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Safety or speed? Assessing alternative vascular access for angiography after resuscitative endovascular balloon occlusion of the aorta (REBOA) in severe pelvic trauma patients

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ABSTRACT

Introduction Pelvic fractures often result in life-threatening bleeding and hemodynamic instability. Resuscitative endovascular balloon occlusion of the aorta (REBOA) has emerged as a promising strategy for patients with severe pelvic fractures, facilitating subsequent hemostatic interventions. Transcatheter arterial embolization (TAE) is a well-established procedure for managing pelvic fractures accompanied by hemorrhage.

Ideally, an angiographic access point distinct from the initial REBOA placement is sought to maintain REBOA deflation without complete removal, thereby preventing hemodynamic instability during the procedure. However, in cases of extreme and severe pelvic trauma, gaining access for REBOA is already challenging, not to mention the additional difficulty posed by subsequent angiographic access.

This study aims to assess the challenges associated with gaining access in cases where successful TAE was ultimately performed, particularly in the context of severe pelvic trauma. We investigate the complexities surrounding access management and its implications for patient outcomes.

Methods We conducted a retrospective analysis of patients who presented with pelvic fractures and underwent sequential REBOA and TAE procedures at our institution between 2017 and 2023. We excluded patients with Abbreviated Injury Scores (AIS) ≥3 in systems other than the pelvis, those who underwent TAE prior to REBOA, and cases of suboptimal REBOA insertion.

We collected demographic data, injury characteristics, details of the REBOA and TAE procedures, information on complications, and data on patient survival. The primary endpoints of our analysis included overall survival and the success of TAE (defined as post TAE mean arterial pressure (MAP) ≥65 mm Hg). Secondary endpoints encompassed the duration details of two interventions.

Results Between 2017 and 2023, a total of 17 patients were included in this study. Among this cohort, 12 (70.6%) were male, with a median age of 51 years. Overall survival was 23.5%. Patients were grouped into angiography after REBOA deflation (AAD) or angiography after REBOA removal (AAR). AAR group was younger (39.0 vs 63.0, p=0.030) and had higher Shock Index at triage (2.30 vs 1.10, p=0.015). More patient whose post TAE MAP >=65 mm Hg was found in the AAR group, although no significant difference on overall survival (25.0% vs 22.2%, p=1.000). Angiographic cannulation times, pre-angiographic MAP, and amount of pre-angiographic transfusion of packed red blood cell were similar across groups.

Conclusion Our findings provide empirical insights into vascular access selection and suggest that AAR in the management of severe pelvic fractures can be beneficial, particularly when pre-angiographic resuscitation is sufficient. Larger studies are required to validate these observations and assess long-term outcomes.

Level of evidence III.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Resuscitative endovascular balloon occlusion of the aorta (REBOA) is used to control hemorrhage in severe cases, and transcatheter arterial embolization (TAE) is an established procedure for managing hemorrhagic pelvic fractures.
⇒ However, securing vascular access for TAE after REBOA remains challenging.

WHAT THIS STUDY ADDS

⇒ This study highlights that angiography after REBOA removal (AAR) is associated with a higher rate of post-TAE mean arterial pressure ≥65 mm Hg and a shorter duration from angiography room arrival to successful cannulation compared with angiography after REBOA deflation.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings of this study indicate that AAR could be a preferable approach in severe pelvic fracture cases, potentially influencing clinical practice by providing a more efficient and effective method for vascular access in these critical situations.

INTRODUCTION

Pelvic trauma poses a significant challenge in trauma care, constituting 3% of skeletal injuries.[1–3] Patients afflicted with pelvic fractures are typically young and present with elevated overall Injury Severity Scores (ISS) ranging from 25 to 48.[4] Despite advancements in trauma care, mortality rates remain elevated, especially among those experiencing hemodynamic instability. The primary contributors to this heightened mortality include rapid exsanguination, the inherent difficulty in achieving hemostasis, and the presence of associated injuries.[2 3 5]

In response to this formidable challenge, resuscitative endovascular balloon occlusion of the aorta (REBOA) has emerged as a promising and innovative strategy for patients suffering from severe pelvic fractures.[6 7] By temporarily occluding the aorta, REBOA provides a crucial window for subsequent hemostatic interventions, effectively managing hemorrhage in these high-stakes situations.[8] Concurrently, transcatheter arterial embolization (TAE) stands as a well-established and effective procedure for addressing pelvic fractures associated with significant hemorrhage.[6 9 10]

The synergy between REBOA and TAE presents a comprehensive approach to managing severe pelvic trauma. However, navigating the intricacies of vascular access becomes particularly challenging in cases of extreme and severe pelvic trauma.[11 12] The difficulty is compounded when considering the need for an angiographic access point distinct from the initial REBOA placement. This strategic requirement arises from the desire to maintain REBOA deflation without complete removal, a delicate balance crucial for preventing hemodynamic instability during subsequent angiographic procedures.

Although the integration of REBOA and TAE holds immense potential, the challenges regarding the route of vascular access and how TAE is ultimately performed remain a focal point of concern. The intricacies of securing access for REBOA, particularly in cases of severe pelvic trauma, significantly contribute to the complexity of treatment strategies. This study seeks to thoroughly examine the challenges of vascular access, specifically when TAE is required after REBOA in severe pelvic trauma cases. By diving deep into the complexities of access management, our goal is to clarify how these challenges affect patient outcomes and provide insights to refine clinical approaches in this critical area. This investigation aims to bridge a crucial knowledge gap, shedding light on the complexities of this integrated therapeutic approach and its impact on the overall care framework for patients with severe pelvic trauma.

PATIENTS AND METHODS

Study design and population

We conducted a single-center, retrospective cohort study of patients with pelvic fractures and subsequently underwent sequential REBOA and TAE at our institution from January 2017 to December 2023. Patients were included if they received both REBOA and TAE as part of their management. Those with significant concurrent injuries, defined as an Abbreviated Injury Score (AIS) of 3 or greater in any body system other than the pelvis, were excluded. Patients who underwent TAE prior to REBOA and those with suboptimal REBOA insertion, as determined by post-procedural imaging or surgical notes, were also excluded.

Retrospective data were collected through a comprehensive review of electronic medical records, radiologic images, and procedural reports. The collected data encompassed demographic information, type and severity of pelvic injuries, details of REBOA procedure, details of TAE procedure and findings, complications, amounts of transfusions and patient outcome.

The study's primary outcome measures are overall survival and TAE successful rate. A successful TAE was defined as optimal embolization and achieving a mean arterial pressure (MAP) ≥65 mmHg after TAE. Secondary outcomes include the duration for which the REBOA device is inflated and taking effect, as well as the time span from patient's arrival at the emergency department (ED) to the successful cannulation in the angiography suite.

Study grouping

Patients were divided into two groups based on the timing of angiographic cannulation relative to the REBOA procedure: angiography after REBOA deflation (AAD) and angiography after REBOA removal (AAR). In the AAD group, angiographic cannulation occurs after REBOA is partially or fully deflated but not removed, necessitating an additional arterial access, typically established contralaterally, for subsequent TAE. Conversely, in the AAR group, patients undergo angiography after the REBOA is removed. Thus, angiographic cannulation can be directly inserted into the sheath used for the preceding REBOA, expediting the procedure.

Statistical analysis

Descriptive statistics were used to summarize demographic and clinical characteristics. Continuous variables were expressed as medians and IQRs, as appropriate. Categorical variables were summarized as counts and percentages. Non-parametric comparisons were conducted using the Mann-Whitney U test, whereas univariate analysis for identifying risk factors associated with mortality employed logistic regression. A p value <0.05 was considered statistically significant. All statistical analyses were performed using IBM SPSS V.25 for Windows.

Ethical considerations

This study was conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Declaration of Helsinki and its later amendments. This study was approved by the Institutional Review Board (IRB) of Chang Gung Memorial Hospital, Taoyuan city, Taiwan on August 1, 2022 (approval number: 201902275B0). Due to the retrospective nature of the study, the requirement for informed consent was waived.

RESULTS

During the 6-year period from 2017 to 2023, after excluding 10 patients who was not fit for our study, we enrolled 17 patients with pelvic fractures who underwent both REBOA and TAE procedures (see figure 1). Among 10 excluded patients, 2 of them was due to failed REBOA attempts, resulting from the kinking of the catheters during REBOA placement. The majority of enrolled patients were male (12 patients, 70.6%), with a median age of 51 years (IQR 37 years). Motor vehicle collisions were the leading cause of injury, accounting for 76.5% of cases (13 patients). Prior to REBOA, 29.4% of patients experienced cardiac arrest. Overall, the survival rate was 23.5%, with only 4 patients surviving to hospital discharge. Notably, 17.6% of patients arrived at the emergency department in a traumatic out-of-hospital cardiac arrest (OHCA) status. Among the factors analyzed for mortality risk, only the body temperature at ED arrival was found to be significant (OR=0.308, p=0.039) (see table 1).

The AAR group had a significantly lower median age (39.0 years vs 63.0 years, p=0.030) and a significantly higher Shock

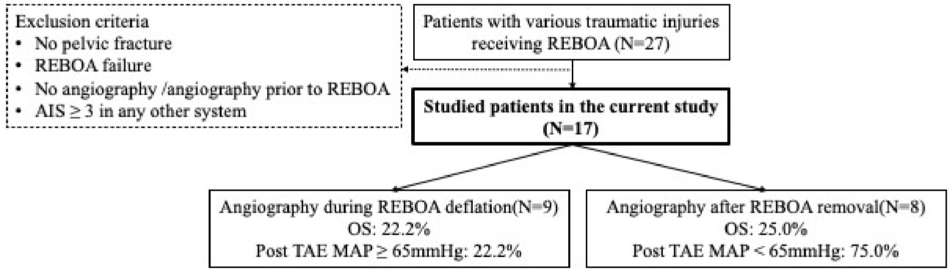

Figure 1 Study population and protocol of the current study. AIS, Abbreviated Injury Scores; MAP, mean arterial pressure; OS, overall survival; REBOA, resuscitative endovascular balloon occlusion of the aorta; TAE, transcatheter arterial embolization.

Index at triage (2.30 vs 1.10, p=0.015) compared with the AAD group (see table 2). However, no statistical disparities were found between the groups regarding trauma mechanism, ratio of traumatic OHCA (12.5% vs 22.2%, p=1.000), temperature (35.40°C vs 34.00°C, p=0.193), Glasgow Coma Scale (GCS) (3.8 vs 9.5, p=0.663), MAP at ED arrival (32.20 mmHg vs 80.15 mmHg, p=0.630), Injury Severity Score (ISS) (13.0 vs 15.0, p=0.697), ratio of associated abdominal injury (25.0% vs 55.6%, p=0.335), pre-angiography MAP (61.00 mmHg vs 79.30 mmHg, p=0.149), arterial contrast leakage (62.5% vs 77.8%, p=0.620), laboratory parameters, or PRBC transfusion before TAE (10.0 IU vs 12.0 IU, p=0.883).

Although more patients in the AAR group achieved a post-TAE MAP ≥65 mmHg compared with the AAD group (75.0% vs 22.2%, p=0.044), there were no significant differences in OS (25.0% vs 22.2%, p=1.000) or survival 72 hours after TAE (37.5% vs 44.4%, p=0.968). Additionally, the AAR group exhibited a significantly shorter duration from angio-room arrival to successful cannulation (5.5 min vs 16.0 min, p=0.038) compared with the AAD group. However, TAE duration, REBOA placement procedure duration, and PRBC transfusion volume 24 hours after TAE were comparable across both groups.

As shown in table 3, there was one case in the AAD group where preperitoneal pelvic packing was performed after REBOA placement, and the patient underwent TAE after preperitoneal packing. Due to severe inguinal crushing injury, arterial access on the contralateral side for angiography is not feasible. Furthermore, the inability to remove the REBOA arises from its severe compression by preperitoneal packing. Consequently, a novel femoral arterial access point proximal to the previous REBOA sheath becomes imperative to facilitate successful completion of TAE. During angiography, confirmation of contralateral external iliac traumatic transection further underscores the complexity and critical nature of the vascular injury management in this context. Additionally, there was another case in the AAR group where the patient received preperitoneal packing prior to TAE and subsequently had a favorable outcome, being discharged without major complications. In contrast, none of our patients received vasopressors or underwent pelvic fixation before TAE.

The most common indication for choosing AAR over AAD was injury to the contralateral internal iliac artery, observed in 50% of AAR patients (four patients), either due to initial trauma or iatrogenic injury. The findings of angiography in our study were listed below: bilateral internal iliac artery and associated branches bleeding (n=4), unilateral internal iliac artery and associated artery bleeding (n=8), unilateral internal iliac artery pseudoaneurysm (n=1), and no evidence of active bleeding (n=4). All of the relevant procedures were non-selective embolization over bilateral internal iliac arteries. Among all AAD patients, two of them underwent reinflation of the balloon due to severe hemodynamic compromise during TAE, whereas one of these two patients had transient left leg hypoperfusion but recovered without complications.

DISCUSSION

The role of REBOA in the management of pelvic fracture

The introduction of REBOA presents a pivotal shift in the paradigm of managing complex pelvic fractures.[3] This study highlights REBOA's integral role in stabilizing patients with severe pelvic trauma by providing temporary hemorrhagic control, which is crucial for facilitating subsequent definitive hemostatic interventions. Our findings found that the median MAP of post-REBOA is increased by 17.0 from pre-REBOA, aligning with previous research indicating REBOA's efficacy in hemodynamic stability among patients with traumatic hemorrhage when employed judiciously.[13]

The synergistic application of REBOA with TAE offers a comprehensive approach that addresses both immediate hemorrhage control and definitive bleeding source management, as suggested by Harfouche *et al*.[14] However, the challenges in achieving vascular access for TAE after REBOA deployment, particularly in the context of severe trauma, underscore the need for advanced planning and procedural proficiency.

Our study is among the first to comprehensively discuss the technical and clinical considerations regarding vascular access route selection in patients with severe pelvic injury. Theoretically, the indication for inclusion into AAR or AAD was the presence of an injury. Typically, the decision would be based on physiology. Patients who are extremely labile would be better served in the AAD, whereas those who are stable could be in the AAR group. Deflation of REBOA without removal of REBOA catheter has the potential benefit that the REBOA can be reinflated whenever the patient's hemodynamics become unstable during TAE. The TAE procedure can be even performed with the partially inflated balloon. Therefore, the hemodynamic stability can be maintained more easily compared with those patients who had their REBOA catheter been removed before TAE.

Interestingly, our results revealed that there was no statistical difference between the AAD and AAR groups regarding their pre-TAE MAP (79.3 mmHg vs 61.0 mmHg, p=0.149) and the amount of PRBC transfusion before TAE (12.0 vs 10.0, p=0.883). This suggests that as long as patients can be adequately resuscitated to maintain hemodynamic stability, both AAR and AAD could be viable options for surgeons.

Furthermore, the severity of MAP drops during TAE, represented by the ratio of (Intra-angiography lowest MAP – Pre-angiography MAP)/Pre-angiography MAP, showed no significant difference between the two groups. Interestingly, there was even

Table 1 Demographic data and univariate analysis of risk factors affecting OS of patients with traumatic pelvic injury underwent REBOA followed by TAE (n=17)

Variables	Numbers/median	%/IQR	OR	P value
Male	12	70.6	1.333	0.825
Age (year)	51	37	1.008	0.760
Mechanism				
MVA	13	76.5	0.000	0.999
Falling	4	23.5	–	
Traumatic OHCA	3	17.6	0.000	0.999
Temperature at ED arrival (°C)	35.0	2.8	0.308	0.039*
HR at ED arrival (bpm)	113.0	57.0	1.002	0.878
Shock index at ED arrival	1.5	1.4	1.236	0.660
MAP at ED arrival (mm Hg)	46.7	50.0	0.996	0.806
Pre-REBOA MAP (mm Hg)	42.0	22.3	1.016	0.647
Post-REBOA MAP (mm Hg)	59.0	25.9	0.986	0.731
Pre-angiography MAP (mm Hg)	69.0	29.4	1.012	0.714
Intra-angiography lowest MAP (mm Hg)	68.0	46.0	1.030	0.336
(Intra-angiography lowest MAP – Pre-angiography MAP)/Pre-angiography MAP (%)	22.0	36.5	4.938	0.490
Post-TAE MAP (mm Hg)	64.3	49.9	1.026	0.194
Post-TAE MAP ≥65 mm Hg	8	47.1	0.208	0.223
GCS at ED arrival	3.0	7.0	0.028	0.999
ISS	45.0	13.0	0.948	0.355
Open pelvic fracture	3	17.6	1.833	0.662
Associated abdominal injury	7	41.2	6.750	0.142
Y-B classification of pelvic fracture			–	
APC I	1	5.9		
APC II	3	17.6		
PC III	7	41.2		
LC II	2	11.8		
LC III	4	23.5		
PT-INR	1.70	0.70	0.714	0.798
Hb (g/dL)	9.60	2.75	0.130	0.623
SBE (mmol/L)	−13.55	−7.45	0.976	0.783
Lactate (mg/dL)	87.55	70.28	0.967	0.153
Procedure time of REBOA placement (min)	9.0	5.5	0.466	0.153
PRBC transfusion before TAE (U)	12.0	16.0	0.925	0.324
PRBC transfusion 24 hours after TAE (U)	18.0	16.0	1.045	0.268
Cardiac arrest before REBOA	5	29.4	0.000	0.999
Zone of REBOA placement			–	
Zone 1	4	23.5		
Zone 3	13	76.5		
REBOA access by cutdown	2	11.8	0.000	0.999
Duration of REBOA inflation (min)	107.0	83.5	0.516	0.994
Duration from ED arrival to cannulation (min)	147.0	80.5	0.979	0.170
Duration from angio-room arrival to cannulation (min)	7.0	12.0	0.966	0.569
Duration of angiographic cannulation (min)	67.0	34.5	1.001	0.952
Type of angiographic cannulation				
AAD	9	52.9	1.120	0.857
AAR	8	47.1	–	
Contrast medium during angiography (mL)	60.0	45.0	0.993	0.770
PPP	2	11.8	4.000	0.373
Iatrogenic vascular injury	1	5.9	–	
LOS (day)	10	39.0	–	
Survival 72 hours after TAE	7	41.2	–	
OS	4	23.5	–	

*P value <0.05.
AAD, angiography after REBOA deflation; AAR, angiography after REBOA removal; APC, anterior-posterior compression; CE, contrast extravasation; CT, computed tomography; ED, emergent department; ED, emergency department; GCS, Glasgow Coma Scale; Hb, hemoglobin; HR, heart rate; IQR, interquartile range; ISS, Injury Severity Score; LC, lateral compression; LOS, length of stay; MAP, mean arterial pressure; MVA, motor vehicle accident; OHCA, out-of-hospital cardiac arrest; OR, odds ratio; OS, overall survival; PPP, pre-peritoneal pelvic packing; PRBC, packed red blood cell; PT-INR, international normalized ratio derived from prothrombin time; REBOA, resuscitative endovascular balloon occlusion of the aorta; SBE, standard base excess; TAE, transcatheter arterial embolization; Y-B classification, Young-Burgess classification.

a trend toward a higher ratio in the AAD group then the AAR group (24.0% vs 2.0%, p=0.092).

These findings suggest that as long as adequate resuscitation can be achieved before TAE, the potential advantages of REBOA deflation might be mitigated, thereby making alternative arterial access methods feasible in clinical practice.

On the other hand, removal of REBOA before starting TAE was believed to be a way to accelerate vascular access and facilitate definitive hemostasis. In our study, we found that the duration from angio-room arrival to starting cannulation was significantly shorter in the AAR group than in the AAD group, whereas the time required for successful cannulation was similar between the two groups. Such results might be attributed to the combined effect of several factors including experiences of individual radiologists.

In addition to the AAR and AAD techniques, there are alternative approaches for performing TAE after REBOA under extreme conditions, such as partial REBOA or intermittent REBOA.[15 16] Although these methods were not used or detailed in our study, we think they represent viable options at the discretion of the radiologist, depending on the clinical scenario and patient-specific factors.

A recent prospective randomized controlled trial[17] involving 1388 patients undergoing coronary angiography and percutaneous coronary intervention demonstrated that ultrasound-guided puncture significantly enhanced the efficiency and overall success rate of arterial access. Similar to the above-mentioned study, we routinely employ ultrasound-guided puncture for every patient requiring arterial access for angiography. This approach helps mitigate operator bias and ensures consistency of successful arterial puncture in a short period of time across all cases.

One retrospective study reported by Awwad *et al*[18] revealed that for the management of severe pelvic injuries, selective embolization had a superior overall survival rate compared with non-selective embolization. Additionally, the use of gelfoam as the sole embolizer had a greater survival benefit compared with those using a combination of gelfoam and coils. However, such differences were not observed in our cohort possibly due to the limited number of cases in the current study.

Table 2 Comparisons of characteristics between angiography after REBOA deflation (AAD) and angiography after REBOA removal (AAR) in patients with traumatic pelvic injury underwent REBOA followed by TAE (n=17)

Variables	AAD (n=9)	AAR (n=8)	P value
Male (n/%)	6 (66.7)	7 (87.5)	0.294
Age (median year/IQR)	63.0 (20.5)	39.0 (27.8)	0.030*
Mechanism (n/%)			1.000
MVA	7 (77.8)	6 (75.0)	
Falling	2 (22.2)	2 (25.0)	
Traumatic OHCA (n/%)	2 (22.2)	1 (12.5)	1.000
Temperature at ED arrival (median °C/IQR)	34.00 (2.45)	35.40 (3.55)	0.193
HR at ED arrival (median bpm/IQR)	84.0 (28.5)	134.0 (19.0)	0.009*
Shock index at ED arrival (median/IQR)	1.10 (0.80)	2.30 (2.55)	0.015*
MAP at ED arrival (mm Hg/IQR)	52.00 (80.15)	37.00 (32.20)	0.630
Pre-REBOA MAP (mm Hg/IQR)	42.70 (47.70)	40.65 (22.50)	0.499
Post-REBOA MAP (mm Hg/IQR)	66.70 (27.50)	57.85 (26.15)	0.847
Pre-angiography MAP (mm Hg/IQR)	79.30 (34.00)	61.00 (30.93)	0.149
Intra-angiography lowest MAP (mm Hg/IQR)	52.7 (35.65)	56.65 (37.28)	0.700
(Pre-angiography MAP – Intra-angiography lowest MAP)/Pre-angiography MAP (%/IQR)	24.0 (38.0)	2.0 (56.7)	0.092
Post-TAE MAP (mm Hg/IQR)	62.30 (22.00)	89.15 (66.73)	0.136
Post-TAE MAP ≥65 mm Hg (n/%)	2 (22.2)	6 (75.0)	0.044*
GCS at ED arrival (median/IQR)	3.0 (9.5)	3.0 (3.8)	0.663
ISS (median/IQR)	45.0 (15.0)	43.0 (13.0)	0.697
Open pelvic fracture (n/%)	1 (11.1)	2 (25.0)	0.576
Associated abdominal injury (n/%)	5 (55.6)	2 (25.0)	0.335
Y-B classification of pelvic fracture (n/%)			–
APC I	1 (11.1)	0 (0.0)	
APC II	1 (11.1)	2 (25.0)	
APC III	3 (33.3)	4 (50.0)	
LC II	1 (11.1)	1 (12.5)	
LC III	3 (33.3)	1 (12.5)	
PT-INR (median/IQR)	1.70 (0.85)	1.70 (0.70)	0.710
Hb (median g/dL/IQR)	9.60 (3.25)	9.50 (3.18)	0.700
SBE (median mmol/L/IQR)	−12.40 (6.25)	−13.90 (18.75)	0.560
Lactate (median mg/dL/IQR)	93.25 (61.68)	78.55 (72.72)	0.834
Procedure time of REBOA placement (median minute/IQR)	9.0 (3.5)	10.0 (8.3)	0.734
PRBC transfusion before TAE (median U/IQR)	12.0 (9.0)	10.0 (25.5)	0.883
PRBC transfusion 24 hours after TAE (median U/IQR)	18.0 (13.0)	14.0 (28.5)	0.529
Cardiac arrest before REBOA (n/%)	4 (44.4)	1 (12.5)	0.294
Zone of REBOA placement (n/%)			0.082
Zone 1	4 (44.4)	0 (0.0)	
Zone 3	5 (55.6)	8 (100.0)	
REBOA access by cutdown (n/%)	0 (0.0)	2 (25.0)	0.206
Duration of REBOA inflation (median minute/IQR)			
Total	112.0 (85.5)	77.0 (127.3)	0.178
Zone 1	130.5 (119.5)	–	–
Zone 3	75.0 (62.5)	77.0 (127.3)	1.000
Duration from ED arrival to cannulation (median minute/IQR)	135.0 (87.0)	153.5 (87.3)	0.563
Duration from angio-room arrival to cannulation (median minute/IQR)	16.0 (18.5)	5.5 (10.8)	0.038*
Duration of angiographic cannulation (median minute/IQR)	67.0 (65.5)	66.5 (18.8)	0.810
Iatrogenic vascular injury (n/%)	0 (0.0)	1 (12.5)	0.471
LOS (median day/IQR)	9.0 (29.8)	22.0 (50.5)	0.226
Survival 72 hours after TAE (n/%)	4 (44.4)	3 (37.5)	0.968
Hemostatic intervention (n/%) before TAE			
PPP	1 (11.1)	1 (12.5)	–
Laparotomy	1 (11.1)	0 (0.0)	–
No	7 (77.8)	7 (87.5)	–
OS (n/%)	2 (22.2)	2 (25.0)	1.000

APC, anterior-posterior compression; CE, contrast extravasation; CT, computed tomography; ED, emergency department; GCS, Glasgow Coma Scale; Hb, hemoglobin; HR, heart rate; IQR, interquartile range; ISS, Injury Severity Score; LC, lateral compression; LOS, length of stay; MAP, mean arterial pressure; MVA, motor vehicle accident; OHCA, out-of-hospital cardiac arrest; OS, overall survival; PPP, pre-peritoneal pelvic packing; PRBC, packed red blood cell; PT-INR, international normalized ratio derived from prothrombin time; REBOA, resuscitative endovascular balloon occlusion of the aorta; SBE, standard base excess; TAE, transcatheter arterial embolization; Y-B classification, Young-Burgess classification.

Outcome and complications of REBOA utilization in severe pelvic fracture

Although REBOA is a promising technique, it is not without complications. Complications associated with the use of REBOA in the management of pelvic fractures include access site complications like hematoma and pseudoaneurysm,[12 19] which may result in lower limb ischemia and consequently lead to amputation of the limbs in severe cases.[20] Technical difficulties in the insertion of the catheter and the potential for iatrogenic injury during the procedure are also reported.[11] In our study, one patient experienced an iatrogenic injury to the external iliac artery, which necessitated TAE of the injured iliac artery after the removal of the REBOA catheter.

The risks associated with prolonged occlusion, such as reperfusion injury and limb ischemia, must be carefully weighed against the benefits, especially in cases where delays to definitive care are anticipated.[21] The balance between maintaining aortic occlusion to ensure hemodynamic stability and mitigating the risks associated with ischemia is a delicate one that requires further

Table 3 Demographics and outcome characteristics of patients with traumatic pelvic injury underwent REBOA followed by TAE (n=17)

Demographics			Trauma characteristics			REBOA details						Angiography details			Outcomes		
No.	Age	S/I at arrival	ISS	Associated injury	MAP ≥65 mm Hg after REBOA	C/A ever	Zone	Access method	Inflation duration	Access duration	Embolizer	Angio duration	Post TAE MAP ≥65 mm Hg	Post TAE survival in 72 hours	LOS	OS	Remark
AAD																	
1	70s	0.7	29	Tibia fx, L-spine fx	Y	N	3	P/C	154	5	Gelatin	34	N	N	2	N	
2	50s	N/A	50	Pneumothorax, mesocolon injury	N	Y	1	P/C	149	58	Gelatin+Coils	113	N	N	0	N	PPP causing REBOA removal failure, contralateral iliac artery transaction
3	60s	1.3	57	Spleen injury, mesentery injury	Y	N	1	P/C	112	19	Gelatin	67	N	Y	22	Y	
4	70s	N/A	45	Hemothorax, lung contusion	Y	Y	1	P/C	112	7	Gelatin	37	N	N	0	N	CPCR at OR without ROSC
5	60s	0.8	41	Pneumo-hemothorax	Y	Y	3	P/C	79	6	Gelatin+Coils	50	N	N	N/A	N	REBOA adjustment at ED
6	30s	1.5	41	Mesentery injury	N	Y	1	P/C	259	30	Gelatin+Coils	105	N	N	2	N	Manpower shortage leading to delayed angiography
7	60s	0.7	48	Pneumo-hemothorax	Y	N	3	P/C	75	18	Gelatin	156	N	Y	32	N	Agitation requiring sedation during angiography
8	80s	1.1	20	Liver laceration	N	N	3	P/C	51	6	Gelatin	99	Y	Y	29	Y	
9	20s	1.9	50	SDH, spleen injury, lung contusion	N	N	3	P/C	57	16	Gelatin	55	Y	Y	20	N	Expired due to brain stem failure
AAR																	
10	30s	4.0	41	Lung contusion, SDH	N	N	3	P/C	137	15	Gelatin	63	Y	N	N/A	N	Altered access due to iatrogenic external iliac artery injury
11	30s	3.9	25	Femoral fx, urethral injury	N	N	3	P/C	107	5	Gelatin	54	Y	Y	12	Y	PPP performed
12	10s	1.2	50	No	N	N	3	P/C	8	3	Gelatin+Coils	76	Y	Y	4	N	Reinflation of REBOA after TAE due to shock
13	40s	4.2	38	Heart contusion, femoral fx	Y	Y	3	Cut-down	15	1	Gelatin	73	Y	N	N/A	N	
14	50s	2.1	36	Spleen injury	Y	N	3	P/C	138	14	Gelatin	52	N	N	N/A	N	Avoiding any BT, as Jehovah's Witness
15	20s	0.9	45	Hemothorax, aortic injury	Y	N	3	P/C	147	1	Gelatin	55	Y	N	1	N	Contralateral internal iliac artery traumatic occlusion
16	60s	2.3	48	SAH, leg traumatic amputation	N	N	3	Cut-down	9	6	Gelatin	70	N	N	N/A	N	Angiography paused due to shock, retrying after REBOA completed
17	20s	2.3	50	EDH, perineal laceration	N	N	3	P/C	47	7	Gelatin+Coils	73	Y	Y	55	Y	Contralateral internal iliac artery traumatic dissection

AAD, angiography after REBOA deflation; AAR, angiography after REBOA removal; BT, blood transfusion; C/A, cardiac arrest; CPCR, cardiopulmonary cerebral resuscitation; ED, emergency department; EDH, epidural hemorrhage; F, female; fx, fracture; ISS, Injury Severity Score; LOS, length of stay; M, male; MVA, motor vehicle accident; N, no; N/A, not associated; N/D, not detected; N/R, not recorded; OR, operation room; OS, overall survival; P/C, percutaneous; PPP, pre-peritoneal packing; REBOA, resuscitative endovascular balloon occlusion of the aorta; ROSC, return of spontaneous circulation; SAH, subarachnoid hemorrhage; SDH, subdural hemorrhage; S/I, Shock Index; TAE, transcatheter arterial embolism; Y, yes.

investigation. In our study, although the median aortic occlusion time (overall: 107.0 min; Zone 1: 130.5 min; Zone 3: 75.0 min) exceeded the optimal durations suggested in the studies by Norii *et al*, Matsumura *et al*, and Sadeghi *et al* (30–45 min for Zone 1 and 60–90 min for Zone 3),[22–24] none of the patients developed limb ischemia or required subsequent amputation. This may be due to the timely provision of definitive treatment at our trauma center.

Limitations

The limitations of our study, including its single-center retrospective design and small sample size of 17 patients over 6 years, restrict the generalizability and statistical power of our findings. We acknowledge that the small sample size of 17 cases limits the reliability of using logistic regression analysis, as it increases the risk of overfitting and instability in the results. Consequently, we have chosen to address potential confounders qualitatively in our discussion. Moreover, the primary objective of this study was to share our experiences with the application of both AAR and AAD methods for patients requiring TAE after REBOA, rather than to establish the superiority of one method over the other. Given this focus, we determined that logistic regression analysis was not essential for this study. Furthermore, the study timeframe is 6 years and the resuscitation protocols as well as the equipment available may change overtime, which could have influenced outcomes. Variations in the REBOA and TAE procedures, such as the partial or intermittent REBOA method, arterial access sites, and embolic materials, contribute to data heterogeneity, complicating result interpretation. These factors collectively underscore the need for caution when extrapolating our conclusions to broader clinical practice.

CONCLUSION

In summary, this cohort study compared the outcomes of different vascular access methods in the combined REBOA-TAE approach for patients with severe pelvic fractures. Our findings suggest that both AAR and AAD are viable options for patients requiring TAE after REBOA. The choice between these techniques should be guided by the clinical scenario, patient-specific factors, and the discretion of the radiologist. Further research with larger cohorts is essential to validate these findings and explore long-term outcomes.

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