Case Report

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The Non-Diagnostic Triad in a Hypotensive Blunt Trauma Victim: What is the Role of REBOA?

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Background: With the growing use of REBOA as an alternative to Emergency Department thoracotomy in select patients, the algorithms are still evolving, and current guidelines for resuscitative endovascular balloon occlusion of the aorta (REBOA) use appear to have gaps as evidenced by this case. Most algorithms include chest x-ray, focused assessment with sonography for trauma (FAST), and pelvic x-ray to guide where to place the device, either in zone 1 or zone 3. There is a lack of guidance for patients in whom all three of these studies are negative, which we define as a non-diagnostic triad (NDT). Furthermore, there is a lack of guidance after placement of the device in patients who fail to respond or only minimally respond.
Methods: We describe a difficult case where a blunt trauma patient with unstable hemodynamics had marginal response to placement of zone 1 REBOA, while physical exam and imaging in the trauma bay did not reveal a source for his hypotension.
Results: The patient was sent to the CT scanner whereupon multiple injuries were identified and detailed in the case. The patient unfortunately expired soon after.
Conclusions: Further clinical studies with better classification are needed in order to better understand the significance of REBOA responders and non-responders in patients with an unknown source of hypotension. The NDT of negative chest x-ray, FAST, and pelvic x-ray represent a significantly challenging patient population that should be studied further.

Keywords: *REBOA; Non-Diagnostic Triad; Blunt Trauma*

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BACKGROUND

Resuscitative endovascular balloon occlusion of the aorta (REBOA) is becoming a standardized adjunct in the management of critically ill patients with non-compressible torso bleeding. Trauma centers using REBOA are instituting algorithms that help guide the location and indications for REBOA use. Most of these algorithms use three basic point of care imaging studies, the chest X-ray (CXR), focused assessment with sonography for trauma (FAST), and pelvic X-ray (PXR). Unfortunately, there is still a lack of evidence or recommendations when all of these studies remain negative in an unstable patient, which we call the "non-diagnostic triad" (NDT). In the age of the Emergency Department (ED) thoracotomy, the patient would immediately go to the operating room (OR). Today, with the advent of REBOA, hybrid ORs, and better diagnostic imaging, decisions have become more complicated. Should Zone 1 REBOA mandate immediate transport to the OR, or can you send the patient to the CT scanner for further imaging? We present a hypotensive blunt trauma victim with NDT who transiently responded to Zone 1 REBOA, and

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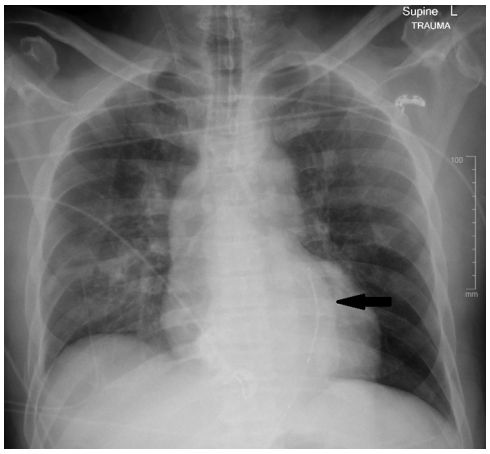

Figure 1 Portable CXR from Trauma Bay after placement of REBOA in (low) Zone 1 (black arrow).

Figure 2 Coronal Iimaging of REBOA in Zone 1 with IV contrast proximal but minimal progression distally.

is thought to have expired from retroperitoneal hemorrhage in the setting of a blunt cardiac injury.

Case Details and Results

A 58-year-old male presented to our Level I trauma center after a high-speed head-on motor vehicle collision. Prior to arrival, the patient underwent pre-hospital advanced cardiac life support (ACLS) with the successful return of spontaneous circulation (ROSC). Upon arrival at our facility, he had weakly palpable pulses with a systolic blood pressure of 80 mmHg. Physical examination was unrevealing for the source of his cardiac arrest and shock, although he had a head laceration and posturing. Blood transfusions were started and the massive transfusion protocol (MTP) was activated. Adjunct imaging included a CXR, FAST, exam, and pelvic X-ray, all of which were grossly negative. The patient lost pulses approximately 7 minutes after arrival, and ACLS was begun again. Given that he had a normal CXR, and FAST was negative for pericardial tamponade, the decision was made to place a REBOA catheter instead of proceeding with an ED thoracotomy.

REBOA was performed percutaneously in the right femoral artery under ultrasound guidance, with ER-REBOA through a 7 Fr sheath. The REBOA balloon was inflated in Zone 1 with 10 mL of saline. The patient had a delta REBOA response from a mean arterial pressure (MAP) of 30 mmHg to a MAP of 70 mmHg, after which ACLS was terminated. ED arrival to full aortic balloon occlusion time was 17 minutes. CXR showed well-positioned Zone I REBOA placement. Adequate inflation was confirmed by a lack of the contralateral femoral pulse. The patient was brought to the CT scanner whereupon a large amount of bilateral retroperitoneal blood was identified, however, due to the balloon occlusion, definitive extravasation was not found.

On final CT imaging reports, the patient was found to have diffuse cerebral and cerebellar contusions without mass effect or shift on the head CT. His chest CT revealed an anterior mediastinal hematoma with contrast extravasation and multiple bilateral rib fractures. The abdominal CT showed a large amount of retroperitoneal hematoma bilaterally with possible contrast extravasation near the infrarenal aorta (balloon occlusion likely limited this finding) and bilateral renal lacerations.

Unfortunately, the patient lost vital signs again soon after leaving the CT scanner and was returned back to the trauma bay. Despite aggressive MTP and receiving 16 units of balanced blood products and ACLS, the patient expired. Post mortem autopsy demonstrated cortical and cerebellar contusions, a mediastinal hematoma with sternal and rib fractures, cardiac contusions with severe coronary atherosclerosis, and retroperitoneal hematoma with bilateral renal lacerations.

DISCUSSION

In 1954, the first reported use of REBOA for the treatment of traumatic hemorrhagic shock was documented in 3 critically ill US soldiers [1]. Since then, many cases and trials have presented favorable outcomes following the use of REBOA for the treatment of hemorrhagic shock, and suggest it as potentially superior (or at least equivalent) to ED Thoracotomy [2]. Aortic balloon occlusion has also been used successfully in many situations such as ruptured aortic aneurysm control, aortoenteric fistula aortic hemorrhage control, postpartum or abdominal/pelvic surgery hemorrhage, hemoperitoneum due to splenic artery aneurysm, gastrointestinal hemorrhage, and for control of other vascular injuries [3].

The areas for REBOA balloon inflation are divided into aortic zones: Zone I extends from the left subclavian artery branch off to the celiac trunk, Zone 2 (no

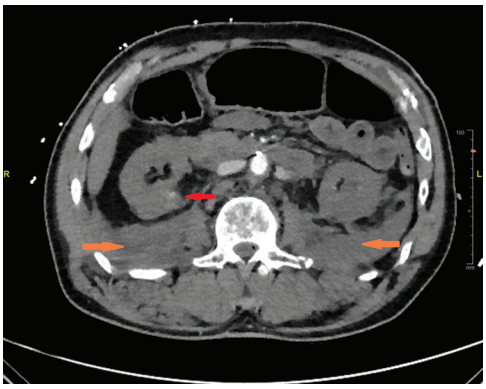

Figure 3 Potential right renal blush (red arrow) with bilateral retroperitoneal blood (orange arrows).

occlusion zone) extends from celiac trunk to the lowest renal artery, and Zone 3 from lowest renal artery to the aortic bifurcation. If there is evidence of abdominal or truncal bleeding, a balloon is inflated in Zone I. With pelvic hemorrhage, the REBOA balloon is inflated in Zone 3. In our particular case, the guidelines as outlined by these algorithms were followed. In the presence of NDT in this patient with persistent class IV shock a REBOA was positioned in Zone 1 and inflated with a transient increase in blood pressure.

Given an NDT, the role of obtaining definitive imaging is unclear if the patient is unstable. Admittedly, CT is the gold standard for thoracic, abdominal, and pelvic trauma imaging. However, the CXR, FAST, and PXR all have a significant advantage in unstable patients due to point of care applicability. CXR was shown to have low sensitivity for thoracic injuries when compared to CT for trauma [4]. However, it is thought most of the missed injuries are clinically less significant in a hypotensive patient, such as non-displaced rib fractures or occult pneumothorax. Our patient was found to have cardiac contusions with a sternal fracture on autopsy, both were not seen on CXR or CT. There were a mediastinal hematoma and rib fractures present on CT, without a sternal fracture. Thus, it is unclear how much of the patient's blunt cardiac findings on autopsy were due to ACLS versus the initial injury.

The FAST exam has been accepted as having an adequate sensitivity for diagnosing intra-peritoneal free fluid as well as pericardial effusion, with an overall sensitivity of 73–99% which is thought to increase in hypotensive patients [5]. PXR in the trauma bay helps to identify life-threatening types of pelvic fracture. While sensitivity remains low (50-68%) for pelvic fractures, it is adequately able to diagnose the major life-threatening pelvic ring injuries, including open book and vertical shear fractures [6].

This case brings into question the controversial decision to delay operative intervention to pursue cross-sectional imaging in the hemodynamically unstable patient. In hindsight, we believe that the patient in the case presented expired due to large retroperitoneal blood loss, with blunt cardiac injury likely contributing. It is hard to determine the extent to which each injury contributed, especially in the setting of prolonged ACLS. The patient's transient initial response to Zone 1 REBOA placement in the setting of NDT raises the question on the need for further diagnostics versus faster surgical intervention with earlier aggressive MTP activation. While MTP was initiated soon after arrival to the trauma bay, the resuscitation was likely sub-optimal while the patient was in the CT suite. Our institution does not currently have a protocol in place for running MTP while obtaining CT imaging. Even slight delays in MTP have been shown to be associated with increased time to hemorrhage control and mortality in the multiply injured patient [7]. REBOA was shown in an animal model to restore central perfusion faster than MTP alone [8], and its use as an adjunct to both resuscitation and hemorrhage control could be synergistic. At the time of this case, our institution stored blood outside the ED and had an average time to release of trauma blood products of 7.5 minutes. This was likely a factor in the patient only receiving 4 units of blood prior to traveling to the CT suite. The amount of time to release MTP at our institution has since been decreased by storing blood products within the ED.

Given the patient's initial report from the field of a head laceration with posturing, we initially had suspicion of a devastating brain injury. There is limited evidence for the safety and efficacy of REBOA in a patient with traumatic brain injury (TBI), however, some important studies do exist. REBOA with MTP versus MTP alone in an animal TBI model was actually shown to increase MAP and carotid blood flow, while at the same time decreasing peak intracranial pressure [9]. Serial imaging in the REBOA groups did not show worsened progression of bleeding compared to controls.

Similar to the TBI population, there is questionable safety and efficacy for REBOA in blunt cardiac injury. REBOA has been compared to intra-aortic balloon pump devices routinely used for cardiogenic shock. Both devices can increase coronary and cerebral perfusion pressures, decrease the required amount of cardiac output, and thus decrease cardiac oxygen demand [10]. Increased coronary pressures and flow were also found to be significant predictors of ROSC, and survival to discharge in patients undergoing ACLS for non-traumatic arrest [11].

Prior to REBOA, when ED thoracotomy was the single resuscitative procedure in non-responder patients with persistent hypotension and trauma codes, obtaining CT with an aortic cross-clamp would be unheard of. With the advent of hybrid ORs, endovascular therapy, MTPs, better imaging capabilities, and ED-REBOA, the algorithms have become more complicated. We believe that a patient with NDT could potentially benefit from

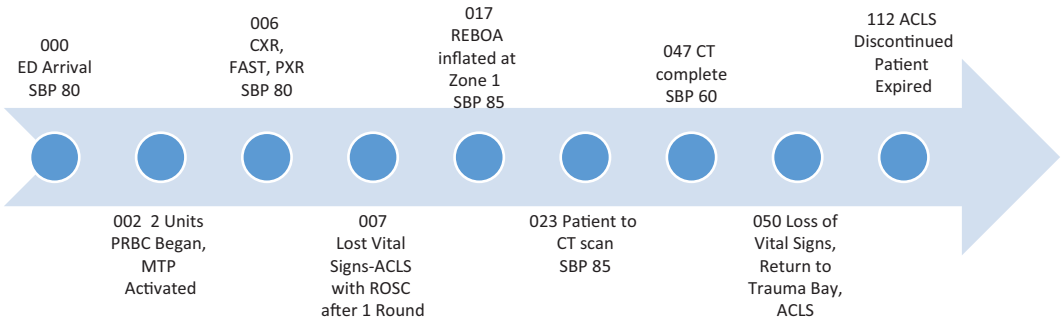

Figure 4 Timeline of events.

a hybrid OR. It is possible that other unstable NDT patients are hiding significant retroperitoneal injuries. Modern hybrid suites have the advantage of diagnosing and treating these conditions without compromising or delaying resuscitation. Currently, at our institution, the role of the hybrid OR for trauma has not been well defined. Time to mobilize catheter-based teams is much longer than for the conventional OR, which currently limits the application in trauma scenarios. It is likely that many institutions across the U.S. face similar challenges, and it is unclear where the hybrid OR will fit into institutional algorithms. Select centers across the world are pioneering the resuscitation of the patient with multiple injuries by combining the trauma bay, OR, angiography suite, and CT scanner in one physical location [12]. The NDT patient raises an important clinical scenario where there is a gap in current algorithms. The case presented was a difficult scenario with a high likelihood of mortality, but the decision to send the patient to the CT suite came with a significant cost in terms of time lost resuscitating and intervening on his injuries. Perhaps with modernized facilities that combine resuscitation, imaging, and intervention, the costs of patient transport will decrease and the algorithms may simplify.

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