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A systematic review of emergency room laparotomy in patients with severe abdominal trauma

Soon Tak Jeong[1,4], Yun Chul Park[2,4], Young Goun Jo[2,4] & Wu Seong Kang[3]✉

Traumatic intra-abdominal hemorrhage contributes to mortality in patients with trauma. However, initiating an emergent laparotomy in the operating room (OR) as a standard treatment can sometimes be time-consuming. To overcome this issue, laparotomy is performed in the emergency room (ER) in some institutions. This systematic review evaluates the efficacy of performing ER laparotomy. Comprehensive searches were conducted in MEDLINE PubMed, EMBASE, and Cochrane databases, up to August 9, 2024. The risk of bias in observational studies was assessed using the ROBINS-I tool. The primary outcome was mortality following ER laparotomy, and the secondary outcome was time from admission to first laparotomy. The review included 10 studies, all of which were observational. A meta-analysis was not performed due to substantial heterogeneity and insufficient data. Mortality rates after ER laparotomy ranged from 23 to 100%. Mortality rates were 23.0–66.7% in the conventional ER group, while they were 0–30% in the OR group. In the hybrid ER group, the 28-day mortality rates were 12.7–15%, compared to 21.7–22% in the conventional group. The time from admission to the first laparotomy was 17–43 min (median) in the conventional ER group, compared to 40–111 min (median) in the OR laparotomy group. In the hybrid ER setting, the time from admission to intervention, including laparotomy, was 35–48 min (median), whereas it was 72–101 min (median) in the conventional group. A high and unclear risk of bias due to confounding was noted across the studies. ER laparotomy may provide rapid bleeding control. However, due to the limited number of studies and significant heterogeneity among the studies reviewed, the true effect size of ER laparotomy in conventional and hybrid ER settings remains unclear.

Keywords Abdomen, Hemorrhage, Systematic review, Laparotomy, Emergency room

Abbreviations

OR	Operating room
ER	Emergency room
CT	Computed tomography
REBOA	Resuscitative endovascular balloon occlusion of the aorta
PRISMA	Preferred reporting items for systematic reviews and meta-analyses
ORs	Odds ratios
PPP	Preperitoneal pelvic packing
ROBINS-I	Risk Of bias In non-randomised studies of interventions
DCS	Damage control surgery
RBC	Red blood cell
SBP	Systolic blood pressure
DOR	Direct-to-OR
EDOR	Emergency department OR

Severe intra-abdominal hemorrhage is one of the leading causes of mortality in patients with trauma[1,2]. The ability to quickly and effectively control bleeding is critical in managing these injuries, yet bleeding remains one of the most significant challenges in modern trauma care[2–4]. Despite advancements in trauma systems and

[1]Department of Physical Medicine and Rehabilitation, Ansanhyo Hospital, Ansan City, Republic of Korea. [2]Division of Trauma, Department of Surgery, Chonnam National University Hospital, Chonnam National University Medical School, Gwangju, Republic of Korea. [3]Department of Trauma Surgery, Jeju Regional Trauma Center, Cheju Halla General Hospital, 65 Doryeong-ro, Jeju, Jeju Special Self-Governing Province 63127, Republic of Korea. [4]Soon Tak Jeong, Yun Chul Park and Young Goun Jo contributed equally to this work. ✉email: wuseongkang@naver.com

innovative techniques, such as resuscitative endovascular balloon occlusion of the aorta (REBOA), achieving hemostasis is often difficult, necessitating swift and decisive interventions[5]. Laparotomy, a surgical procedure involving an incision in the abdominal cavity, remains a cornerstone in the management of severe abdominal trauma, even in the era of minimally invasive treatment[3]. Laparotomy is typically performed in an operating room (OR) when rapid access to the abdominal organs is necessary to control bleeding and prevent further deterioration. However, performance of laparotomy in the OR may not always be sufficient for complex trauma cases, particularly in patients with severe intra-abdominal hemorrhage, because transferring patients to the OR can be time-consuming[3,4]. An increase in time to operation is known to be associated with increased mortality in patients with a positive focused assessment with sonography for trauma (FAST) scan[4]. Therefore, expeditious hemorrhagic control is crucial.

In response to these challenges, several trials have been conducted where laparotomy is performed in the emergency room (ER) before transferring patients to the OR[6–11]. Although resuscitative thoracotomy in the ER, performed outside the OR for expeditious damage control and treatment of cardiac arrest or cardiac tamponade in patients with abdominal trauma, has been introduced and widely adopted, the efficacy and safety of ER laparotomy remains unclear[12]. Recently, a more innovative approach, the hybrid ER system, has been introduced[13,14]. This all-in-one system integrates multiple modalities into a single suite, including diagnosis by whole-body computed tomography (CT), angioembolization, and surgery. Simultaneous and prompt diagnosis and treatment, including both angioembolization and surgery, are conducted in the hybrid ER without the need to transfer patients to a conventional OR. This advanced technology has the potential to change the paradigm of modern trauma care. However, performing a laparotomy outside the OR is inherently limited due to restricted facilities, equipment, and human resources[15]. Therefore, despite its innovative nature, explicit criticism and evaluation are warranted to assess the efficacy and safety of the hybrid ER system, which requires higher installation costs and more human resources than conventional settings. These high costs are slowing the adoption of the hybrid ER system. Therefore, ER laparotomy in a conventional ER or trauma bay may be a more realistic option in many countries.

This systematic review evaluates the efficacy and safety of ER laparotomy in conventional and hybrid ER settings. By analyzing the outcomes associated with these different approaches, we aim to provide a comprehensive understanding of the relative advantages and limitations of these approaches in the management of severe abdominal trauma. This review also identifies areas where further research and innovation may be needed to optimize trauma care in emergency settings.

Methods

Search and selection criteria

This study was conducted in accordance with the preferred reporting Items for systematic reviews and meta-analyses (PRISMA) guidelines[16]. (**Supplementary**) All methods were performed in accordance with the relevant guidelines and regulations. The study protocol was prospectively registered in PROSPERO (CRD42024510902; https://www.crd.york.ac.uk/prospero). We identified relevant articles through comprehensive searches of the MEDLINE PubMed, EMBASE, and Cochrane databases, up to August 9, 2024. The search strategy included the keywords: ((emergency department) OR (emergency room) OR hybrid OR (hybrid room) OR (hybrid ER) OR (hybrid emergency room)) AND (trauma* OR injur*) AND (surgery OR surgeries OR laparotomy OR laparotomies OR (emergency department laparotomy) OR (emergency room laparotomy)). Additionally, we conducted a thorough review of the reference lists of relevant articles. All retrieved articles were screened by their titles and abstracts to assess their suitability for inclusion. Review articles and meta-analyses were also examined to identify further studies that met the eligibility criteria. The final selection included studies focusing on ED laparotomy in patients with severe abdominal injuries.

The primary outcome was mortality following ER laparotomy, the time from admission to the first laparotomy, while the secondary outcomes were surgical complication and hospital stay. The inclusion criteria were: (i) patients with traumatic abdominal injuries or significant intra-abdominal hemorrhage who needed massive transfusion or immediate bleeding control; (ii) patients who underwent laparotomy in the ER before being transferred to the OR; (iii) studies comparing ER laparotomy with OR laparotomy; (iv) the availability of relevant outcomes, such as mortality or morbidity, in the reported data; and (v) provision of odds ratios (ORs), means with standard deviations, or data allowing for their calculation. Studies were excluded if they reported direct-to-OR (DOR) or beside laparotomy, preperitoneal pelvic packing (PPP), lacked sufficient information, focused on conditions other than those specified, were non-original research articles like case reports, or were not published in English.

Data extraction

From all eligible studies, two investigators independently extracted essential information, including the first author's name, publication year, study location, design, duration, total number of patients analyzed, patient age, injury severity score, vital signs, location of the laparotomy, any additional surgical interventions (e.g., PPP, angioembolization, ER thoracotomy), time from admission to the first laparotomy, complications related to laparotomy, and mortality rate. We defined ER laparotomy as a procedure performed in the ER, and OR laparotomy as a procedure performed in the OR.

Quality assessment

To evaluate the risk of bias in observational studies, we used the Risk Of Bias In Non-randomised Studies of Interventions (ROBINS-I) tool, which is commonly employed for assessing bias in nonrandomized, interventional studies[17]. Two independent investigators reviewed all the studies, and any discrepancies in study selection or data extraction were resolved through consensus.

Results

Study selection and characteristics

A systematic search identified 8318 studies, after duplicate records were removed with a citation manager. Of the total studies identified, 8295 were excluded by screening the title/abstract. Thus, 23 full-text articles were analyzed, and 13 were removed from the analysis for the following reasons: failure to meet the inclusion criteria or lacking adequate information ($n=7$), a focus on diseases unrelated to the topic of interest ($n=3$); and not original research ($n=3$). Ultimately, 10 studies[6–11,15,18–20] met the predetermined eligibility criteria and were included in this systematic review (Fig. 1).

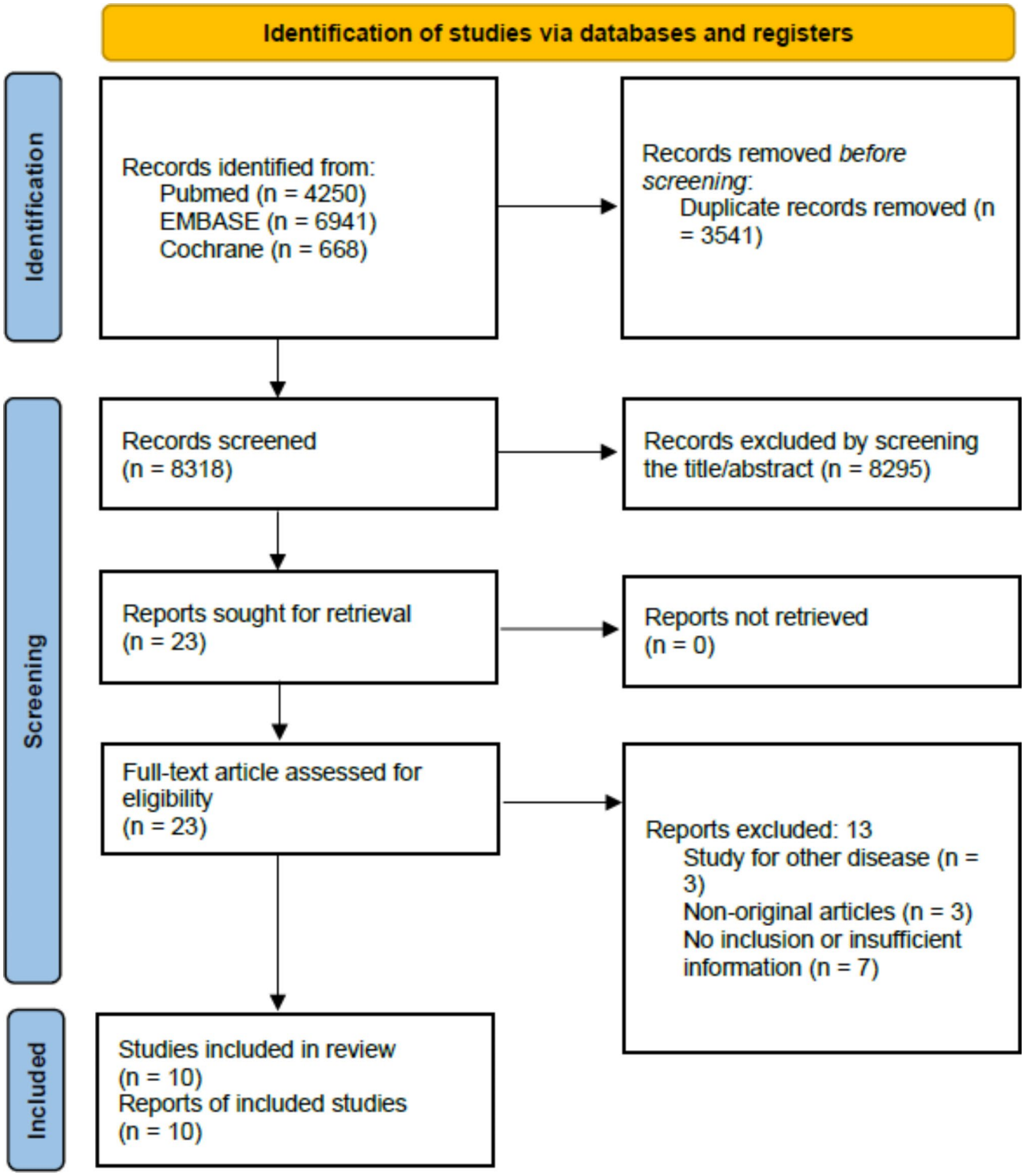

Fig. 1. Flowchart summarizing study selection.

Included studies

Table 1 summarizes detailed information on the studies that met the eligibility criteria. All the studies were observational, single-center, and nonrandomized. In five studies[6–11], ER laparotomies were performed in a conventional setting, whereas in four studies[15,18–20], laparotomies were performed in a hybrid ER. Six studies[9,10,15,18–20] were conducted in Japan, and other studies were conducted in Denmark[8], USA[6], Norway[7], and South Korea[11]. One study[6] was non-comparative. Four studies[7,9–11] compared ER laparotomy with OR laparotomy. Three studies[15,18,19] compared a hybrid ER with a conventional setting. One study[20] compared 'CT-first' with 'aortic occlusion first'. Four studies[15,18–20] regarding a hybrid ER did not report ER laparotomy alone, but reported ER laparotomy together with other procedures such as thoracotomy or angioembolization for hemostasis. Two studies[9,10] regarding conventional ER laparotomy reported ER laparotomy with ER thoracotomy, so they did not report laparotomy alone. The primary outcome of nine studies[6–11,18,20] was mortality, whereas one study[19] reported blood transfusion as a primary outcome. Two studies[9,10] were conducted in the same hospital; thus, the patients may be duplicated. Similarly, two other studies[15,18] were conducted in the same hospital and may also be duplicated. We did not conduct a meta-analysis due to duplication issues and limited data for calculating effect sizes. We described the range of effect sizes and p-values in each eligible study.

Excluded studies

Studies regarding DOR, where patients were transferred directly to the OR, bypassing the resuscitation room, were excluded[21–24]. Several studies reported the initial experience of hybrid ER installation but were excluded because they were case reports involving a small number of patients and not original articles[13,14,25,26]. Reitano et al. reported PPP in the ER but did not report any laparotomies, so this study was also excluded[27]. Several studies reporting bedside laparotomy, which may be performed in trauma intensive care units, were excluded[28,29].

Quality assessment

Overall, all eligible studies were retrospective and observational. In seven studies[6–11,20], injuries and vital signs were more severe in the ER laparotomy group; thus, we judged that these studies had a high risk of bias due to confounding. Three studies[15,18,19] regarding hybrid ER reported different treatment periods between the

Author	Year	Study design	Location	Study period	Setting	Comparison of interventions	Outcomes
Mattox et al.	1979	Observational, single-center	USA	1972–1977	Conventional ER	None, 51 ER laparotomies	All patients died (51/51; 100%)
Lund et al.	2011	Observational, single-center	Denmark	2003–2009	Conventional ER	ER laparotomy (44) SBP > 80 mmHg (14) vs. 80 mmHg ≥ SBP > 60 mmHg (10) vs. SBP ≤ 60mmHg (20)	59% mortality after 30 days. SBP > 80 mmHg (36% mortality) vs. 80 mmHg ≥ SBP > 60 mmHg (50% mortality) vs. SBP ≤ 60mmHg (66% mortality)
Groven et al.	2013	Observational, single-center	Norway	2002–2009	Conventional ER	ER laparotomy (80) vs. OR laparotomy (87)	Mortality (65% in ER group vs. 30% in OR group; $p < 0.001$) Time to laparotomy (median 17.0 min in ER group vs. 40.0 min in OR group; $p < 0.001$)
Ito et al.	2018	Observational, single-center	Tokyo, Japan	2013–2017	Conventional ER	ER surgery (26 laparotomies) vs. OR surgery (34 laparotomies)	In-hospital mortality (38.2% in ER group vs. 0.0% in OR group; $p < 0.001$) Time to surgery (median 43 min in ER group vs. 109 min in OR group; $p = 0.043$)
Ito et al.	2019	Observational, single-center	Tokyo, Japan	2013–2017	Conventional ER	ER laparotomy (31)/thoracotomy (13)/PPP (16) vs. OR laparotomy (37)/thoracotomy (8)	In-hospital mortality (23% in ER group vs. 0.0% in OR group; $p < 0.01$) Time to operation (median 43 min in ER group vs. 111 min in OR group; $p = 0.09$)
Kinoshita et al.	2019	Observational, single-center	Osaka, Japan	2007–2015	Hybrid ER	Hybrid ER (336, 18 laparotomies) vs. conventional (360, 32 laparotomies) in terms of bleeding control surgery	28-day mortality due to exsanguination (3% in hybrid ER group vs. 8% in conventional group; $p = 0.007$) Time to bleeding control surgery (median 48 min in hybrid ER group vs. 73 min in conventional group; $p = 0.079$)
Umemura et al.	2021	Observational, single-center	Osaka, Japan	2007–2020	Hybrid ER	Hybrid ER (690, 59 emergency truncal surgeries) vs. conventional (360, 44 emergency truncal surgeries) in terms of bleeding control intervention	28-day mortality (12.7% in hybrid ER group vs. 21.7% in conventional group; $p < 0.001$) Time to bleeding control intervention (median 42 min in hybrid ER group vs. 72 min in conventional group; $p < 0.001$)
Watanabe et al.	2021	Observational, single-center	Shimane, Japan	2016–2019	Hybrid ER	Hybrid ER (145, 39 interventions*) vs. conventional (134, 24 interventions) in terms of intervention	RBC transfusion (median 6 units in hybrid ER group vs. 2 units in conventional group; $p = 0.012$) Intervention (median 41 min in hybrid ER group vs. 101 min in conventional group; $p = 0.0007$)
Maruyama et al.	2024	Observational, single-center	Osaka, Japan	2016–2023	Hybrid ER	'CT first' (6, 5 DCS) vs. 'aortic occlusion first' (7, 4 DCS)	54% 28-day mortality (50% in 'CT-first' group vs. 57% in 'aortic occlusion first' group) Time to intervention (median 35 min)
Lee et al.	2024	Observational, single-center	South Korea	2020–2022	Conventional ER	ER laparotomy (6) vs. OR laparotomy (105)	In-hospital mortality (66.7% in ER group vs. 17.1% in OR group; $p = 0.006$) Time to operation (median 28.5 min in ER group vs. 104 min in OR group; $p < 0.001$)

Table 1. Characteristics of eligible studies. *CT* computed tomography, *DCS* damage control surgery, *ER* emergency room, *OR* operating room, *PPP* preperitoneal pelvic packing, *RBC* red blood cell, *SBP* systolic blood pressure. *Intervention includes resuscitative thoracotomy, laparotomy, pelvic external fixation, craniotomy, or embolization.

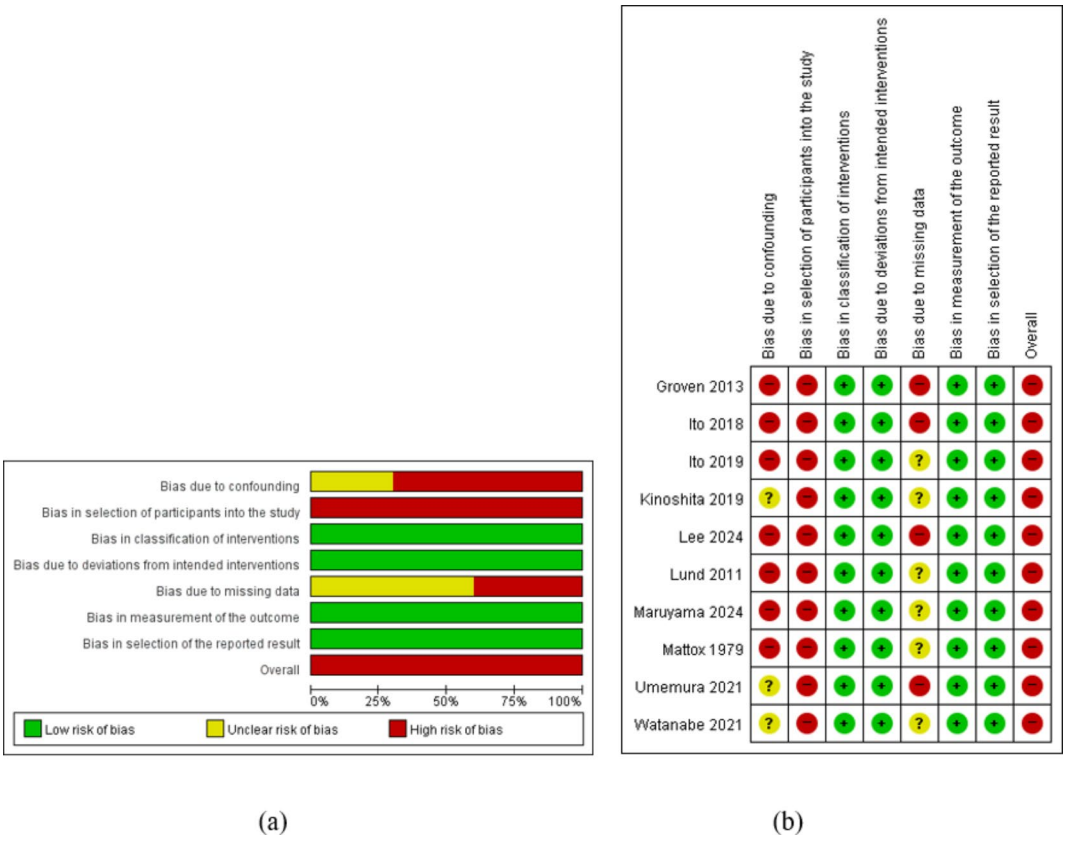

Fig. 2. (**A**) Risk of bias graph: Review authors' assessments of each risk-of-bias item, presented as percentages for all included studies; (**B**) Risk of bias summary: Review authors' assessments of each risk-of-bias item for each included study.

conventional and hybrid ER groups. We judged these studies to have an unclear risk of bias due to potential confounding. Three studies[6,8,20] did not compare the ER laparotomy group with the OR laparotomy group; thus, we judged that these studies had an high risk of bias due to confounding and patient's selection. Four studies[7,9,11,18] reported missing values in certain variables, such as admission blood pressure, base excess, intraoperative transfusion, estimated blood loss, or FAST. However, they did not report the results for the missing values; thus, we judged these studies to have a high risk of bias. We judged six studies to have an unclear risk of bias because they did not report any information regarding missing values[6,8,10,15,19,20]. (Fig. 2) Overall, we concluded that there was a high risk of bias across all eligible studies[6–11,15,18–20]. Moreover, six studies[9,10,15,18–20] did not report the effect size of laparotomy alone. They reported laparotomy with other surgical procedures, such as thoracotomy or angioembolization. Therefore, we judged that substantial heterogeneity existed, and it is not appropriate for meta-analysis.

Clinical settings for ER laparotomy: conventional and hybrid ER

In five studies[6–11], laparotomies were performed only in conventional ERs, whereas four studies[15,18–20] reported a hybrid ER system. Mattox et al., in a first report from 1979, stated several problems with ER laparotomies, including mass confusion, loss of laparotomy sponges, poor lighting, and lack of proper instruments[6]. Conversely, four more recent studies[7,9–11] reported that a laparotomy set was always available in the ER; however, ER laparotomies were performed under limited environmental conditions, without an anesthesiologist or nursing staff[7,9–11]. The hybrid ER system had more advanced equipment, manpower, and environments, including a dedicated bed, lighting, devices, and nursing staff for surgery. Anesthesiology was performed by non-anesthesiologists, such as emergency physicians, in both conventional and hybrid ER systems. Notably, all initial damage control laparotomies were performed in the hybrid ER system[15,18–20].

Indications for ER laparotomy

Mattox et al.[6] performed ER laparotomies to control major exsanguination hemorrhage prior to transfer to an OR. Grove et al.[7] used a treatment protocol (until 2006) that encouraged ER damage control laparotomies for minimizing delays to surgery; however, they changed the protocol in 2007 to prioritize OR laparotomies over ER laparotomies. Lund et al. performed ER laparotomies for patients with hemodynamic instability and positive findings on focused abdominal sonography in trauma[8]. Ito et al.[9,10] performed damage control surgery in the ER, and definitive surgery, when required, in the OR. Lee et al.[11] performed ER laparotomies in patients requiring hemostasis but for whom transfer to the OR was expected to be delayed. In a hybrid ER setting[15,18–20],

all emergency surgeries, including damage control laparotomy, resuscitative thoracotomy, and burr-hole craniostomy, were performed in the hybrid suite.

Other procedures for intra-abdominal hemorrhage

Mattox et al.[6] performed concurrent resuscitative thoracotomy and aortic cross-clamping of the descending aorta in most patients. In other studies[7,9–11,15,18–20], the thoracotomy was performed in some patients (4–54%). REBOA was reported in four studies[9–11,20], and angioembolization was reported in five studies[9,15,18–20].

Mortality following ER laparotomy

Notably, a 100% mortality rate was reported in an early study from 1979 [6]. However, more recent reports, since the 2010s, demonstrated survivors. Mortality rates were 23.0–66.7% in the conventional ER group, while they were 0–30% in the OR group (Table 1)[7–11]. Four studies[7,9–11], reported significantly higher mortality rates in the conventional ER group. Two studies[15,18] reported significantly lower 28-day mortality rates in the hybrid ER setting (22% in the conventional ER vs. 15% in the hybrid ER[15], and 21.7% in conventional vs. 12.7% in hybrid ER[18]).

Time from admission to ER laparotomy

The time from admission to the first laparotomy was 17–43 min (median) in the conventional ER group, compared to 40–111 min (median) in the OR laparotomy group[7,9–11]. , Three studies[7,9,11] reported significantly shorter times in the conventional ER group. In the hybrid ER setting, the time from admission to intervention, including laparotomy, was 35–48 min (median), whereas it was 72–101 min (median) in the conventional group[15,18–20]. Two studies[18,19] reported statistically significant shorter times in the hybrid ER setting.

Surgical-site infection following ER laparotomy

One study[9] reported comparable rates of infectious complications (10.4% in the conventional ER group vs. 7.3% in the OR group; $p = 0.374$). Two studies[10,11] reported similar rates of surgical-site infections: 14% in the conventional ER group vs. 9% in the OR group ($p = 0.45$)[10], and 0% in the conventional ER group vs. 4% in the OR group ($p = 0.999$)[11].

Other complications following ER laparotomy

Lee et al.[11] reported there were no difference between ER laparotomy and OR laparotomy group in terms of complications such as acute kidney injury, acute respiratory failure, deep vein thrombosis, pneumoniae, or pulmonary thromboembolism.

Risk factors for mortality

Lund et al.[8] reported that SBP ≤ 60 mmHg was a significant risk factor using a univariable logistic regression model (7.2 odds ratio, 95% confidence interval 1.5–33.8, $p = 0.012$). Ito et al.[10] reported that the Revised Trauma Score ($p = 0.01$), Trauma and Injury Severity Score (TRISS, $p = 0.02$), blunt trauma ($p = 0.03$), laparotomy alone ($p < 0.01$), REBOA placement ($p = 0.02$), and laparotomy followed by thoracotomy ($p = 0.02$) were significant risk factors for mortality in the ED group. However, Lund et al.[8] and Ito et al.[10] did not conduct multivariable analysis. Kinoshita et al.[15] reported that Hybrid ER, compared to conventional ER, was associated with a reduction in 28-day mortality (OR 0.50, 95% CI 0.29–0.85) and death from exsanguination (OR 0.17, 95% CI 0.06–0.47) in a multivariable analysis. Umemura et al.[18] reported that 28-day mortality was significantly lower in the Hybrid ER group on multivariable logistic regression analysis adjusted for the probability of survival.

Length of stay

Ito et al.[9] reported no difference in the length of ICU stay and hospital stay. Kinoshita et al. reported a longer number of ICU-free days in the Hybrid ER group (15 (2–23) days in Hybrid ER vs. 14 (0–21) days in conventional ER; median, interquartile range; $p = 0.017$), while hospital stays did not differ.

Discussion

Our systematic review demonstrates that ER laparotomy can be quickly performed in either conventional or hybrid ER settings. However, the mortality rate associated with ER laparotomy in conventional settings was substantially higher, which may be attributed to selection bias. Patients in a more severe condition may have undergone an ER laparotomy. The studies concerning the hybrid ER did not report the results of laparotomy alone. In the hybrid ER, all initial damage control laparotomies were performed in the hybrid room, where a trauma team including trauma surgeons and emergency physicians performed both surgery and angioembolization. Nonetheless, in our review, the exact effect size regarding mortality or complications from ER laparotomy remains unclear due to the retrospective nature and substantial heterogeneity of the eligible studies. In various countries, performing laparotomy in a conventional ER with a more advanced environment may be a realistic option due to the high costs and manpower requirements of hybrid ERs. Nonetheless, it is important to note the adoption of hybrid ERs in Japan and the resulting paradigm shift[15,18–20]. To the best of our knowledge, this is the first systematic review regarding ER laparotomy. However, a meta-analysis was not performed due to substantial heterogeneity and insufficient data to calculate effect size.

The endeavor for more expeditious hemostasis has been ongoing for a long time. The first original report of ER laparotomy in our review was in 1979 [6]: Mattox et al. performed damage control procedures, such as clamping major vessels or packing for compression of a liver laceration, and then transferring patients to the OR for definitive surgery. However, these researchers did not report the time from admission to surgery, although

they acknowledged the limitations of the conventional ER environment for performing laparotomies, which may have been the reason for only performing damage control with a subsequent OR laparotomy[6].

More recently, Ito et al.[9] in Japan, and Lee et al.[11] in South Korea, described their ER laparotomy protocols, noting that ER laparotomies can be performed based on the injury severity or the availability of ORs and anesthesiologists. When all ORs are occupied by other surgeries, or when human resources such as anesthesiologists or nurses are unavailable, laparotomies may be substantially delayed. Although trauma centers should always have an OR available for emergent laparotomies, a worst-case scenario can occur at any time. Notably, Lee et al.[11] reported two successful cases of mesenteric bleeding, which is relatively easy to ligate with a clamp. This implies that ER laparotomy may be feasible in specific patients with a reasonable level of effort and when equipped with the appropriate laparotomy instrument set. Nonetheless, as described by Ito et al.[9], ER laparotomy has inherent limitations, such as the absence of anesthesiologists, trained scrub nurses, and uncertainty about the sterility of the room. There was no protocol for infection precautions during ER laparotomy in our review. Although ER laparotomy can be performed quickly, our systematic review could not clarify whether a shorter time from admission to laparotomy is associated with adverse outcomes such as mortality or complications. However, as described in the studies[9–11] in our review, limited resources for OR laparotomy or ER crowding can delay laparotomy. Further investigation, including regression modeling, is needed.

As a more advanced, all-in-one facility for diagnosis and treatment, including whole-body CT, angiography, thoracotomy, and laparotomy, the hybrid ER system was first introduced in Japan in 2011 [13]. The institution of Ito et al., which previously reported conventional ER laparotomy, recently installed a hybrid ER[9], and as of March 2023, 24 hospitals in Japan had a hybrid ER[20]. In Japan, a paradigm shift from conventional ER to hybrid ER seems to be starting. However, the hybrid ER is not popular in other countries, where no meaningful results have been reported regarding hybrid ERs. Generally, performing laparotomy outside the OR is challenging due to limited instruments, poor lighting, and the absence of essential personnel, including an anesthesiologist and surgical nursing staff. Moreover, preventing surgical infections is also challenging. In our review, studies regarding hybrid ERs[14,15,19,20] demonstrated promising results, but the studies did not sufficiently address the limitations of hybrid ERs, such as infection control. A crucial limitation of hybrid ERs is the cost. The recent price of an angiography CT machine is approximately over 1,700,000 USD[30]. Indeed, the initial installation cost of hybrid ERs and the need for a large workforce make hospitals have financial concerns about the operational efficiency of such ERs. Emergency room (ER) laparotomy can be a practical alternative for centers with limited resources by deploying laparotomy instruments or surgical pads in a conventional ER. The selective application of ER laparotomy for extremely severe patients may be more cost-effective, given the high expense of the hybrid ER for some trauma centers. Laparotomy in a hybrid ER is conducted in a different environment compared to a standard OR. In a standard OR, well-trained and dedicated nursing staff assist with the prompt preparation of various surgical devices, including energy devices, instruments, surgical pads, and retractors. However, in a hybrid ER setting, equipping the environment to be comparable to a standard OR remains challenging. Additionally, the lack of anesthesiologist support is a major challenge in the hybrid ER. Infection precautions are also limited in the hybrid ER. Basic principles of infection control in a standard OR include hand hygiene, aseptic technique, personal protective equipment, environmental management, air quality management, and staff education and training[31]. However, relevant principles are not reported in the hybrid ER setting.

In our systematic review, a high overall risk of bias was observed across all eligible studies, particularly regarding bias due to confounding and patient selection. Moreover, only two studies on hybrid ER conducted multivariable analyses to adjust for confounding factors. Kinoshita et al.[15] performed a multivariable logistic regression analysis, adjusting for factors such as mechanism of injury, heart rate, body temperature, lactate, PT-INR, and Ps, which was calculated using the TRISS. Umemura et al.[18] also used multivariable logistic regression to adjust for Ps, age, gender, contrast blush on CT, serum lactate, head AIS, ISS, and endovascular treatment. Additionally, Kinoshita et al.[15] conducted a propensity score analysis and stratification to adjust for confounding factors. However, other observational studies[6–11,19,20] in our systematic review conducted only univariable analyses and did not perform further analysis, raising critical concerns about bias. Moreover, the indications for ER laparotomy differed between conventional and hybrid settings. In hybrid settings, more aggressive ER laparotomies appeared to be performed, while in conventional settings, ER laparotomy was typically conducted in more limited situations, such as when OR resources were limited. Concurrent procedures, such as ED thoracotomy, REBOA, or PPP, also varied across the eligible studies. Therefore, further prospective studies are warranted to minimize confounding and selection bias.

Another challenge for expeditious laparotomy is DOR. A recent systematic review demonstrated that the use of DOR shortens the time to surgery[32]; however, there were no randomized controlled trials and the researchers did not estimate the effect size of DOR[32]. There may be substantial heterogeneity across the studies regarding DOR. Interestingly, one study from the USA demonstrated the efficacy of an emergency department OR (EDOR) located next to the trauma bay[23]. DOR also appears to be an attractive system compared to hybrid ER. The staff response for the EDOR comprised an anesthesia attending and OR nurses, and the response seems to be more appropriate for the surgical treatment itself. Generally, however, cooperation among these staff members may be challenging in many hospitals. Indeed, given the significant role of interventional radiology in trauma care, a hybrid ER may be a more advanced and appropriate concept. Prompt diagnosis using CT and angiography is also an advantage of hybrid ER, while DOR is limited in utilizing these diagnostic tools.

Our study has several limitations. First, we only included observational studies, as our search did not identify any randomized controlled trials. We found an overall high risk of bias across the eligible studies, particularly regarding confounding, patient selection, and missing data. To address this issue, multicenter randomized controlled trials are warranted. Prospective studies may also present challenges, particularly for patients with unstable conditions. Second, we could not calculate a pooled effect size due to insufficient data and variability among the studies reviewed. In some studies, particularly those regarding a hybrid ER, the outcomes of

laparotomy alone were absent. Additionally, there was a possibility of patient duplication, since some studies were conducted at the same hospital, preventing us from performing a meta-analysis. Therefore, we conducted only a systematic review. Third, our review was restricted to articles published in English. Excluding non-English studies can introduce language bias. However, evidence indicates that this does not alter the conclusions of most systematic reviews[33,34]. Lastly, data on long-term outcomes were scarce.

Conclusions

ER laparotomy can be an effective method for expediting hemostasis and reducing exsanguination, despite challenges related to equipment, the operative environment, and manpower. The efficacy of ER laparotomy may be particularly dependent on OR availability. Innovations in the ER system, such as implementing a hybrid ER, could provide alternatives to enhance treatment quality and improve the overall trauma system. However, multicenter randomized controlled trials are needed to determine the exact effect size for patients with severe intra-abdominal hemorrhage. Importantly, at present, a hybrid suite may not be a feasible option for trauma centers in many countries. An ER laparotomy setup in a conventional ER or DOR may be more practical. Nonetheless, the innovation and endeavor to provide optimal trauma care should continue.

Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Author contributions

All the authors wrote the manuscript and created the figure. Concept and design: STJ, YCP, YGJ, and WSK. Statistical Analysis: STJ, YCP, YGJ, and WSK. Interpretation of data: STJ, YCP, YGJ, and WSK. All authors critically reviewed and agreed to the submission of the final manuscript. STJ, YCP, and YGJ contributed equally to this work and should be considered co-first authors.

Declarations

Competing interests

The authors declare no competing interests.

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Correspondence and requests for materials should be addressed to W.S.K.

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