to fracture stability assessment and bleeding exclusion, including these aspects without overly complicating the flowchart may be worth considering.

Diagnostic method

FAST was included in over 80% of the flowcharts and became particularly prominent in publications from 2011 onward. Since its introduction in the 1990s, FAST has become a rapid and effective diagnostic tool in trauma care [45], which explains its lower usage rate in earlier years. According to Smith and Wood, the sensitivity and specificity of FAST scans for blunt trauma are as high as 93.1% and 100%, respectively, underscoring its utility in quickly assessing unstable patients and guiding initial treatment [46]. This high accuracy makes FAST an essential component of the flowcharts for rapidly diagnosing and stabilizing pelvic fractures accompanied by hemodynamic instability. On the other hand, DPL appears in a smaller

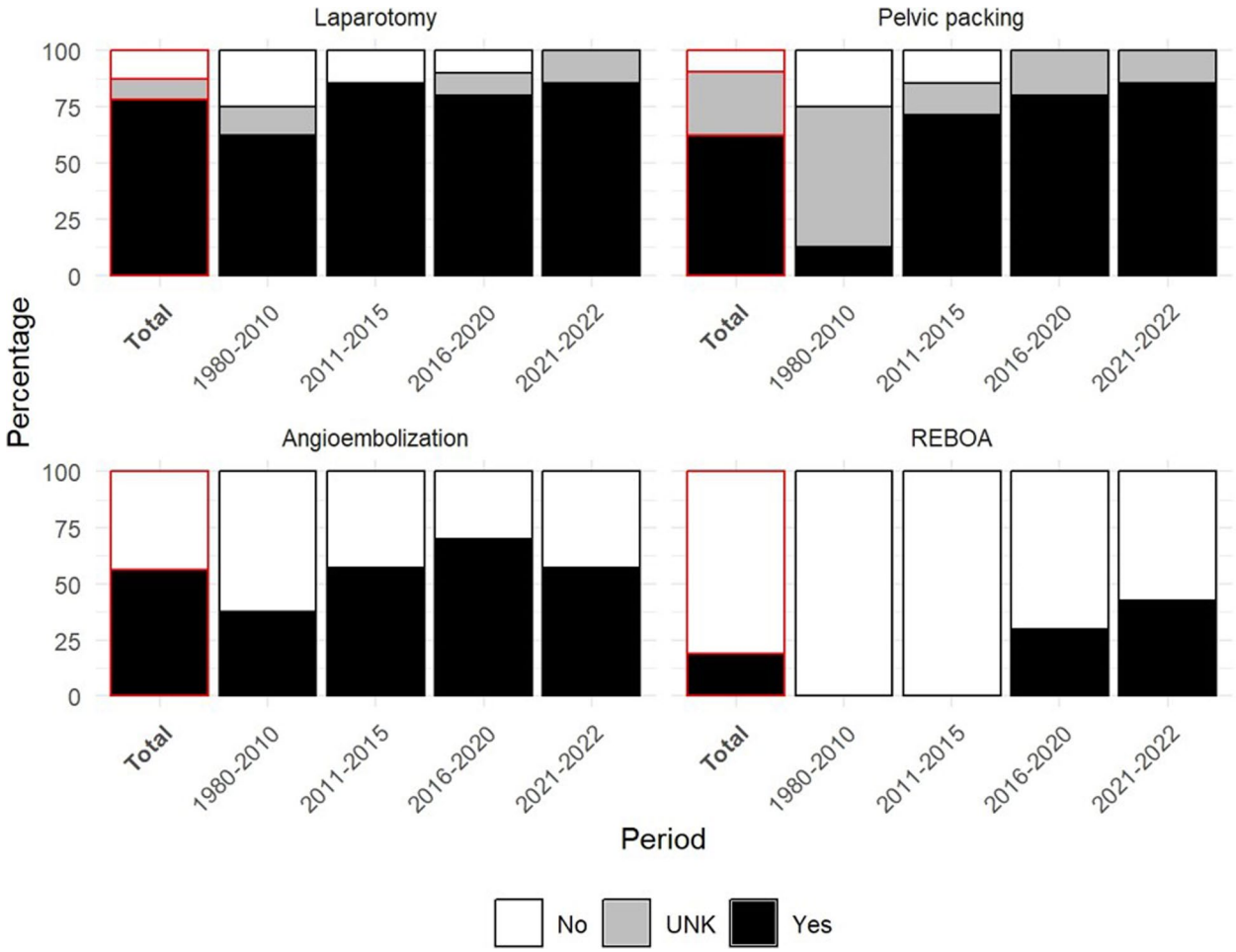

Fig. 6 Interventions for Hemorrhage Control

proportion of flowcharts and has not been included at all since 2016. This aligns with reports indicating that DPL usage has declined with the increasing adoption of FAST [47]. Given that FAST is a non-invasive and quick diagnostic method, it suggests that DPL is unlikely to be frequently used in the future.

Pelvic X-rays appear in approximately 50% of flowcharts across all periods, indicating a role in the initial assessment of pelvic ring fractures with hemodynamic instability, though not necessarily as a primary diagnostic priority. This may be attributed to the increased use of more advanced imaging modalities, such as CT scans, which offer superior diagnostic capabilities. While pelvic X-ray remains an integral part of the ATLS assessment, a retrospective study by Hilty et al. indicates that in hemodynamically stable patients with a clinically stable pelvis, its sensitivity is only 67%, and it may safely be omitted in favor of pelvic CT if such adjunctive imaging is planned and available [48]. However, in physiologically highly unstable patients, pelvic X-ray might still be required to expedite initial assessment and facilitate rapid decision-making. CT scan inclusion in flowcharts has increased significantly, from 50% in 1980–2010 to universal inclusion in 2021–2022. The improvements in CT technology and its enhanced speed and diagnostic precision underscore its growing importance in assessing pelvic fractures, identifying hemorrhage sources, and establishing treatment plans. Angiography has also been consistently included and mentioned separately from CT imaging in a high percentage of flowcharts across all periods, highlighting its value in rapidly identifying and controlling bleeding in cases of hemodynamically unstable pelvic ring fractures. Nowadays, angiography is usually integrated in the emergency CT scans, allowing for more rapid and accurate assessment of

trauma, including arterial injuries, and providing a more effective diagnostic approach compared to performing them separately [49]. Considering the above, it is recommended that FAST, CT scans, and Angiography be included in flowcharts as evaluation methods, provided that the facility's resources and human capital allow.

Pelvic stabilization

Pelvic fixation is included in high frequency across all periods, reflecting its consistent role as a critical intervention for hemodynamically unstable pelvic ring fractures. Pelvic stabilization reduces intrapelvic bleeding and lowers the risk of hemorrhagic shock, confirming its efficacy [50]. External fixation is the most commonly used stabilization technique, largely due to its relatively rapid implementation and less demanding training requirements compared to other methods [5]. On the other hand, techniques such as C-Clamp, INFIX, rescue screws, and ORIF require more advanced skills and specialized expertise, and as a result, are typically limited to select facilities. For instance, C-Clamp is effective for posterior pelvic stabilization in patients with hemodynamic instability, yet its application requires specific training to avoid potential complications [51]. Similarly, rescue screws play a critical role in sacroiliac joint stabilization in emergency cases; however, inadequate training can increase the risk of screw misplacement and associated nerve injury [52]. Because these methods are not always clearly defined in flowcharts, definitive conclusions are challenging. However, pelvic stabilization, especially through external fixation, remains crucial in initial treatment, and including these approaches in flowcharts is recommended. Furthermore, external fixation and C-Clamp are commonly used as temporary measures for pelvic stabilization, while INFIX, rescue screws, and ORIF are primarily used for definitive fixation. These techniques are systematically incorporated into several flowcharts according to the treatment phase and the patient's physiology according to the safe definitive surgery concept (SDS) [53].

Interventions for hemorrhage control

Laparotomy is frequently included in all periods and remains the primary method for hemorrhage control in pelvic ring fractures. In contrast, pelvic packing was rarely mentioned in publications from 1980 to 2010, but its inclusion has increased significantly in more recent literature. Pelvic packing may not always be explicitly noted in the flowcharts, as it is often described within the context of laparotomy. Angioembolization is slightly less frequently included than pelvic packing, likely due to the specialized skills and resources required for its implementation. Both preperitoneal packing and angioembolization have been shown to be effective in controlling bleeding in hemodynamically unstable pelvic fracture patients, but meta-analyses suggest no significant difference in mortality between the two, highlighting the need for further evidence [54]. REBOA first appeared in the flowcharts in 2016 and has gradually gained traction as an emerging method for temporarily controlling bleeding through balloon occlusion [55]. These findings suggest that while laparotomy continues to be positioned as the standard treatment method, pelvic packing follows closely in terms of usage rate. Additionally, newer techniques such as REBOA are on the rise, and these methods are anticipated to contribute to the standardization of future flowcharts.

Limitation

This review has several limitations. First, as it is based on past literature, it may not fully reflect actual clinical outcomes or the latest technologies. In particular, if new technologies or protocols have been introduced, their effects may not be represented. Additionally, variations in the algorithms present another limitation. The algorithms reviewed differed in both specific details and holistic structure, with some steps in certain algorithms being indicative but not consistently standardized; as a result, these steps were not uniformly included in this analysis. Furthermore, it remains unclear whether the effectiveness of the flowcharts can be uniformly applied across all facilities. Future research should focus on validating these flowcharts with real clinical data and developing flexible guidelines that can be adapted to the unique conditions of different facilities.

Conclusions

This review provides foundational insights toward the standardization of initial treatment for hemodynamically unstable pelvic ring fractures and holds significant importance in enhancing the consistency and efficiency of treatment. The development of standardized flowcharts has the potential to contribute to improved patient outcomes and higher quality of care by unifying diagnostic procedures and establishing appropriate treatment protocols, representing a crucial step in refining clinical guidelines. Furthermore, future research should focus on accumulating higher-quality evidence to evaluate the effectiveness of standardized protocols and explore the applicability of new treatment methods.

Appendix

Table 2 Summary of included studies

Authors	Paper title	Journal	Year	Country
Evers BM, et al. [9]	Pelvic fracture hemorrhage. Priorities in management	Archives of Surgery	1989	USA
Gruen GS, et al. [10]	The acute management of hemodynamically unstable multiple trauma patients with pelvic ring fractures	The Journal of Trauma	1994	USA
van Veen IH, et al. [11]	Unstable pelvic fractures: a retrospective analysis	Injury	1995	Netherlands
Biffl WL, et al. [12]	Evolution of a multidisciplinary clinical pathway for the management of unstable patients with pelvic fractures	Annals of Surgery	2001	USA
Cook RE, et al. [13]	The role of angiography in the management of haemorrhage from major fractures of the pelvis	Journal of Bone and Joint Surgery - Series B	2002	UK
Croce MA, et al. [14]	Emergent Pelvic Fixation in Patients with Exsanguinating Pelvic Fractures	Journal of the American College of Surgeons	2007	USA
Tötterman A, et al. [15]	Extraperitoneal pelvic packing: a salvage procedure to control massive traumatic pelvic hemorrhage	The Journal of Trauma	2007	Norway
Jeske HC, et al. [16]	Management of hemorrhage in severe pelvic injuries	The Journal of Trauma	2010	Austria
Black EA, et al. [17]	Open pelvic fractures: the University of Tennessee Medical Center at Knoxville experience over ten years	The Iowa orthopaedic journal	2011	USA
Fu CY, et al. [18]	Angioembolization provides benefits in patients with concomitant unstable pelvic fracture and unstable hemodynamics	American Journal of Emergency Medcine	2012	Taiwan
Abrassart S, et al. [19]	Unstable pelvic ring injury with hemodynamic instability: what seems the best procedure choice and sequence in the initial management?	Orthopaedics & Traumatology: Surgery & Research	2013	Switzerland
El-Haj M, et al. [20]	Outcome of angiographic embolisation for unstable pelvic ring injuries: Factors predicting success	Injury	2013	Israel
Cheng M, et al. [21]	Improvement in institutional protocols leads to decreased mortality in patients with haemodynamically unstable pelvic fractures	Emergency Medicine Journal	2015	Hong Kong
Lustenberger T, et al. [22]	The role of angio-embolization in the acute treatment concept of severe pelvic ring injuries	Injury	2015	Germany
Ron G, et al. [23]	Extra-peritoneal pressure packing without external pelvic fixation: A life-saving stand-alone surgical treatment	Journal of Emergencies, Trauma and Shock	2015	Israel
Chiara O, et al. [24]	Efficacy of extra-peritoneal pelvic packing in hemodynamically unstable pelvic fractures, a Propensity Score Analysis	World Journal of Emergency Surgery	2016	Italy
Gaski IA, et al. [25]	Reduced need for extraperitoneal pelvic packing for severe pelvic fractures is associated with improved resuscitation strategies	Journal of Trauma and Acute Care Surgery	2016	Norway
Hermans E, et al. [26]	Research on relation of mortality and hemodynamics in patients with an acute pelvic ring fracture	Journal of Acute Disease	2016	Netherlands

Authors	Paper title	Journal	Year	Country
Burlew CC, et al. [27]	Preperitoneal pelvic packing reduces mortality in patients with life-threatening hemorrhage due to unstable pelvic fractures	The Journal of Trauma and Acute Care Surgery	2017	USA
Leung HCA, et al. [28]	Outcome of Haemodynamically Unstable Open Pelvic Fracture Patients Managed With "3-in-1" Pelvic Damage Control Protocol in a Major Trauma Centre	Journal of Orthopaedics, Trauma and Rehabilitation	2018	Hong Kong
Pieper A, et al. [29]	Resuscitative endovascular balloon occlusion of the aorta for pelvic blunt trauma and life-threatening hemorrhage: A 20-year experience in a Level I trauma center	The Journal of Trauma and Acute Care Surgery	2018	France
Chou CH, et al. [30]	Hemostasis as soon as possible? The role of the time to angioembolization in the management of pelvic fracture	World Journal of Emergency Surgery	2019	Taiwan
Lee MA, et al. [31]	Effects of the establishment of a trauma center and a new protocol on patients with hemodynamically unstable pelvic fractures at a single institution in Korea	European Journal of Trauma and Emergency Surgery	2019	South Korea
Frassini S, et al. [32]	Extraperitoneal packing in unstable blunt pelvic trauma: A single-center study	The Journal of Trauma and Acute Care Surgery	2020	Italy
Ito K, et al. [33]	Hybrid emergency room system improves timeliness of angioembolization for pelvic fracture	The Journal of Trauma and Acute Care Surgery	2020	Japan
Frassini S, et al. [34]	Emergency Management of Pelvic Bleeding	Journal of Clinical Medicine	2021	Italy
Hundersmarck D, et al. [35]	Pelvic packing and angio-embolization after blunt pelvic trauma: a retrospective 18-year analysis	Injury	2021	USA
Magnone S, et al. [36]	Prospective validation of a new protocol with preperitoneal pelvic packing as the mainstay for the treatment of hemodynamically unstable pelvic trauma: a 5-year experience	European Journal of Trauma and Emergency Surgery	2021	Italy
Tiziani S, et al. [37]	Early fixation strategies for high energy pelvic ring injuries - the Zurich algorithm	Injury	2021	Switzerland
Fonseca VC, et al. [38]	Predictive factors of mortality in patients with pelvic fracture and shock submitted to extraperitoneal pelvic packing	Revista do Colégio Brasileiro de Cirurgiões	2022	Brazil
Jang JY, et al. [39]	Comparison between external fixation and pelvic binder in patients with pelvic fracture and haemodynamic instability who underwent various haemostatic procedures	Scientific Reports	2022	South Korea
Tuchayi AM et al. [40]	Comparative effectiveness of pelvic arterial embolization versus laparotomy in adults with pelvic injuries: A National Trauma Data Bank analysis	Clinical Imaging	2022	USA

Table 3 Evaluation of initial management items

Authors	Fracture stability assessment	Physiology assessment	Ruling out other bleeding source	Pelvic binder/sheet	Resuscitation
Evers BM, et al. [9]	No	Yes	No	No	No
Gruen GS, et al. [10]	Yes	Yes	Yes	No	No
van Veen IH, et al. [11]	No	Yes	No	No	No
Biffl WL, et al. [12]	Yes	Yes	Yes	Yes	Yes
Cook RE, et al. [13]	Yes	Yes	No	No	No
Croce MA, et al. [14]	Yes	Yes	Yes	Yes	No
Tötterman A, et al. [15]	No	Yes	Yes	Yes	No
Jeske HC, et al. [16]	Yes	Yes	No	No	No
Black EA, et al. [17]	Yes	Yes	No	Yes	No
Fu CY, et al. [18]	Yes	Yes	No	No	No
Abrassart S, et al. [19]	Yes	Yes	No	No	No
El-Haj M, et al. [20]	No	Yes	Yes	Yes	Yes
Cheng M, et al. [21]	No	Yes	No	Yes	Yes
Lustenberger T, et al. [22]	No	Yes	No	Yes	Yes
Ron G, et al. [23]	No	Yes	No	No	Yes
Chiara O, et al. [24]	Yes	Yes	No	Yes	No
Gaski IA, et al. [25]	No	Yes	No	Yes	Yes
Hermans E, et al. [26]	Yes	Yes	No	Yes	Yes
Burlew CC, et al. [27]	Yes	Yes	No	Yes	Yes
Leung HCA, et al. [28]	No	Yes	No	Yes	Yes
Pieper A, et al. [29]	No	Yes	Yes	No	No
Chou CH, et al. [30]	No	Yes	Yes	No	No
Lee MA, et al. [31]	Yes	Yes	Yes	Yes	Yes
Frassini S, et al. [32]	Yes	Yes	No	Yes	Yes
Ito K, et al. [33]	No	Yes	Yes	Yes	Yes
Frassini S, et al. [34]	No	Yes	No	Yes	Yes
Hundersmarck D, et al. [35]	No	Yes	No	Yes	Yes
Magnone S, et al. [36]	No	Yes	No	Yes	No
Tiziani S, et al. [37]	Yes	Yes	No	Yes	Yes
Fonseca VC, et al. [38]	Yes	Yes	Yes	Yes	Yes
Jang JY, et al. [39]	No	Yes	No	Yes	No
Tuchayi AM et al. [40]	Yes	Yes	No	Yes	Yes

Table 4 Evaluation of diagnostic methods

Authors	FAST	DPL	X-ray (pelvis)	CT-scan	Angiography
Evers BM, et al. [9]	No	Yes	No	No	Yes
Gruen GS, et al. [10]	No	No	No	No	Yes
van Veen IH, et al. [11]	Yes	No	Yes	Yes	Yes
Biffl WL, et al. [12]	Yes	Yes	No	Yes	Yes
Cook RE, et al. [13]	Yes	Yes	No	Yes	Yes
Croce MA, et al. [14]	No	No	No	No	Yes
Tötterman A, et al. [15]	No	No	Yes	No	Yes
Jeske HC, et al. [16]	Yes	No	Yes	Yes	No
Black EA, et al. [17]	Yes	No	No	Yes	Yes
Fu CY, et al. [18]	Yes	No	Yes	No	No
Abrassart S, et al. [19]	No	No	No	No	Yes
El-Haj M, et al. [20]	Yes	No	Yes	Yes	Yes

Authors	FAST	DPL	X-ray (pelvis)	CT-scan	Angiography
Cheng M, et al. [21]	Yes	Yes	Yes	Yes	Yes
Lustenberger T, et al. [22]	Yes	No	Yes	Yes	Yes
Ron G, et al. [23]	Yes	Yes	Yes	No	No
Chiara O, et al. [24]	Yes	No	Yes	Yes	Yes
Gaski IA, et al. [25]	Yes	No	Yes	Yes	Yes
Hermans E, et al. [26]	Yes	No	Yes	Yes	Yes
Burlew CC, et al. [27]	Yes	No	No	Yes	Yes
Leung HCA, et al. [28]	Yes	No	No	Yes	Yes
Pieper A, et al. [29]	Yes	No	Yes	No	Yes
Chou CH, et al. [30]	Yes	No	Yes	Yes	Yes
Lee MA, et al. [31]	Yes	No	No	Yes	Yes
Frassini S, et al. [32]	Yes	No	Yes	Yes	Yes
Ito K, et al. [33]	Yes	No	No	Yes	No
Frassini S, et al. [34]	Yes	No	Yes	Yes	Yes
Hundersmarck D, et al. [35]	Yes	No	Yes	Yes	Yes
Magnone S, et al. [36]	Yes	No	No	Yes	Yes
Tiziani S, et al. [37]	No	No	No	NA	NA
Fonseca VC, et al. [38]	Yes	No	Yes	Yes	Yes
Jang JY, et al. [39]	Yes	No	No	Yes	Yes
Tuchayi AM et al. [40]	Yes	No	Yes	Yes	Yes

Table 5 Evaluation of pelvic stabilization methods

Authors	Pelvic fixation	External fixation	C-Clamp	INFIX	Rescue Screws	ORIF
Evers BM, et al. [9]	Yes	UNK	UNK	UNK	UNK	UNK
Gruen GS, et al. [10]	Yes	No	No	No	No	Yes
van Veen IH, et al. [11]	Yes	Yes	No	No	No	Yes
Biffl WL, et al. [12]	Yes	UNK	Yes	UNK	UNK	UNK
Cook RE, et al. [13]	Yes	Yes	No	No	No	No
Croce MA, et al. [14]	Yes	No	No	No	No	Yes
Tötterman A, et al. [15]	UNK	UNK	UNK	UNK	UNK	UNK
Jeske HC, et al. [16]	Yes	Yes	No	No	No	No
Black EA, et al. [17]	Yes	Yes	No	No	No	Yes
Fu CY, et al. [18]	No	No	No	No	No	No
Abrassart S, et al. [19]	Yes	Yes	No	No	No	No
El-Haj M, et al. [20]	Yes	Yes	No	No	No	Yes
Cheng M, et al. [21]	Yes	Yes	No	No	No	No
Lustenberger T, et al. [22]	Yes	UNK	UNK	UNK	UNK	UNK
Ron G, et al. [23]	No	No	No	No	No	No
Chiara O, et al. [24]	Yes	Yes	No	No	No	No
Gaski IA, et al. [25]	No	No	No	No	No	No
Hermans E, et al. [26]	Yes	Yes	Yes	Yes	No	Yes
Burlew CC, et al. [27]	Yes	UNK	UNK	UNK	UNK	UNK
Leung HCA, et al. [28]	Yes	Yes	Yes	No	No	No
Pieper A, et al. [29]	No	No	No	No	No	No
Chou CH, et al. [30]	No	No	No	No	No	No
Lee MA, et al. [31]	Yes	Yes	No	No	No	No
Frassini S, et al. [32]	Yes	Yes	UNK	UNK	UNK	UNK
Ito K, et al. [33]	No	No	No	No	No	No
Frassini S, et al. [34]	Yes	UNK	UNK	UNK	UNK	UNK

Authors	Pelvic fixation	External fixation	C-Clamp	INFIX	Rescue Screws	ORIF
Hundersmarck D, et al. [35]	Yes	Yes	No	No	No	Yes
Magnone S, et al. [36]	Yes	Yes	No	No	No	No
Tiziani S, et al. [37]	Yes	Yes	No	Yes	Yes	Yes
Fonseca VC, et al. [38]	Yes	Yes	No	No	No	No
Jang JY, et al. [39]	Yes	Yes	No	No	No	No
Tuchayi AM et al. [40]	Yes	Yes	No	No	No	No

Table 6 Evaluation of interventions for hemorrhage control

Authors	Laparotomy	Pelvic packing	Angioembolization	REBOA
Evers BM, et al. [9]	Yes	UNK	No	No
Gruen GS, et al. [10]	No	No	Yes	No
van Veen IH, et al. [11]	Yes	Yes	Yes	No
Biffl WL, et al. [12]	Yes	UNK	No	No
Cook RE, et al. [13]	Yes	UNK	No	No
Croce MA, et al. [14]	No	No	No	No
Tötterman A, et al. [15]	UNK	UNK	No	No
Jeske HC, et al. [16]	Yes	UNK	Yes	No
Black EA, et al. [17]	Yes	Yes	No	No
Fu CY, et al. [18]	Yes	UNK	Yes	No
Abrassart S, et al. [19]	Yes	Yes	Yes	No
El-Haj M, et al. [20]	No	No	No	No
Cheng M, et al. [21]	Yes	Yes	Yes	No
Lustenberger T, et al. [22]	Yes	Yes	Yes	No
Ron G, et al. [23]	Yes	Yes	No	No
Chiara O, et al. [24]	Yes	Yes	Yes	No
Gaski IA, et al. [25]	Yes	Yes	No	No
Hermans E, et al. [26]	Yes	Yes	Yes	No
Burlew CC, et al. [27]	Yes	Yes	No	Yes
Leung HCA, et al. [28]	Yes	Yes	Yes	No
Pieper A, et al. [29]	Yes	UNK	No	Yes
Chou CH, et al. [30]	No	Yes	Yes	No
Lee MA, et al. [31]	Yes	Yes	Yes	No
Frassini S, et al. [32]	UNK	Yes	Yes	No
Ito K, et al. [33]	Yes	UNK	Yes	Yes
Frassini S, et al. [34]	UNK	Yes	Yes	Yes
Hundersmarck D, et al. [35]	Yes	Yes	Yes	No
Magnone S, et al. [36]	Yes	Yes	No	No
Tiziani S, et al. [37]	Yes	UNK	Yes	No
Fonseca VC, et al. [38]	Yes	Yes	No	No
Jang JY, et al. [39]	Yes	Yes	No	Yes
Tuchayi AM et al. [40]	Yes	Yes	Yes	Yes

Abbreviations

CT-scan	Computed Tomography scan
DPL	Diagnostic Peritoneal Lavage
FAST	Focused Assessment with Sonography for Trauma
INFIX	Anterior Subcutaneous Internal Fixation
ORIF	Open Reduction and Internal Fixation
REBOA	Resuscitative Endovascular Balloon Occlusion of the Aorta
SDS	Safe Definitive Surgery
X-ray	X-radiation

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13037-024-00421-z.

Supplementary Material 1.

Acknowledgements
Not applicable.

Authors' contributions
K.S.: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. L.E.: Data curation, Investigation, Writing – review & editing. Y.K.: Conceptualization, Methodology, Writing – review & editing. Z.A.: Methodology, Writing – review & editing. V.N.: Methodology, Writing – review & editing. H.-C.P.: Conceptualization, Project administration, Supervision, Writing – review & editing. F.K.L.K.: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. R.P.: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Writing – review & editing. All the authors have read and approved the final article.

Funding
No external funding sources were utilized.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Trauma Surgery, University Hospital Zurich, University of Zurich, Raemistr. 100, Zurich 8091, Switzerland. [2]Harald-Tscherne Laboratory for Orthopaedic and Trauma Research, University of Zurich, Raemistr. 100, Zurich 8091, Switzerland. [3]Department of Orthopaedic Surgery, Kobe University Graduate School of Medicine, 7-5-1, Kusunoki-cho, Chuo- ku, Kobe 650-0017, Japan.

Received: 7 November 2024 Accepted: 28 November 2024
Published online: 27 December 2024

References

1. Gabbe BJ, de Steiger R, Esser M, Bucknill A, Russ MK, Cameron PA. Predictors of mortality following severe pelvic ring fracture: results of a population-based study. Injury. 2011;42:985–91.
2. White CE, Hsu JR, Holcomb JB. Haemodynamically unstable pelvic fractures. Injury. 2009;40:1023–30.
3. Stahel PF, Ziran N. The pathophysiology of pelvic ring injuries: a review. Patient Saf Surg. 2024;18:16.
4. Papakostidis C, Giannoudis PV. Pelvic ring injuries with haemodynamic instability: efficacy of pelvic packing, a systematic review. Injury. 2009;40(Suppl 4):S53–61.
5. Klingebiel FK, Hasegawa M, Parry J, Balogh ZJ, Sen RK, Kalbas Y, et al. Standard practice in the treatment of unstable pelvic ring injuries: an international survey. Int Orthop. 2023;47:2301–18.
6. Blondeau B, Orlando A, Jarvis S, Banton K, Berg GM, Patel N, et al. Variability in pelvic packing practices for hemodynamically unstable pelvic fractures at US level 1 trauma centers. Patient Saf Surg. 2019;13:3.
7. Jarvis S, Orlando A, Blondeau B, Banton K, Reynolds C, Berg GM, et al. Variability in the timeliness of interventional radiology availability for angioembolization of hemodynamically unstable pelvic fractures: a prospective survey among U.S. level I trauma centers. Patient Saf Surg. 2019;13:23.
8. Tang J, Shi Z, Hu J, Wu H, Yang C, Le G, et al. Optimal sequence of surgical procedures for hemodynamically unstable patients with pelvic fracture: a network meta-analysis. Am J Emerg Med. 2019;37:571–8.
9. Evers BM, Cryer HM, Miller FB. Pelvic fracture hemorrhage. Priorities in management. Arch Surg. 1989;124:422–4.
10. Gruen GS, Leit ME, Gruen RJ, Peitzman AB. The acute management of hemodynamically unstable multiple trauma patients with pelvic ring fractures. J Trauma. 1994;36:706–11. discussion 711-3.
11. van Veen IH, van Leeuwen AA, van Popta T, van Luyt PA, Bode PJ, van Vugt AB. Unstable pelvic fractures: a retrospective analysis. Injury. 1995;26:81–5.
12. Biffl WL, Smith WR, Moore EE, Gonzalez RJ, Morgan SJ, Hennessey T, et al. Evolution of a multidisciplinary clinical pathway for the management of unstable patients with pelvic fractures. Ann Surg. 2001;233:843–50.
13. Cook RE, Keating JF, Gillespie I. The role of angiography in the management of haemorrhage from major fractures of the pelvis. J Bone Joint Surg Br. 2002;84:178–82.
14. Croce MA, Magnotti LJ, Savage SA, Wood GW 2nd, Fabian TC. Emergent pelvic fixation in patients with exsanguinating pelvic fractures. J Am Coll Surg. 2007;204:935–9. discussion 940-2.
15. Tötterman A, Madsen JE, Skaga NO, Røise O. Extraperitoneal pelvic packing: a salvage procedure to control massive traumatic pelvic hemorrhage. J Trauma. 2007;62:843–52.
16. Jeske HC, Larndorfer R, Krappinger D, Attal R, Klingensmith M, Lottersberger C, et al. Management of hemorrhage in severe pelvic injuries. J Trauma. 2010;68:415–20.
17. Black EA, Lawson CM, Smith S, Daley BJ. Open pelvic fractures: the University of Tennessee Medical Center at Knoxville experience over ten years. Iowa Orthop J. 2011;31:193–8.
18. Fu CY, Wang YC, Wu SC, Chen RJ, Hsieh CH, Huang HC, et al. Angioembolization provides benefits in patients with concomitant unstable pelvic fracture and unstable hemodynamics. Am J Emerg Med. 2012;30:207–13.
19. Abrassart S, Stern R, Peter R. Unstable pelvic ring injury with hemodynamic instability: what seems the best procedure choice and sequence in the initial management? Orthop Traumatol Surg Res. 2013;99:175–82.
20. El-Haj M, Bloom A, Mosheiff R, Liebergall M, Weil YA. Outcome of angiographic embolisation for unstable pelvic ring injuries: factors predicting success. Injury. 2013;44:1750–5.
21. Cheng M, Cheung MT, Lee KY, Lee KB, Chan SC, Wu AC, et al. Improvement in institutional protocols leads to decreased mortality in patients with haemodynamically unstable pelvic fractures. Emerg Med J. 2015;32:214–20.
22. Lustenberger T, Wutzler S, Störmann P, Laurer H, Marzi I. The role of Angio-embolization in the acute treatment concept of severe pelvic ring injuries. Injury. 2015;46(Suppl 4):S33–8.
23. Ron G, Epstein D, Ben-Galim P, Klein Y, Kaban A, Sagiv S. Extra-peritoneal pressure packing without external pelvic fixation: a life-saving stand-alone surgical treatment. J Emerg Trauma Shock. 2015;8:181–7.
24. Chiara O, di Fratta E, Mariani A, Michaela B, Prestini L, Sammartano F, et al. Efficacy of extra-peritoneal pelvic packing in hemodynamically unstable pelvic fractures, a propensity score analysis. World J Emerg Surg. 2016;11:22.
25. Gaski IA, Barckman J, Naess PA, Skaga NO, Madsen JE, Kløw NE, et al. Reduced need for extraperitoneal pelvic packing for severe pelvic

fractures is associated with improved resuscitation strategies. J Trauma Acute Care Surg. 2016;81:644–51.
26. Hermans E, Biert J, van Vugt AB, Edwards MJR. Research on relation of mortality and hemodynamics in patients with an acute pelvic ring fracture. J Acute Dis. 2016;2:117–22.
27. Burlew CC, Moore EE, Stahel PF, Geddes AE, Wagenaar AE, Pieracci FM, et al. Preperitoneal pelvic packing reduces mortality in patients with life-threatening hemorrhage due to unstable pelvic fractures. J Trauma Acute Care Surg. 2017;82:233–42.
28. Leung HCA, Chui KH, Lee KB, Li W. Outcome of Haemodynamically Unstable Open Pelvic fracture patients managed with 3-in-1 pelvic damage control protocol in a Major Trauma Centre. J Orthop Trauma Rehabil. 2018;25:62–8.
29. Pieper A, Thony F, Brun J, Rodière M, Boussat B, Arvieux C, et al. Resuscitative endovascular balloon occlusion of the aorta for pelvic blunt trauma and life-threatening hemorrhage: a 20-year experience in a Level I trauma center. J Trauma Acute Care Surg. 2018;84:449–53.
30. Chou CH, Wu YT, Fu CY, Liao CH, Wang SY, Bajani F, et al. Hemostasis as soon as possible? The role of the time to angioembolization in the management of pelvic fracture. World J Emerg Surg. 2019;14:28.
31. Lee MA, Yu B, Lee J, Park JJ, Lee GJ, Choi KK, et al. Effects of the establishment of a trauma center and a new protocol on patients with hemodynamically unstable pelvic fractures at a single institution in Korea. Eur J Trauma Emerg Surg. 2019;45:273–9.
32. Frassini S, Gupta S, Granieri S, Cimbanassi S, Sammartano F, Scalea TM, et al. Extraperitoneal packing in unstable blunt pelvic trauma: a single-center study. J Trauma Acute Care Surg. 2020;88:597–606.
33. Ito K, Nagao T, Tsunoyama T, Kono K, Tomonaga A, Nakazawa K, et al. Hybrid emergency room system improves timeliness of angioembolization for pelvic fracture. J Trauma Acute Care Surg. 2020;88:314–9.
34. Frassini S, Gupta S, Granieri S, Cimbanassi S, Sammartano F, Scalea TM, et al. Emergency Management of pelvic bleeding. J Clin Med. 2021;10:129.
35. Hundersmarck D, Hietbrink F, Leenen LPH, Heng M. Pelvic packing and angio-embolization after blunt pelvic trauma: a retrospective 18-year analysis. Injury. 2021;52:946–55.
36. Magnone S, Allievi N, Ceresoli M, Coccolini F, Pisano M, Ansaloni L. Prospective validation of a new protocol with preperitoneal pelvic packing as the mainstay for the treatment of hemodynamically unstable pelvic trauma: a 5-year experience. Eur J Trauma Emerg Surg. 2021;47:499–505.
37. Tiziani S, Halvachizadeh S, Knöpfel A, Pfeifer R, Sprengel K, Tarkin I, et al. Early fixation strategies for high energy pelvic ring injuries - the Zurich algorithm. Injury. 2021;52:2712–8.
38. Fonseca VC, Menegozzo CAM, Cardoso JMDF, Bernini CO, Utiyama EM, Poggetti RS. Predictive factors of mortality in patients with pelvic fracture and shock submitted to extraperitoneal pelvic packing. Rev Col Bras Cir. 2022;49:e20223259.
39. Jang JY, Bae KS, Kang BH, Lee GJ. Comparison between external fixation and pelvic binder in patients with pelvic fracture and haemodynamic instability who underwent various haemostatic procedures. Sci Rep. 2022;12:3664.
40. Tuchayi AM, Nezami N, Zhang Y, Hanna TN, Johnson JO, Newsome J, et al. Comparative effectiveness of pelvic arterial embolization versus laparotomy in adults with pelvic injuries: a National Trauma Data Bank analysis. Clin Imaging. 2022;86:75–82.
41. Pfeifer R, Klingebiel FK, Halvachizadeh S, Kalbas Y, Pape HC. How to clear Polytrauma patients for fracture fixation: results of a systematic review of the literature. Injury. 2023;54:292–317.
42. Morris R, Loftus A, Friedmann Y, Parker P, Pallister I. Intra-pelvic pressure changes after pelvic fracture: a cadaveric study quantifying the effect of a pelvic binder and limb bandaging over a bolster. Injury. 2017;48:833–40.
43. Scott I, Porter K, Laird C, Greaves I, Bloch M. The prehospital management of pelvic fractures: initial consensus statement. Emerg Med J. 2013;30:1070–2.
44. Hsu SD, Chen CJ, Chou YC, Wang SH, Chan DC. Effect of Early Pelvic Binder Use in the Emergency Management of Suspected Pelvic Trauma: A Retrospective Cohort Study. Int J Environ Res Public Health. 2017;14:1217. Erratum in: Int J Environ Res Public Health. 2022;19:6654.
45. Montoya J, Stawicki SP, Evans DC, Bahner DP, Sparks S, Sharpe RP, et al. From FAST to E-FAST: an overview of the evolution of ultrasound-based traumatic injury assessment. Eur J Trauma Emerg Surg. 2016;42:119–26.
46. Smith ZA, Wood D. Emergency focussed assessment with sonography in trauma (FAST) and haemodynamic stability. Emerg Med J. 2014;31:273–7.
47. Ollerton JE, Sugrue M, Balogh Z, D'Amours SK, Giles A, Wyllie P. Prospective study to evaluate the influence of FAST on trauma patient management. J Trauma. 2006;60:785–91.
48. Hilty MP, Behrendt I, Benneker LM, Martinolli L, Stoupis C, Buggy DJ, et al. Pelvic radiography in ATLS algorithms: a diminishing role? World J Emerg Surg. 2008;3:11.
49. Foster BR, Anderson SW, Uyeda JW, Brooks JG, Soto JA. Integration of 64-detector lower extremity CT angiography into whole-body trauma imaging: feasibility and early experience. Radiology. 2011;261:787–95.
50. Bottlang M, Krieg JC, Mohr M, Simpson TS, Madey SM. Emergent management of pelvic ring fractures with use of circumferential compression. J Bone Joint Surg Am. 2002;84-A Suppl 2:43 – 7.
51. Audretsch CK, Mader D, Bahrs C, Trulson A, Höch A, Herath SC, et al. Comparison of pelvic C-clamp and pelvic binder for emergency stabilization and bleeding control in type-C pelvic ring fractures. Sci Rep. 2021;11:2338.
52. Rysavý M, Pavelka T, Khayarin M, Dzupa V. Iliosacral screw fixation of the unstable pelvic ring injuries. Acta Chir Orthop Traumatol Cech. 2010;77:209–14.
53. Langford JR, Burgess AR, Liporace FA, Haidukewych GJ. Pelvic fractures: part 2. Contemporary indications and techniques for definitive surgical management. J Am Acad Orthop Surg. 2013;21:458–68.
54. McDonogh JM, Lewis DP, Tarrant SM, Balogh ZJ. Preperitoneal packing versus angioembolization for the initial management of hemodynamically unstable pelvic fracture: a systematic review and meta-analysis. J Trauma Acute Care Surg. 2022;92:931–9.
55. Jarvis S, Kelly M, Mains C, Corrigan C, Patel N, Carrick M, et al. A descriptive survey on the use of resuscitative endovascular balloon occlusion of the aorta (REBOA) for pelvic fractures at US level I trauma centers. Patient Saf Surg. 2019;13:43.

Publisher's note