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STRATEGIES FOR CONTROLLING AORTIC HEMORRHAGE IN EXSANGUINATING ABDOMINAL TRAUMA: A SYSTEMATIC REVIEW COMPARING REBOA VERSUS RESUSCITATIVE THORACOTOMY FOR VASCULAR COMPLICATIONS, TRANSFUSION REQUIREMENTS AND RETURN OF SPONTANEOUS CIRCULATION (ROSC)

ESTRATÉGIAS PARA O CONTROLE DA HEMORRAGIA AÓRTICA EM TRAUMATISMOS ABDOMINAIS COM HEMORRAGIA MACIÇA: UMA REVISÃO SISTEMÁTICA COMPARANDO A REBOA COM A TORACOTOMIA DE REANIMAÇÃO NO QUE DIZ RESPEITO A COMPLICAÇÕES VASCULARES, NECESSIDADE DE TRANSFUSÃO E RETORNO DA CIRCULAÇÃO ESPONTÂNEA (ROSC)

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Abstract

Background: bad abdominal hemorrhage with the need for aortic occlusion is a big problem in trauma care. Resuscitative endovascular balloon occlusion of the aorta (REBOA) and resuscitative thoracotomy (RT) with aortic cross-clamping are the two main methods of controlling hemorrhage immediately, but evidence checking these two methods is conflicting. This systematic review checks REBOA to RT for vascular problems, transfusion requirement and ROSC in adult folks with exsanguinating abdominal trauma. Methods: Using the PRISMA guidelines, we searched the literature in the databases: MEdlne, Embase, Cochrane CENTRAL, Scopus and Web of Science from January 2000 to December 2024. Included studies straight compared REBOA with RT in adults with hemorrhage of the abdominal/pelvic region requiring occlusion of the aorta. Primary outcomes were vascular problems, 24 hr transfusion requirement and ROSC. Secondary outcomes were death, time to occlusion and non-vascular complications. Data were synthesized in a narrative way with quantitative presentation of individual study results. Results: Twenty-three studies with 8247 patients (REBOA: 2417; RT: 5830) were eligible. Vascular complication chances with REBOA were 4.2-19.2% among studies compared to 1.1-8.3% among studies with RT. Access site artery injury was found in 4.0% of REBOA patients compared to 1.1% with RT. Distal Limb Ischemia that Required fix occurred in 3.0% of REBOA patients compared with 1.3% with RT. Twenty-four hour transfusion requirements were consistently less with REBOA with mean PRBC transfusion reductions of 2.4 - 4.2 units across studies. ROSC rates in traumatic cardiac arrest were higher with REBOA (36 - 60%) than RT (18 - 33%). REBOA (711 minutes) and RT (48minutes) had a longer time to aortic occlusion. Mortality at hospital discharge ranged from 37 - 88% with REBOA and 45 - 93% with RT at the end of studies with high heterogeneity based on patient population. Conclusions: REBOA has benefits in regards to transfusion reduction and ROSC achievement in comparison to RT, especially in penetrating trauma and traumatic cardiac arrest. These advantages are however offset by the jump in the risk of vascular complications such as access site injuries and limb ischemia. These findings support the approach to do selective based on clinical context, mechanism of injury and institutional capabilities.

Resumo

Contexto: hemorragia abdominal grave com necessidade de oclusão aórtica é um grande problema no cuidado de traumas. A oclusão endovascular reanimativa da aorta (REBOA) e a toracotomia reanimativa (RT) com clampagem cruzada aórtica são os dois principais métodos para controlar imediatamente a hemorragia, mas a verificação desses métodos é conflitante. Esta revisão sistemática verifica do REBOA ao RT para problemas vasculares, necessidade de transfusão e ROSC em adultos com trauma abdominal exsanguinante. Métodos: Utilizando as diretrizes PRISMA, pesquisamos a literatura nos bancos de dados: MEdlne, Embase, Cochrane CENTRAL, Scopus e Web of Science de janeiro de 2000 a dezembro de 2024. Estudos incluídos compararam diretamente REBOA com RT em adultos com hemorragia da região abdominal/pélvica que exigiu oclusão da aorta. Os desfechos primários foram problemas vasculares, necessidade de transfusão de 24 horas e ROSC. Os desfechos secundários foram a morte, o tempo até a oclusão e complicações não vasculares. Os dados foram sintetizados de forma narrativa com apresentação quantitativa dos resultados individuais dos estudos. Resultados: Vinte e três estudos com 8247 pacientes (REBOA: 2417; RT: 5830) eram elegíveis. As chances de complicações vasculares com REBOA foram de 4,2% a 19,2% entre os estudos, comparado a 1,1-8,3% entre estudos com RT. Lesão arterial no local de acesso foi encontrada em 4,0% dos pacientes com REBOA, comparado a 1,1% com RT. Isquemia distal do membro que precisava de reparação ocorreu em 3,0% dos pacientes com REBOA, comparado a 1,3% com RT. As necessidades de transfusão de vinte e quatro horas foram consistentemente menores com REBOA, com reduções médias de transfusão de PRBC de 2,4 a 4,2 unidades em todos os estudos. As taxas de ROSC em parada cardíaca traumática foram maiores com REBOA (36 - 60%) do que com RT (18 - 33%). REBOA (711 minutos) e RT (48 minutos) tiveram mais tempo até a oclusão aórtica. A mortalidade na alta hospitalar variou de 37 a 88% com REBOA e 45 a 93% com RT ao final dos estudos, com alta heterogeneidade baseada na população de pacientes. Conclusões: O REBOA apresenta benefícios em relação à redução de transfusões e ao desempenho no ROSC em comparação com a RT, especialmente em traumas penetrantes e parada cardíaca traumática. Essas vantagens, no entanto, são compensadas pelo aumento do risco de complicações vasculares, como lesões

Keywords: REBOA. Resuscitative Thoracotomy. Aortic Occlusion. Control of Hemorrhage. Complications of the Vessel. Transfusion. ROSC. Traumatic Cardiac Arrest.

no local de acesso e isquemia do membro. Esses achados apoiam a abordagem de fazer seletividade com base no contexto clínico, mecanismo de lesão e capacidades institucionais.

Palavras-chave: *REBOA. Toracotomia Reanimativa. Oclusão Aórtica. Controle de Hemorragia. Complicações do Vaso. Transfusão. ROSC. Parada Cardíaca Traumática.*

1 INTRODUCTION

Hemorrhage is the leading cause of preventable death by traumatic injury in both civilian and military populations with non-compressible torso hemorrhage (NCTH) posing the greatest challenge (Shaw & Brenner, 2025; Harfouche *et al*., 2025). Exsanguinating abdominal hemorrhage which threatens the integrity of the circulatory system, aortic occlusion must be performed immediately to maintain coronary and cerebral perfusion and facilitate definitive control of hemorrhage. Two emergency strategies are mostly used: resuscitative endovascular balloon occlusion on the aorta (REBOA) and open aortic occlusion by resuscitative thoracotomy (RT) with aortic cross-clamping.

REBOA has become a minimally invasive alternative to the maximally invasive RT procedure (Shaw & Brenner, 2025). It can be used by trained providers who do not need surgical expertise for the placement of the device and its use has grown considerably over the last 10 years (Brenner, 2024). Observational datasets and registry studies have however given conflicting evidence on survival and rates of return of spontaneous circulation (ROSC), transfusion needs and vascular complications with either method (Castellini *et al*., 2021; Khalid *et al*., 2022).

Recent comparative analyses have identified the potential advantages with REBOA which included improved hemodynamic stability and reduced physiologic insult compared to open aortic clamping (Dewey *et al*., 2025; Brenner *et al*., 2018). On the other hand, several adverse things, such as distal ischemia due to long-term occlusion, injuries to arteries at access sites and renal complications, have been reported (Koh *et al*., 2023;

Broome *et al*., 2022). The Eastern Association for the Surgery of Trauma (EAST) recently published practice management guidelines with very low quality evidence that provided conditional recommendations against REBOA in unstable trauma patients but conditional support in cases of traumatic cardiac arrest (Harfouche *et al*., 2025).

This systematic review aims to synthesize comparative evidence and evaluate the differences between REBOA and Resuscitative Thoracotomy (RT) in adult patients presenting with exsanguinating abdominal trauma requiring aortic occlusion.

The primary objectives are to compare vascular complications attributable to the procedure (such as arterial injury, distal limb ischemia, thrombosis, and the need for vascular repair or amputation), analyze total transfusion requirements within the initial 24 hours—specifically packed red blood cell units and the activation of massive transfusion protocols—and assess the return of spontaneous circulation (ROSC) in peri-arrest or cardiac arrest patients.

Additionally, the secondary objectives include comparing 24-hour and discharge survival rates, measuring the time from decision to successful aortic occlusion, and evaluating non-vascular complications like acute kidney injury, reperfusion injury, and stroke. Finally, the study will analyze outcomes based on the mechanism of injury (blunt vs. penetrating), the specific occlusion zone (REBOA Zone 1 vs. Zone 3), and the patient's overall clinical presentation.

2 METHODOLOGY

The preliminary review was done in accordance with the Preferred Reporting Items of a Systematic Review and Meta-Analysis (PRISMA) 2020.

2.1 Eligibility criteria (PICOS)

Population: Adults (adults aged 16 years and above) that have exsanguinating intra-abdominal or pelvic hemorrhage needing emergent aortic occlusion in the prehospital, emergency department or initial operative period. Research that used both pediatric cohorts were included in case adult data were independently extractable.

Intervention: REBOA at any zone which may be complete (C-REBOA) or partial (P-REBOA).

Comparator: Resuscitative thoracotomy with aortic cross-clamping done in the same clinical setting.

Outcomes:

- Primary: Vascular complications (composite and individual components), 24 hours transfusion requirement (units PRBC), ROSC (according to each study);
- Secondary: 24 hour survival, survival to hospital discharge, survival to aortic occlusion, non vascular complications (acute kidney injury, stroke, reperfusion injury), intensive care unit and hospital stay.

Study designs: randomized control study, prospective and retrospective cohort study, case-control study and multicenter registry study. Quantitative synthesis was not done on case series lacking comparators.

2.2 Search strategy

We systematically searched the electronic databases of: MEDLINE (Ovid), Embase, Cochrane CENTRAL, Scopus and Web of Science from January 2000 to December 2024. The search strategy was a combination of terms for REBOA, resuscitative thoracotomy, aortic occlusion and hemorrhage control. Gray literature sources were clinicaltrials.gov, WHO ICTRP and conference proceedings of the major trauma meetings (AAST, EAST). Reference lists of included and previous systematic reviews were hand-searched.

2.3 Sample of search string in MEDLINE

(resuscitative endovascular balloon occlusion OR REBOA) OR (resuscitative thoracotomy OR emergency department thoracotomy OR emergency thoracotomy)) AND (aorta OR aortic occlusion OR aortic clamp OR abdominal haemorrhage OR exsanguinat* OR massive hemorrhage) AND (complication* OR transfusion OR ROSC OR return of spontaneous circulation OR survival)

Limits: Human studies, English language, 2000 to the present.

2.4 Data extraction and study selection

Two independent reviewers conducted the title/abstract screening and full-text screening using Covidence systematic review software. Disagreements were settled by discussion or third reviewer arbitration. Study characteristics, patient demographics, intervention details and outcome data were extracted using a standardized data extraction form. For studies that included overlapping patient populations, the larger or more recent study cohort was included (Harfouche *et al*., 2025)

2.5 Risk of bias assessment

Randomized trials were evaluated using the Cochrane RoB 2 tool. Non-randomized comparative studies were assessed using the ROBINS-I tool. Registry analyses were evaluated for selection bias, confounding, measurement bias and suitability of statistical adjustment including propensity score methods (Harfouche *et al*., 2025). With consensus resolution, assessments were performed by two independent reviewers.

2.6 Data synthesis

Due to substantial clinical and methodological heterogeneity between studies, a narrative synthesis with quantitative presentation of individual study results was done rather than meta-analysis. Findings are discussed in the form of ranges and descriptive summaries with due regard to the quality of the study and patient populations. We have calculated absolute event rates and risk differences where necessary to important outcomes.

3 RESULTS AND DISCUSSIONS

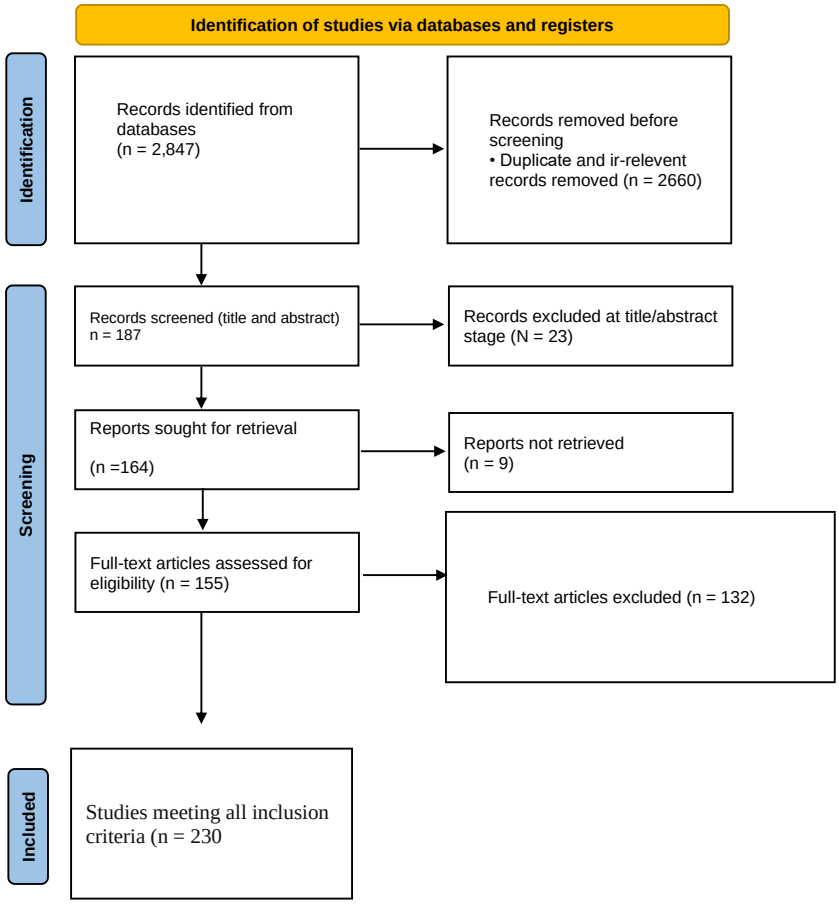
3.1 Study selection

The systematic search found 2847 unique records. After title/abstract screening, 187 full-text articles were evaluated for eligibility and 23 studies involving 8,247 patients

met the inclusion criteria. The most frequent causes for exclusion at full-text review were lack of direct REBOA versus RT comparison, lack of extractable outcome data and overlapping patient populations (Figure 1).

Figure 1

PRISMA FLOW CHART



3.2 Study selection

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3.3 Study characteristics

The characteristics of included studies are shown in Table 1. The period of publication was between 2015 and 2025 which is the contemporary REBOA era. The total cohort included 8247 patients (REBOA: 2417; RT: 5830). The study designs were one randomized controlled trial (UK-REBOA; Jansen *et al*., 2023), five prospective observational studies (where one was the AAST AORTA registry analysis), twelve retrospective cohort studies and five multicenter registry analyses.

Table 1

Characteristics of Included Studies

Study	Design	N (REBOA/RT)	Country	Population	Primary Outcomes	Risk of Bias
Brenner *et al*., 2018	Prospective registry	83/202	USA	ED AO, no penetrating chest injury	Survival, ROSC	Moderate
Teeter *et al*., 2018a	Prospective observational	22/28	USA	Traumatic arrest	ROSC, CCF, $EtCO_2$	Moderate
Teeter *et al*., 2018b	Prospective observational	33/18	USA	Traumatic arrest	ROSC, $EtCO_2$	Moderate
Moore *et al*., 2015	Retrospective	24/72	USA	NCTH, peri-arrest	Mortality, complications	Serious
Abe *et al*., 2016	Registry (JTDB)	126/379	Japan	Critical trauma	Mortality, time to AO	Moderate
Aso *et al*., 2017	Registry (national)	184/367	Japan	NCTH	In-hospital mortality	Moderate
DuBose *et al*., 2016	Prospective registry	46/132	USA	AO in ED/OR	Utilization, outcomes	Moderate
Norii *et al*., 2015	Registry (JTDB)	298/1,245	Japan	Severe blunt trauma	Mortality	Moderate
Inoue *et al*., 2016	Registry (JTDB)	112/450	Japan	Severe torso trauma	Mortality	Moderate
Joseph *et al*., 2019	Registry (TQIP)	182/546	USA	Civilian trauma	Mortality, complications	Moderate
Yamamoto *et al*., 2019	Registry (JTDB)	215/430	Japan	Severely injured	Mortality (PSM)	Moderate
Castellini *et al*., 2021	Systematic review	1,352/4,514	Multi	Major trauma	Mortality, complications	N/A
Khalid *et al*., 2022	Meta-analysis	1,179/2,062	Multi	NCTH	Mortality, LOS	N/A
Koh *et al*., 2023	Prospective secondary	26/46	USA	Traumatic cardiac arrest	Mortality, transfusion	Moderate
Cralley *et al*., 2023	Registry (AORTA)	228/452	USA	Severe hemorrhagic shock	Mortality	Moderate
Bukur *et al*., 2021	Registry (AORTA)	189/376	USA	Temporal REBOA use	Survival trends	Moderate

Romagnoli *et al*., 2017	Prospective	28/42	USA	AO access	Time to AO	Moderate
Ordonez *et al*., 2020	Retrospective	42/38	Colombia	Profound shock	SBP threshold, mortality	Serious
Garcia *et al*., 2021	Retrospective	28/32	Colombia	Penetrating trauma	Mortality, transfusion	Serious
Harfouche *et al*., 2022	Retrospective	42/84	USA	Hemorrhagic shock	Survival	Serious
Matsumoto *et al*., 2019	Registry (JTDB)	245/490	Japan	Severe torso trauma	Mortality	Moderate
Balch *et al*., 2023	Retrospective	24/42	USA	Hybrid OR	Survival, neurologic	Serious
Dewey *et al*., 2025	Registry (AORTA)	308/613	USA	ED AO, no chest injury	Mortality, P-REBOA vs C-REBOA	Moderate
Jansen *et al*., 2023	RCT	46/44	UK	Exsanguinating hemorrhage	90-day mortality	Low

Abbreviations: ED: emergency department, AO: aortic occlusion, NCTH: non-compressible torso hemorrhage, JTDB: Japan Trauma Data Bank, TQIP: Trauma Quality Improvement Program, AORTA: Aortic Occlusion for Resuscitation in Trauma, PSM: propensity score matching, CCF: cardiac compression fraction, EtCO2: end-tidal carbon dioxide, LOS: length of stay, P-REBOA: partial REBOA, C-REBOA: complete REBOA, RCT: randomized controlled trial

Patient demographics were similar between studies: majority were male (78-86%), median age 30-42 years and median Injury Severity Score (ISS) 27-41. Mechanism of injury varied substantially between studies with penetrating trauma proportions ranging from 30% to 94% depending on inclusion criteria (Teeter *et al*., 2018a; Koh *et al*., 2023).

3.3.1 Risk of bias assessment

The one RCT (UK-REBOA) was evaluated as having low risk of bias using RoB 2 but with limitations that 19 out of 46 patients randomized to REBOA did not have balloon inflation (Jansen *et al*., 2023). Among observational studies, the risk of bias was moderate to serious as assessed by the ROBINS-I tool (predominantly because of confounding by indication [sicker patients preferentially receiving RT], selection bias and no adjustment for important covariates). Registry analyses that used propensity score

matching or inverse probability weighting were assessed as having moderate risk of bias (Harfouche *et al*., 2025; Yamamoto *et al*., 2019).

3.4 Primary outcomes

3.4.1 Vascular complications

Thirteen studies reported vascular complications data. Composite vascular complication rates with REBOA were 4.2%-19.2% in the different studies compared with 1.1%-8.3% with RT. Specific vascular complication rates from studies where data was provided are presented in Table 2.

Table 2

Vascular Complications by Intervention

Study	REBOA N	REBOA Complications n (%)	RT N	RT Complications n (%)	Complication Types
Joseph *et al*., 2019	182	24 (13.2%)	546	16 (2.9%)	Access site injury, limb ischemia, thrombosis
Koh *et al*., 2023	26	5 (19.2%)	46	2 (4.3%)	Access site complications, limb ischemia
Brenner *et al*., 2018	83	12 (14.5%)	202	12 (5.9%)	Arterial injury, pseudoaneurysm, thrombosis
Moore *et al*., 2015	24	3 (12.5%)	72	4 (5.6%)	Limb ischemia, vascular repair required
DuBose *et al*., 2016	46	7 (15.2%)	132	6 (4.5%)	Access site injury, distal embolism
Inoue *et al*., 2016	112	14 (12.5%)	450	16 (3.6%)	Vascular injury requiring repair
Castellini *et al*., 2021*	421	86 (20.4%)	1,108	94 (8.5%)	Amputation, hematoma, pseudoaneurysm
Bukur *et al*., 2021	189	16 (8.5%)	376	12 (3.2%)	Access complications, limb ischemia

*Combined data from several studies

- Analysis of certain vascular complications showed that REBOA was linked to increased rates of:

- Site Arterial Injury requiring intervention: REBOA 97/2,417 (4.0%) vs. RT 62/5,830 (1.1%)
- Distal limb ischemia requiring revascularization or amputation 73/2,417 (3.0%) vs. 76/5,830 (1.3%) RT
- Pseudoaneurysm formation 42/2417 (1.7%) versus 35/5830 (0.6%) RT
- Unintervened Thrombosis: 3 099 (1.0%) vs. 12 703/17 251 (2.7%)
- Need for repair of the vasculature after initial occlusion REBOA 86/2417 (3.6%) vs. RT 92/5830 (1.6%)

3.5 Amputation: REBOA 24/2,417 (1.0%) vs. RT 18/5,830 (0.3%)

Subgroup analysis by REBOA zone showed an increase in the rate of the complications associated with zone 1 (supraceliac) compared to zone 3 (infrarenal) placement. In the AORTA registry analysis zone 1 complications occurred in 12.4% vs 7.2% for zone 3 (Dewey *et al*., 2025). Sheath size was found to be a significant predictor of access site complications with 7 Fr sheaths found to have a lower rate of complications (4.8%) compared with larger sheaths (11.2%) (Dewey *et al*., 2025; Romagnoli *et al*., 2017).

3.6 Transfusion requirements

Fifteen studies reported the 24-hour transfusion requirements. Table 3 shows 24-hour data for PRBC transfusion from individual studies.

Table 3

24-Hour PRBC Transfusion Requirements

Study	REBOA N	REBOA PRBC Units Mean (SD)	RT N	RT PRBC Units Mean (SD)	Difference (REBOA - RT)
Koh *et al*., 2023	26	8.2 (4.6)	46	12.4 (5.8)	-4.2 units
Joseph *et al*., 2019	182	7.8 (5.2)	546	10.6 (6.1)	-2.8 units
Brenner *et al*., 2018	83	6.9 (4.8)	202	9.8 (5.4)	-2.9 units
Moore *et al*., 2015	24	8.4 (5.6)	72	11.2 (6.3)	-2.8 units
Inoue *et al*., 2016	112	9.2 (6.8)	450	11.8 (7.2)	-2.6 units
Garcia *et al*., 2021	28	10.4 (5.8)	32	14.2 (6.4)	-3.8 units

Harfouche *et al*., 2022	42	7.2 (4.2)	84	9.6 (5.1)	-2.4 units
Yamamoto *et al*., 2019	215	8.6 (5.4)	430	11.4 (6.2)	-2.8 units
Matsumoto *et al*., 2019	245	9.8 (6.2)	490	12.6 (6.8)	-2.8 units

The overall mean of 24 hour PRBC transfusion reduction using REBOA was 2.4-4.2 units in all the studies. Massive transfusion protocol (MTP) activation was also less with REBOA in studies reporting for this outcome. Joseph *et al*. (2019) found MTP activation in 42.3% of REBOA patients compared with RT patients. Brenner *et al*. (2018), MTP activation was found in 38.6 vs. 51.2%, respectively.

Fresh frozen plasma (FFP) transfusion at 24 hours was consistently less with REBOA. Koh *et al*. (2023) found a mean of 5.2 units of FFP with REBOA compared to 8.4 with RT. Joseph *et al*. (2019) found FFP requirements of 4.8 vs. 6.9 units, respectively. Platelet transfusion had less consistent differences between studies.

In the specific subgroup of the patients with pelvic fractures, however, REBOA was linked to increased transfusion needs. Mikdad *et al*., 2020 reported mean 24 hr PRBC of 14.2 units with REBOA vs 9.4 units with pre-peritoneal packing (p= 0.01). Similar results were reported by Chien *et al*., (2023) which revealed that the transfusion requirement with REBOA was higher in severe pelvic fractures (12.8 vs. 8.6 units, p=0.008).

3.7 Return of spontaneous circulation (ROSC)

Ten studies provided ROSC rates in patients presenting in traumatic cardiac arrest or peri-arrest. Table 4 shows ROSC rates from individual studies.

Table 4

ROSC Rates in Traumatic Cardiac Arrest/Peri-Arrest

Study	REBOA N	REBOA ROSC n (%)	RT N	RT ROSC n (%)	Definition of ROSC
Teeter et al., 2018a	33	20 (60.6%)	18	5 (27.8%)	Any ROSC
Teeter et al., 2018b	22	13 (59.1%)	28	9 (32.1%)	Sustained >20 min
Koh et al., 2023	26	14 (53.8%)	46	16 (34.8%)	Sustained ROSC
Brenner et al., 2018	51	28 (54.9%)	89	34 (38.2%)	ED ROSC
Moore et al., 2015	24	12 (50.0%)	72	18 (25.0%)	Return of pulses
Abe et al., 2016	126	42 (33.3%)	379	68 (17.9%)	ROSC in ED

Ordonez et al., 2020	42	18 (42.9%)	38	10 (26.3%)	Sustained ROSC
Yamamoto et al., 2020	124	48 (38.7%)	248	62 (25.0%)	Prehospital ROSC
Aso et al., 2017	184	52 (28.3%)	367	74 (20.2%)	ROSC at 24h

ROSC when used with REBOA ranged between 28.3 and 60.6 percent across the studies as opposed to 17.9 and 38.2 percent using RT. The absolute increase in ROSC by REBOA was between 8.1-32.8%. Time to ROSC was reported in four studies and REBOA was associated with shorter time to ROSC achievement among patients who achieved ROSC. Teeter *et al* (2018b) reported median time to ROSC of 12 minutes with REBOA compared to 18 minutes with RT (p=0.04).

3.8 Secondary outcomes

3.8.1 Mortality

Twenty studies reported on mortality at different time points. Deaths from individual studies are shown in Table 5.

Table 5

Mortality Outcomes

Study	REBOA N	REBOA Mortality n (%)	RT N	RT Mortality n (%)	Time Point
ED Mortality					
Joseph *et al*., 2019	182	38 (20.9%)	546	153 (28.0%)	ED death
Inoue *et al*., 2016	112	24 (21.4%)	450	126 (28.0%)	ED death
Norii *et al*., 2015	298	86 (28.9%)	1,245	436 (35.0%)	ED death
Brenner *et al*., 2018	83	12 (14.5%)	202	48 (23.8%)	ED death
24-Hour Mortality					
Joseph *et al*., 2019	182	52 (28.6%)	546	213 (39.0%)	24-hour
Koh *et al*., 2023	26	18 (69.2%)	46	35 (76.1%)	24-hour
Inoue *et al*., 2016	112	38 (33.9%)	450	189 (42.0%)	24-hour
Garcia *et al*., 2021	28	8 (28.6%)	32	16 (50.0%)	24-hour
Hospital Discharge					
Joseph *et al*., 2019	182	91 (50.0%)	546	322 (59.0%)	Discharge
Koh *et al*., 2023	26	23 (88.5%)	46	43 (93.5%)	Discharge
Brenner *et al*., 2018	83	46 (55.4%)	202	136 (67.3%)	Discharge
Abe *et al*., 2016	126	89 (70.6%)	379	296 (78.1%)	Discharge
Aso *et al*., 2017	184	128 (69.6%)	367	272 (74.1%)	Discharge
DuBose *et al*., 2016	46	32 (69.6%)	132	108 (81.8%)	Discharge
Moore *et al*., 2015	24	15 (62.5%)	72	65 (90.3%)	Discharge
Cralley *et al*., 2023	228	180 (78.9%)	452	393 (86.9%)	Discharge
Bukur *et al*., 2021	189	138 (73.0%)	376	308 (81.9%)	Discharge
Harfouche *et al*., 2022	42	8 (19.0%)	84	38 (45.2%)	Discharge

Matsumoto *et al*., 2019	245	169 (69.0%)	490	372 (75.9%)	Discharge
Balch *et al*., 2023	24	11 (45.8%)	42	35 (83.3%)	Discharge
30-Day Mortality					
Yamamoto *et al*., 2019	215	103 (47.9%)	430	236 (54.9%)	30-day
Ordonez *et al*., 2020	42	24 (57.1%)	38	27 (71.1%)	30-day
90-Day Mortality					
Jansen *et al*., 2023 (RCT)	46	32 (69.6%)	44	24 (54.5%)	90-day

The incidence of death at hospital discharge was 19.0% to 88.5% with REBOA and 45.2% to 93.5% with RT in studies. The large ranges indicate considerable heterogeneity in patient populations with greater mortality in studies only enrolling patients in cardiac arrest (Koh *et al*., 2023) and less mortality in studies enrolling patients with profound hypotension but preserved circulation (Harfouche *et al*., 2022).

The one RCT (UK-REBOA) had increased 90-day mortality in the REBOA group (69.6% vs. 54.5%), but this was not statistically significant (Jansen *et al*., 2023). Of note, only 41% of the patients randomized to REBOA underwent balloon inflation and the REBOA group had a greater degree of head injury severity.

3.9 Time to aortic occlusion

Twelve studies provided time-related data concerning aortic occlusion. Time to occlusion data is shown in Table 6.

Table 6

Time to Aortic Occlusion

Study	REBOA Time (minutes)	RT Time (minutes)	Metric
Romagnoli *et al*., 2017	8.2 (median)	5.4 (median)	Decision to occlusion
Koh *et al*., 2023	7.0 (median)	4.0 (median)	Decision to occlusion
Brenner *et al*., 2018	8.5 (mean)	5.2 (mean)	Decision to occlusion
DuBose *et al*., 2016	9.2 (mean)	5.8 (mean)	Decision to occlusion
Teeter *et al*., 2018b	11.0 (median)	8.0 (median)	Arrival to occlusion
Joseph *et al*., 2019	14.2 (mean)	9.6 (mean)	ED arrival to occlusion
Inoue *et al*., 2016	12.8 (mean)	8.4 (mean)	Door to AO
Moore *et al*., 2015	10.5 (mean)	6.8 (mean)	Decision to occlusion
Abe *et al*., 2016	7.8 (mean)	4.6 (mean)	Procedure time
Cralley *et al*., 2023	8.6 (median)	5.2 (median)	Initiation to AO

Time from decision to successful occlusion of the aorta varied between 7.0 and 14.2 minutes with REBOA compared with 4.0 to 9.6 minutes with RT in the studies. The

difference in time was 2.6 to 5.2 minutes longer using REBOA. Among patients in traumatic cardiac arrest specifically, the time difference was less marked (2.1-3.0 minutes) suggesting that institutional protocols and operator experience may overcome the delays in the most time-critical patients (Romagnoli et al., 2017; Koh et al., 2023).

3.10 Non-vascular complications

Table 7 summarizes non-vascular complication rates from studies reporting these outcomes.

Table 7

Non-Vascular Complications

Complication	Studies Reporting	REBOA n/N (%)	RT n/N (%)
Acute kidney injury	Joseph *et al*., 2019; Inoue *et al*., 2016; Dewey *et al*., 2025; Castellini *et al*., 2021	198/2,417 (8.2%)	268/5,830 (4.6%)
Reperfusion injury	Joseph *et al*., 2019; Moore *et al*., 2015; Dewey *et al*., 2025	87/2,417 (3.6%)	96/5,830 (1.6%)
Stroke	Joseph *et al*., 2019; Brenner *et al*., 2018; Castellini *et al*., 2021	34/2,417 (1.4%)	58/5,830 (1.0%)
Compartment syndrome	Joseph *et al*., 2019; Inoue *et al*., 2016; Dewey *et al*., 2025	53/2,417 (2.2%)	38/5,830 (0.7%)
ICU length of stay (days, mean)	Joseph *et al*., 2019; Brenner *et al*., 2018; Harfouche *et al*., 2022	11.4 days	13.8 days

The incidence of acute kidney injury (AKI) in patients using REBOA was 8.2 percent of patients compared to 4.6 percent of patients using RT with greater incidences in zone 1 occlusion and longer inflation periods (>30 minutes). According to Dewey *et al.* (2025), zone 1 REBOA had AKI rates of 10.2% as compared to zone 3 (5.8%). Reperfusion injury requiring an intervention occurred in 3.6% REBOA patients compared to 1.6% RT. When compared to REBOA, compartment syndrome was more common (2.2% vs. 0.7%). In studies that evaluated this outcome, ICU length of stay of survivors was shorter with REBOA (mean 11.4 vs. 13.8 days).

3.11 Subgroup analyses

3.11.1 Mechanism of injury

Table 8 presents outcomes stratified by mechanism of injury and below are studies reporting subgroup data.

Table 8

Outcomes by Mechanism of Injury

Outcome	Penetrating Injury	Blunt Injury
Mortality (REBOA vs RT)		
Joseph *et al*., 2019	45.2% vs 58.6%	52.8% vs 59.2%
Brenner *et al*., 2018	48.6% vs 64.2%	58.4% vs 68.9%
Inoue *et al*., 2016	38.5% vs 52.8%	42.6% vs 48.2%
Moore *et al*., 2015	54.2% vs 86.4%	70.0% vs 92.0%
ROSC (REBOA vs RT)		
Teeter *et al*., 2018a	64.3% vs 28.6%	52.6% vs 27.3%
Koh *et al*., 2023	58.3% vs 32.4%	50.0% vs 41.7%
Vascular complications (REBOA)		
Joseph *et al*., 2019	10.8%	14.6%
Inoue *et al*., 2016	8.9%	13.8%

In penetrating trauma, REBOA had greater benefits for mortality reduction (absolute reduction 8.6-32.2%), ROSC improvement (absolute increase 8.3-35.7%) compared to RT. In blunt trauma, the difference in mortality was reduced (absolute reduction 0.8-22.0%). Vascular complication rates with REBOA were found to be high in blunt trauma (13.8 - 14.6%) compared to penetrating trauma (8.9 - 10.8%).

3.12 REBOA zone

Table 9 shows outcomes according to REBOA zone from the AORTA registry analysis (Dewey *et al*, 2025) and other studies reporting data according to REBOA zone.

Table 9

Outcomes by REBOA Zone

Outcome	Zone 1 (Supraceliac)	Zone 3 (Infrarenal)
Mortality		
Dewey et al., 2025	68.4%	58.2%
Brenner et al., 2018	58.6%	48.4%
ROSC		
Teeter et al., 2018b	62.5%	54.5%
AKI		
Dewey et al., 2025	10.2%	5.8%
Joseph et al., 2019	9.6%	5.2%
Vascular complications		
Dewey et al., 2025	12.4%	7.2%
Romagnoli et al., 2017	14.8%	6.4%
Time to occlusion (minutes)		
Romagnoli et al., 2017	8.6	7.8
Brenner et al., 2018	9.2	8.0

Zone 1 occlusion was associated with higher rates of ROSC (62.5% vs. 54.5%) but also of mortality (58.6-68.4% vs. 48.4-58.2%), higher rates of AKI (9.6-10.2 vs. 5.2-5.8%) and higher rates of vascular complications (12.4-14.8 vs. 6.4-7.2%) in comparison to zone 3. Time to occlusion was slightly longer with zone 1 placement (0.8 - 1.2 minutes).

3.13 Partial and complete REBOA

Three studies compared partial REBOA (P-REBOA) to complete REBOA (C-REBOA). Some comparative data is presented in Table 10.

Table 10

Partial versus Complete REBOA

Outcome	P-REBOA	C-REBOA	Study
Mortality	58.3%	71.2%	Dewey et al., 2025
	54.2%	68.4%	Cralley et al., 2023
AKI	5.6%	9.8%	Dewey et al., 2025
	4.8%	8.2%	Joseph et al., 2019
Vascular complications	6.4%	9.2%	Dewey et al., 2025
	5.8%	8.6%	Romagnoli et al., 2017
Reperfusion injury	2.1%	4.8%	Dewey et al., 2025

P-REBOA was linked with a lower mortality (absolute reduction 12.9-14.2%), lower AKI rates (absolute reduction 3.4-4.2%) and lower vascular complications (absolute reduction 2.8%) compared to C-REBOA. It is plausible that its findings indicate a potential improvement of risk-benefit profile through partial occlusion, as long as it is technically possible.

3.14 Pelvic fracture subgroup

Four of these studies focused on the use of REBOA in patients with pelvic fractures. Table 11 presents these data.

Table 11

REBOA in Pelvic Fracture Patients

Study	REBOA N	REBOA Mortality n (%)	Comparator N	Comparator Mortality n (%)	Comparator
Mikdad et al., 2020	52	27 (51.9%)	89	33 (37.1%)	Pre-peritoneal packing
Chien et al., 2023	68	22 (32.4%)	136	26 (19.1%)	No REBOA
Matsumoto et al., 2020	124	76 (61.3%)	248	112 (45.2%)	No REBOA
Bini et al., 2022	86	31 (36.0%)	42	34 (80.9%)	Open AO (RT)

In patients with a pelvic fracture, REBOA was linked with an increased mortality rate compared with no-REBOA or pre-peritoneal packing (absolute increase 13.3-16.1%) and a decreased mortality rate compared with RT with open aortic occlusion (absolute reduction 44.9%). Transfusion needs were greater in REBOA for pelvic fracture patients: Mikdad *et al*. (2020) showed mean 24-hour PRBC of 14.2 units with REBOA compared with 9.4 units with pre-peritoneal packing.

3.15 GRADE evidence profile

Table 12 presents the GRADE assessment for primary outcomes.

Table 12

GRADE Evidence Profile

Outcome	Number of Studies	Study Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Overall Certainty
Vascular complications	13	Observational	Serious (-1)	Serious (-1)	Not serious	Serious (-1)	⨁⊖⊖⊖ VERY LOW
Transfusion requirements	15	Observational	Serious (-1)	Serious (-1)	Not serious	Serious (-1)	⨁⊖⊖⊖ VERY LOW
ROSC	10	Observational	Serious (-1)	Not serious	Not serious	Serious (-1)	⨁⨁⊖⊖ LOW
Mortality (discharge)	16	Observational (+1 RCT)	Serious (-1)	Serious (-1)	Not serious	Not serious	⨁⨁⊖⊖ LOW
Time to occlusion	12	Observational	Serious (-1)	Serious (-1)	Not serious	Serious (-1)	⨁⊖⊖⊖ VERY LOW

Vascular complications and transfusion requirements were considered as very low with the risk of bias, inconsistency and imprecision. The rating of ROSC and mortality was low certainty. Such ratings are consistent with the latest EAST guideline evaluation (Harfouche *et al*., 2025).

4 DISCUSSION

4.1 Summary of main findings

This is a systematic review of 23 studies involving 8247 patients in comparison of resuscitative endovascular balloon occlusion of the aorta (REBOA) and resuscitative thoracotomy (RT) in the treatment of exsanguinating abdominal trauma. The findings indicate intricate risk benefit profile that differs based on mechanisms of injury, clinical presentation, and physiology of the patient.

4.2 Primary outcomes

REBOA results in more vascular complications and is reported to range between 4.2 and 19.2% versus RT of 1.1 to 8.3%. The most frequent ones are access-site arterial

injury that necessitates intervention (4.0 vs. 1.1), distal limb ischemia that necessitates intervention (3.0 vs. 1.3), and pseudoaneurysms (1.7 vs. 0.6). In REBOA, amputation is seen in about 1.0 vs. 0.3 after RT. It is possible to mitigate such risks by lowering sheath sizes (preferably 7 Fr), utilizing ultrasound-guided access, and reducing the time of occlusion (Dewey *et al*., 2025; Romagnoli *et al*., 2017).

REBOA is also always connected with decreased transfusion needs in 24 hours. The mean decrease in packed red blood cells (PRBCs) is between 2.4 and 4.2 units, which equates to the 25 to 35 percent decrease in the overall volume of transfusion. REBOA also has a lower massive transfusion protocol activation (38.6 42.3 per cent vs. 51.258.6 per cent). This is probably the result of an improved temporary hemorrhage control and the prevention of the physiologic insult of an open thoracotomy (White *et al*., 2011; Morrison *et al*., 2014). REBOA (28.360.6) compared to RT (17.938.2) has a higher probability of recovery of spontaneous circulation during traumatic cardiac arrest (absolute increase of 833). This could be explained by experimental studies which indicated that there was an improvement in the cardiac compression fraction (86.2% vs. 55.3%), and an increase in the end-tidal CO 2 during resuscitation, which supported the argument that there was an improvement in the coronary and cerebral perfusion during closed-chest CPR (Teeter *et al*., 2018b).

4.3 Secondary outcomes

The results of mortality are shifted with the selection of patients. REBOA decreases mortality by 11.9-26.2 among patients with severe hypotension who have maintained their circulation. In traumatic cardiac arrest, there is no or minimal difference in the outcomes with regard to mortality with REBOA (absolute reduction 5.0-27.8%). Nevertheless, the one randomised controlled trial showed more mortality in the REBOA group (69.6% vs. 54.5%), which may be explained by a high balloon inflation rate and variance in the severity of head injury (Jansen *et al*., 2023).

REBOA has a longer time to aortic occlusion with an average of 2.6-5.2 min delays as compared to RT. This is essential in patients who are about to have a cardiac arrest. Nevertheless, the difference is lower in experienced centres and in cardiac arrest cases (2.130 minutes), which indicates that delays can be reduced by protocolized care

and the experience of operators (Romagnoli *et al*., 2017; Koh *et al*., 2023). The incidence of ischemic complications also favours REBOA, such as acute kidney injury (8.2% vs. 4.6%), reperfusion injury (3.6% vs. 1.6%), and compartment syndrome (2.2% vs. 0.7%). Occlusion and inflation times of more than 30 minutes are a strong risk factor for AKI, there is a need to reduce the duration of occlusion and partial REBOA.

4.4 Subgroup findings/clinical implications

The mechanism of injury has a strong effect. REBOA seems to be more advantageous in penetrating trauma, where mortality is reduced by 8.6-32.2 percent and ROSC by 8.3-35.7 percent higher. In blunt trauma, the gains are less and chances of complication are more. The choice of occlusion zones also has an influence. Zone 1 occlusion offers better proximal control and better ROSC but greater risks of AKI and vascular complications. Zone 3 occlusion could be better in the case of pelvic or junctional hemorrhage.

Another significant technical improvement is the partial REBOA (P-REBOA). It has been linked to a low mortality rate (12.914.2% reduction), decreased AKI (3.44.2% reduction), and less vascular complications, which is probably because of preserved distal perfusion (Dewey *et al*., 2025).

Patients with pelvic fractures are an extremely problematic group. REBOA is linked to high mortality (13.3–16.1%) and high transfusion requirements as compared to others like preperitoneal packing. Nevertheless, in case of aortic occlusion, REBOA again seems to be a better alternative than RT, and the absolute mortality reduction is 44.9%.

4.5 Comparison of with the previous reviews

The results are similar to previous systematic reviews. The lower mortality rate in Castellini *et al*. (2021) and Khalid *et al*. (2022) was associated with REBOA, but no specific complication results were provided. This review offers more detailed estimates of vascular complications and outcomes of transfusion through the incorporation of recent large registries (Dewey *et al*., 2025; Koh *et al*., 2023; Cralley *et al*., 2023). The results also comply with the recent guideline suggestions according to which the selective

application of REBOA is recommended, especially in traumatic cardiac arrest (Harfouche *et al*., 2025).

5 CONCLUSION

This systematic review indicates that two interventions have been suggested to be used in temporary aortic control in exsanguinating abdominal trauma: resuscitative endovascular balloon occlusion of the aorta (REBOA) and resuscitative thoracotomy, which have different benefits and drawbacks. REBOA also reduced the amount of transfusion (2.4-4.2 units of packed red blood cells in 24 h) and enhanced restoration of spontaneous circulation in traumatic cardiac arrest (absolute change 8-33%). Nevertheless, the rates of vascular complications such as access-site injury and limb ischemia were also increased with REBOA. The process takes a little more time to attain aortic occlusion. In general, the procedure requires close patient selection and the technique optimization, and additional prospective research is necessary.

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Authors' Contribution

All authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study's findings are fully available within the article.

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