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Resuscitative endovascular balloon occlusion of the aorta in trauma management: a comprehensive study of clinical indications and challenges

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ABSTRACT

Background The application of resuscitative endovascular balloon occlusion of the aorta (REBOA) in trauma resuscitation, including for profound shock and cardiac arrest, has gained prominence. This study aimed to determine the characteristics of patients who were transported to the trauma resuscitation area (the TTRA group) and those who died at the scene (the DAS group), aiming to identify suitable REBOA candidates and critical contraindications.

Methods A descriptive research design was used. We retrospectively reviewed 1158 adult trauma patients managed at a level I trauma center in 2020 and 2021. The TTRA group comprised 215 patients who, upon arrival at the trauma resuscitation area, either presented with a systolic blood pressure under 90 mm Hg or were in traumatic cardiac arrest but still exhibited signs of life. The study included patients directly transferred from incident scenes to the forensic unit. The DAS group comprised 434 individuals who were declared deceased at the scene of major trauma. REBOA indications were considered for two purposes: anatomic bleeding control for sources below the diaphragm to the groin, and circulatory restoration in patients with profound shock or cardiac arrest. Absolute REBOA contraindications were assessed, particularly for aortic and cardiac injuries, with or without cardiac tamponade.

Results Predominantly male, the cohort largely consisted of motorcycle accident victims. The median Injury Severity Score was 41 (range 1–75). Within the TTRA group, the prospective applicability of REBOA was 52.6%, with a prevalence of major hemorrhagic sources from the abdomen to the groin of 38.6% and substantial intra-abdominal bleeding of 28.8%. The DAS group exhibited a prevalence of major hemorrhagic sources from the abdomen to the groin of 50.2%, and substantial intra-abdominal bleeding of 41.2%. In terms of REBOA contraindications, the DAS group demonstrated a greater prevalence of overall contraindications of 25.8%, aortic injuries 17.3%, and concomitant conditions of 16.4%. In the TTRA group, the rates of overall contraindications, aortic injury, and comorbid conditions were 12.6%, 4.2%, and 8.8, respectively. Cardiac injuries were noted in approximately 10% of patients in both groups.

Conclusions This investigation underscores the potential benefits of REBOA in the management of major trauma patients. The prevalence of bleeding sources suitable for REBOA was high in both the TTRA and DAS groups. However, a significant number of patients in both groups also had contraindications to the procedure. These outcomes highlight the critical importance of enhanced training in patient assessment to ensure the safe and effective deployment of REBOA, particularly in resource-limited environments such as ongoing trauma resuscitation and prehospital care.

Level of evidence Level III.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Resuscitative endovascular balloon occlusion of the aorta (REBOA) is an effective adjunct in trauma resuscitation, especially for patients with non-compressible torso hemorrhage and profound shock.
⇒ However, identifying contraindications before REBOA is applied is essential for preventing adverse outcomes after balloon inflation.
⇒ Patient characteristics and trauma system capabilities vary across regions, necessitating tailored approaches.

WHAT THIS STUDY ADDS

⇒ This study demonstrated a high prevalence of potential REBOA candidates among individuals who were transported to a trauma resuscitation area and those who died at the scene of major trauma.
⇒ Individuals who died at the scene exhibited greater rates of REBOA contraindications and concomitant conditions, complicating its application in patients with profound shock or impending traumatic cardiac arrest, particularly when ongoing resuscitation and prehospital interventions are needed.
⇒ Our findings indicate a lower likelihood of REBOA suitability in major trauma patients with severe or non-survivable traumatic brain injuries.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These findings underscore the need for enhanced training and improved patient assessment skills to identify REBOA contraindications early, especially during active resuscitation in unstable trauma patients and prehospital assessment.

BACKGROUND

There is a diverse spectrum of causes of mortality after traumatic injury, with hemorrhage and traumatic brain injury (TBI) consistently among the predominant causes of death.[1–5] Modern trauma

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care emphasizes early interventions, notably in damage control resuscitation, to enhance survival pending definitive treatment. A significant innovation in this domain is resuscitative endovascular balloon occlusion of the aorta (REBOA), employed as an interim measure to control exsanguination in patients with bleeding suitable for occlusion below the level of the balloon.[5–10] Advances in REBOA techniques now also focus on preserving perfusion to vital organs in profound shock or cardiac arrest cases, broadening its application beyond trauma. However, REBOA has contraindications, especially in the presence of cardiac and aortic injuries, due to the risk of exacerbating these conditions upon balloon inflation.[11–13]

With the proven effectiveness of REBOA in trauma resuscitation, the concepts of using it during preliminary resuscitation or before hospital admission without complete evaluation have attracted increased interest. The current criteria for REBOA include managing non-compressible torso hemorrhage and restoring circulation in severe shock or cardiac arrest.[11 14–16] However, the specific contraindications in these urgent scenarios are not well defined, posing challenges in applying REBOA when a complete patient assessment is impossible. Consequently, there have been recommendations against using REBOA in prehospital settings.[11]

This study aimed to identify which individuals may benefit from REBOA during trauma resuscitation and to delineate explicit contraindications for this treatment in trauma patients. The objective was to facilitate decision-making in the application of REBOA, particularly in environments with limited resources.

METHODS

In this retrospective analysis, we reviewed adult patients aged older than 18 years who had sustained major trauma and were transported to a level I trauma center in Bangkok, Thailand, from 2020 to 2021. Our definition of major trauma drew upon the criteria in the 2011 version of the Field Triage Decision Scheme.[17] The criteria were modified to fit the resources and capabilities of the trauma resuscitation unit at our institution. Patient triage involved evaluating the physiological status, anatomic injury severity, and injury mechanism, with major trauma patients promptly directed to the trauma resuscitation room for immediate management.

The inclusion criteria categorized individuals into two groups. The first one, the transported to the trauma resuscitation area (TTRA) group included patients with severe trauma presenting with unstable conditions, such as systolic blood pressure below 90 mm Hg and/or traumatic cardiac arrest with signs of life on arrival. The second group was the died at the scene (DAS) group. The cohort included individuals who were declared deceased at the scene of major trauma and were transported to our forensic science unit, as well as those pronounced dead upon arrival at the hospital. Patients who did not meet these inclusion criteria or had incomplete medical records were excluded.

We focused on the DAS group due to limitations in effective patient status assessment at the scene in our system. In the context of Thailand's trauma system, not all severe trauma patients are treated by highly trained emergency medical teams. Often, their care involves volunteers and private ambulance services with varying degrees of experience. This can result in gaps in critical assessment, especially in cases of profound shock or traumatic cardiac arrest, where the presence of subtle signs of life might be overlooked.

The study aimed to perceive the characteristics and injuries of these two groups to enhance the understanding and practice of in-hospital and prehospital resuscitation with the descriptive study design.

The criteria for identifying potential candidates for REBOA were patients with traumatic cardiac arrest and/or significant intra-abdominal bleeding. The latter was defined as follows:

- Abbreviated Injury Scale scores of 3 or more for liver and spleen injuries and scores of 4 or more for kidney injuries.
- Active hemorrhage from abdominal vasculature, unstable pelvic fractures, or groin junctions.

The absolute contraindications for REBOA application were aortic injury and cardiac injury, with or without cardiac tamponade, due to the risk of exacerbation after balloon inflation.

Subgroup analyses of major trauma patients with severe or non-survivable TBI were performed. The TBI severity was determined using CT scans and/or autopsy reports and was categorized by Abbreviated Injury Scale scores for the head region.

Statistical analysis

The demographic and clinical characteristics of the individuals were summarized using descriptive statistics. Statistical analyses were performed using PASW Statistics, V.18 (SPSS). Categorical data are presented as numbers and percentages, and continuous data are reported as means±SDs or medians (IQRs). All continuous data in this study were normally distributed.

RESULTS

We retrospectively evaluated 1158 major trauma cases who were transported to our center during 2020 and 2021. Of the 724 patients admitted to the trauma unit, 509 were excluded because they did not meet the inclusion criteria; 215 patients were included in the TTRA group (figure 1). Of these, 434 were assigned to the DAS group.

Most patients in both groups were male. The TTRA group demonstrated a slightly higher mean age (43.7±19.0 years) than the DAS group (38.0±14.7 years). Blunt injuries were highly prevalent in both groups, affecting 83.7% of the TTRA group and 92.6% of the DAS group. Motorcycle accidents were the predominant cause of injury in the TTRA and DAS groups (44.2% and 70%, respectively). In the TTRA group, 5.1% of the injuries were related to other mechanisms that were less likely to cause severe bleeding, such as hanging, major burns with shock, intoxication, and electrical injury arrest. These injury types, which present with instability or cardiac arrest but with a lower likelihood of bleeding, may still benefit from REBOA for resuscitation purposes. The application of REBOA in such cases could be advantageous for increasing proximal pressure to critical organs during cardiopulmonary resuscitation or as a bridge to extracorporeal cardiopulmonary resuscitation. Notably, such injuries were not observed in the DAS group.

The Injury Severity Score was calculated for only the TTRA group, for which the median score was 41 (range 1–75). Autopsies in the DAS group, conducted as per institutional policy, were not performed on minor wounds unless they were associated with significant injuries. The incidence of severe or non-survivable TBI was greater in the DAS group (63.1%) than in the TTRA group (35.4%) (table 1).

Within the TTRA group, over half (56.3%) of the patients were identified as potential REBOA candidates. Considering bleeding sources amenable to REBOA intervention, the prevalence of severe abdomen-to-groin bleeding and major intra-abdominal hemorrhage was 38.6% and 28.8%, respectively. Among the 215 patients in the TTRA group, 52 (24.2%) suffered

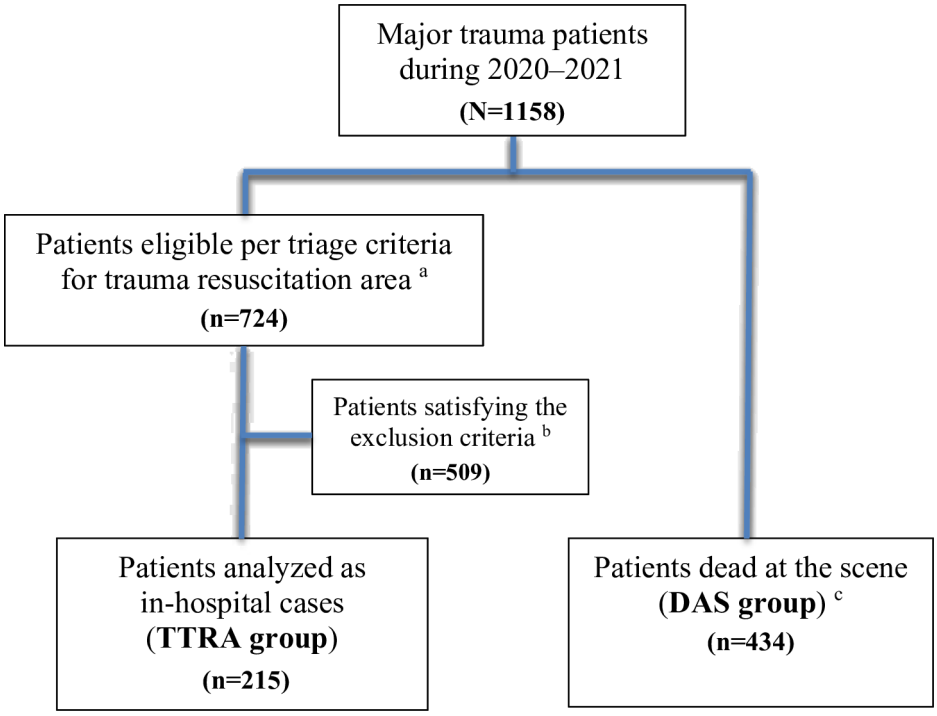

Figure 1 Patient selection and allocation flow chart illustrating the methodology for grouping major trauma cases into TTRA and DAS categories. [a]Defined as major trauma cases who were triaged to our center's trauma resuscitation area following the institution's triage criteria. [b]Defined as age ≤18 years; no major trauma with unstable conditions, such as systolic blood pressure ≥90 mm Hg and/or no cardiac arrest on arrival; and/or incomplete medical record. [c]Defined as declared dead at the scene of major trauma and transferred to our center's forensic science unit, or patients who presented as dead on arrival with no signs of life at our center's trauma resuscitation area. DAS, died at the scene group; TTRA, transported to the trauma resuscitation area group.

a traumatic cardiac arrest. Additionally, 13 of these 52 patients (representing 6.1% of the total TTRA group) exhibited major bleeding sources suitable for REBOA intervention. REBOA contraindications were present in 12.6% of the TTRA group overall, including aortic injuries in 4.2% of cases. Cardiac injuries were observed in approximately 10% of individuals in both groups (table 2). Additionally, concomitant conditions were found in 4.2% of non-arrested TTRA patients and 8.8% of the entire TTRA group (table 2).

Table 1 Demographic and injury profiles in major trauma cases of the transported to the trauma resuscitation area (TTRA) and died at the scene (DAS) groups

Characteristics	TTRA group (n=215)	DAS group (n=434)
Age (years), mean±SD	43.7±19.0	38.0±14.7
Male sex, n (%)	183 (85.1)	366 (84.3)
Mechanism of injury, n (%)		
► Blunt	180 (83.7)	402 (92.6)
– Motorcycle accident	95 (44.2)	304 (70)
– Motor vehicle collision	17 (7.9)	30 (6.9)
– Pedestrian struck	25 (11.6)	40 (9.2)
– Fall from height	17 (7.9)	26 (6.0)
– Fall from the same level	21 (9.8)	0 (0.0)
– Other blunt injuries	5 (2.3)	2 (0.5)
► Penetrating	24 (11.2)	33 (7.6)
– Gunshot wound	5 (2.3)	24 (5.5)
– Stab wound	12 (5.6)	9 (2.1)
– Other penetrating injuries	7 (3.3)	0 (0.0)
► Others*	11 (5.1)	0 (0.0)
Injury Severity Score, median	41	Not available†
Initial Glasgow Coma Scale, mean±SD	10.8±8.5	Not available†
Non-survivable or severe TBI, n (%)	76 (35.4)	274 (63.1)

*Includes hanging, major burns with shock, intoxication, and electrical injury arrest.
†Complete information not available for calculation of Injury Severity Score due to institutional policy on autopsy practices.
TBI, traumatic brain injury.

The DAS group demonstrated a 50.2% prevalence of severe abdomen-to-groin bleeding and a 41.2% prevalence of major intra-abdominal hemorrhage. REBOA contraindications were higher in the DAS group, with overall contraindications of 25.8% and aortic injuries of 17.3%. Concomitant conditions were present in 16.4% of the DAS group (table 2).

Among patients with severe or non-survivable TBI, 52.6% of the TTRA group exhibited overall potential for REBOA use. However, this potential was lower when focusing specifically in the TBI subgroup than when focusing on the entire study cohort (table 3). Among patients with TBI with traumatic cardiac arrest, the potential for REBOA utilization for bleeding control purposes was 7.9% in the TTRA group and 36.1% in the DAS group. No contraindications for REBOA were found in the TBI subgroup of the DAS group. These findings suggest a potential role for REBOA in major trauma patients with severe TBI.

DISCUSSION

Our assessment of implementing REBOA at our center centered on achieving a balance between maximizing patient benefits and minimizing the potential for harm. The efficacy of REBOA—particularly in controlling bleeding below the balloon and boosting perfusion to critical organs such as the heart and brain—is supported by various guidelines.[8 14 18 19] We analyzed different aspects of trauma patients, such as injury mechanism, severity,

Table 2 REBOA utilization criteria for transported to trauma resuscitation area (TTRA) and died at the scene (DAS) major trauma patients

Factors	TTRA group (n=215)	DAS group (n=434)
Potential indications for REBOA, n (%)		
► Overall potential indication for REBOA, including traumatic cardiac arrest	121 (56.3)	–
► Significant bleeding source(s) at the abdomen→groin	83 (38.6)	218 (50.2)
– Major intra-abdominal bleeding	62 (28.8)	179 (41.2)
– Unstable pelvic injury	33 (15.4)	63 (14.5)
– Junctional hemorrhage injury at the groin	3 (1.4)	0 (0.0)
► Traumatic cardiac arrest	52 (24.2)	–
– With significant bleeding	13 (6.1)	218 (50.2)
Absolute contraindications for REBOA, n (%)		
► Overall	27 (12.6)	112 (25.8)
► Aortic injury	9 (4.2)	75 (17.3)
► Cardiac injury with or without cardiac tamponade	20 (9.3)	49 (11.3)
Potential indications and contraindications for REBOA in the same case, n (%)		
► Overall	19 (8.8)	71 (16.4)
► Excluding traumatic cardiac arrest	9 (4.2)	–

REBOA, resuscitative endovascular balloon occlusion of the aorta.

and type, to identify suitable candidates for REBOA. However, reported candidacy rates vary significantly across studies due to differing REBOA indications, trauma system capacities, and patient demographics. Some studies indicate minimal REBOA suitability within their institutions.[15 20–23] Conversely, a study conducted at a high-volume trauma center reported a higher candidacy rate (13.6%) based on autopsy findings.[16] These works underscore the caution that must be taken when considering REBOA contraindications, particularly given the increased risk of thoracic aorta, heart, neck, or cerebral hemorrhage after balloon inflation.[11 13 24]

Our study contributes significantly to the strategic application of REBOA, offering guidance for its use across a spectrum of settings, from prehospital scenarios to in-hospital trauma resuscitation. This approach is particularly crucial in environments constrained by limited personnel expertise, inadequate equipment, or financial restrictions. Thus, understanding the characteristics of TTRA and DAS patient groups is essential for appropriately adapting REBOA protocols to diverse and challenging clinical scenarios.

Our analysis revealed a substantial number of potential REBOA candidates for both hemorrhage control and resuscitation purposes, comprising 38.6% of the TTRA group and 50.2% of the DAS group. These figures exceed those of previous reports, underscoring the broad applicability of REBOA for both hemorrhage control and resuscitation in arrested patients within our trauma center.

A significant benefit of these findings, demonstrating high prevalence of potential REBOA applicability, is that they support the integration of this potentially life-saving intervention into our trauma system. This aligns with ongoing discussions regarding the comparative efficacy of REBOA and emergency resuscitative thoracotomy for patients in profound shock or cardiac arrest. One study examining REBOA in zone 1 revealed a markedly lower mortality rate after REBOA than after resuscitative thoracotomy (78.6% vs. 92.9%, respectively; p=0.03), with subgroup analyses suggesting comparable or improved outcomes with REBOA.[25] These findings resonate with our data from both patient groups, highlighting a substantial correlation between exsanguination and potential REBOA application.

Table 3 Subgroup analysis: REBOA suitability in severe/non-survivable traumatic brain injury cases among transported to trauma resuscitation area (TTRA) and died at the scene (DAS) groups

Factors	TTRA group (n=76)	DAS group (n=274)
Potential indications for REBOA, n (%)		
► Overall potential indication for REBOA, including traumatic cardiac arrest	40 (52.6)	–
► Significant bleeding source(s) at the abdomen→groin	20 (26.3)	99 (36.1)
– Major intra-abdominal bleeding	16 (21.1)	82 (29.9)
– Unstable pelvic injury	9 (11.8)	29 (10.6)
– Junctional hemorrhage injury at the groin	1 (1.3)	0 (0.0)
► Traumatic cardiac arrest	26 (34.2)	–
– With significant bleeding sources	6 (7.9)	99 (36.1)
Absolute contraindications for REBOA, n (%)		
► Overall	5 (6.6)	0 (0.0)
► Aortic injury	3 (4.0)	0 (0.0)
► Cardiac injury with or without cardiac tamponade	3 (4.0)	0 (0.0)
Potential indications and contraindications for REBOA in the same case, n (%)		
► Overall	3 (4.0)	0 (0.0)
► Excluding traumatic cardiac arrest	0 (0.0)	–

REBOA, resuscitative endovascular balloon occlusion of the aorta.

These insights underscore the importance of REBOA in enhancing trauma resuscitation strategies. By delineating the high potential for REBOA use, our study advocates for the refinement of assessment and management protocols in trauma care. These findings position REBOA as a crucial tool for managing life-threatening hemorrhages and arrest situations, potentially helping to elucidate the landscape of trauma resuscitation.

Although REBOA is an effective intervention for controlling exsanguination, its applicability is not universal. In particular, this approach is less suited for patients with cardiac or thoracic aorta injuries or for whom there is no discernible survival benefit, such as in patients with severe or non-survivable TBI. When assessing REBOA contraindications, we focused on the absolute contraindications outlined in several guidelines, notably, aortic injury and significant cardiac injury, due to the elevated risk of fatal bleeding after balloon inflation. However, intrathoracic bleeding, such as hemothorax and cervical vascular injuries, was not classified as an absolute contraindication, as the progression of these conditions can typically be monitored and managed.

The challenge lies in detecting these absolute contraindications, where standard bedside screening tools such as chest X-ray and ultrasound have limited diagnostic capability. Our findings indicated a higher prevalence of contraindications, particularly aortic injuries, in both groups. Remarkably, cardiac injuries were observed in approximately 10% of both groups. Additionally, the DAS group exhibited a greater rate of concurrent conditions alongside contraindications. These insights highlight the complexities encountered in emergency scenarios with incomplete evaluations, where inappropriate REBOA deployment could exacerbate a patient's condition.

This study underscores the importance of accurately identifying contraindications in major trauma patients, especially those with profound instability or who are experiencing cardiac arrest. Accurate identification of these contraindications is crucial for ensuring the safe and effective application of REBOA in trauma resuscitation.

In our study, the DAS group exhibited a distinct subset of severely unstable patients who might have benefited from REBOA intervention due to their high prevalence of hemorrhage requiring control. However, the concomitant high incidence of contraindications presents a serious concern in such critically unstable patients where accurate assessment is challenging. Therefore, a thorough risk–benefit evaluation is crucial. The integration of prehospital REBOA into emergency trauma care systems necessitates careful deliberation, weighing these risks against the potential benefits within the framework of system-wide protocols and resource availability. This intricate balance between risks and benefits should be a focal point in discussions on expanding prehospital REBOA use.

TBI, which is characterized by poor prognosis, is a predominant cause of death in trauma patients.[1 2] Our subgroup analysis focused on patients with severe and non-survivable TBIs to evaluate the potential for REBOA application in this population. A critical question in trauma management is whether REBOA is appropriate for patients with low Glasgow Coma Scale. A low initial score may not solely indicate primary brain injury but could also be influenced by other factors, such as airway obstruction, hypoxemia from respiratory compromise, or hypotension due to hemorrhagic shock.

Our approach to these patients advocates for prognostic optimism. In critical situations, priority is given to thorough assessment and resuscitation, often in contexts where complete evaluations, such as CT scans, are impractical owing to patient instability. Our study revealed that although the proportion of patients with severe TBI suitable for REBOA was less than that in the overall study population, the proportion was still greater than that reported in the literature. Interestingly, our data showed no absolute contraindications for REBOA in the severe TBI subgroup within the DAS cohort.

Recent findings from the Trauma Quality Improvement Program indicate no significant differences in in-hospital mortality or complications between patients with and without TBI.[26] This underscores the need for careful clinical judgment: low Glasgow Coma Scale alone should not deter further resuscitative efforts. Our findings highlight the necessity of nuanced decision-making in trauma care, especially in settings with limited resources, and reinforce the importance of considering all factors when managing patients with severe TBI.

Limitations

Our study's limitations include its retrospective design and confinement to a single-center setting with a small sample size. Furthermore, the institutional policy on autopsy practices limited the availability of detailed injury information, precluding comprehensive Injury Severity Score calculations for the DAS group. Additionally, variations in trauma care systems, patient characteristics, and available medical resources compared with those of other studies necessitate the development of individualized institutional protocols. To better assess the applicability of REBOA on a broader scale, future studies should be multicenter and international in scope, integrating diverse clinical experiences to refine guidelines and enhance their practicality.

CONCLUSIONS

Our findings reinforce the utility of REBOA for managing major trauma while also highlighting specific contraindications. Notably, its effect is less pronounced in patients with severe TBI. The need for meticulous identification of comorbid contraindications is critical. These insights underscore the need for improved patient assessment training that focuses on accurately identifying REBOA contraindications. Such enhanced assessment skills are vital for ensuring the safe application of REBOA, especially in scenarios where comprehensive evaluation is limited.

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