Original Article

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Unstable Without a Source: The Non-Diagnostic Triad in Hypotensive Blunt Trauma Victims

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Background: Current algorithms for resuscitation of blunt trauma patients rely on chest x-ray (CXR), pelvic x-ray (PXR), and focused assessment with sonography for trauma (FAST), to quickly elicit a source of major bleeding in the trauma bay. The non-diagnostic triad (NDT), defined as negative initial CXR, PXR, and FAST, complicates the management of the hypotensive blunt trauma victim. Currently, there are no evidence-based recommendations for management of hemodynamically unstable patients with NDT.

Methods: Hypotensive blunt abdominal trauma without a source was defined as a systolic blood pressure below 100 mmHg with NDT. Retrospective chart review was performed to characterize patient demographics, injuries, and outcomes. Subgroup analysis was performed to compare NDT patients with and without severe injury.

Results: We reviewed 649 hypotensive blunt trauma victims. A total of 47 patients (33 males, 14 females) with a mean age of 40.0 years (standard error of the mean 2.5) had NDT upon initial assessment. Of the NDT group, 19/47 (40.4%) were found to have a major injury contributing to hypotension, while 28/47 (59.6%) were not diagnosed with a severe injury that could contribute to hypotension.

Conclusions: Hypotensive blunt trauma patients with NDT are a unique and difficult population to diagnose and resuscitate. The majority of NDT patients lack significant injury. Among the severely injured NDT patients, acute blood loss was common and the potential utility for resuscitative endovascular balloon occlusion of the aorta in these patients warrants future study.

Keywords: *REBOA; Blunt Trauma; ATLS; Algorithms*

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INTRODUCTION

Critically ill trauma patients require advanced trauma life support (ATLS) and institution-based protocols to guide resuscitation. When an unstable patient arrives at the trauma bay, the primary and secondary survey, adjunctive imaging (chest x-ray (CXR), pelvic x-ray (PXR), and focused assessment with sonography for trauma (FAST)), and resuscitative measures (advanced cardiac life support, massive transfusion protocol, thoracotomy, and resuscitative endovascular balloon occlusion of the aorta (REBOA)) are initiated. These protocols are implemented to diagnose and treat life-threatening injury, as well as determine patient disposition (operating room, computed tomography, intensive care unit, interventional radiology suite).

In this retrospective review, we examine a specific patient population that lacks evidence-based recommendation for treatment—hypotensive blunt trauma patients with a "non-diagnostic triad (NDT)", which we define as a negative CXR, PXR, and FAST. REBOA placement is becoming increasingly common for hypotensive, blunt trauma patients. Current published algorithms for REBOA use these three point-of-care imaging modalities to determine treatment, but the guidelines

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are unclear when all three are negative [1]. This subset of blunt trauma victims should be evaluated to determine injury patterns, extent of resuscitation required, interventions performed, and potential utility of REBOA. We identify hypotensive blunt trauma victims admitted to a busy inner-city Level 1 Trauma Center with a negative CXR, PXR, and FAST. We determine the types of injuries present, attempt to elicit the cause of hypotension, and discuss the implications of these injuries in the context of REBOA.

METHODS

Blunt abdominal trauma victims presenting to an inner-city Level 1 Trauma Center between 2016 and 2018 were identified using appropriate ICD 9/10 codes. Patients were initially stratified by their systolic blood pressure (SBP) upon presentation. Hypotensive blunt abdominal trauma without a source was defined as a SBP below 100 mmHg with a NDT (negative CXR, PXR, and FAST). A SBP of less than 100 mmHg in the prehospital setting or in the trauma bay was included. Retrospective chart review was performed by two independent reviewers. Patients with a positive CXR, displaced pelvic fracture on PXR, or a positive FAST were excluded from the NDT group. We did not exclude patients with non-displaced rib fractures without concurrent hemothorax, pneumothorax, or flail chest. Patients with non-displaced pelvic fractures were also not excluded. Preliminary data collection included patient demographics, length of stay, disposition at discharge, injury severity score, and mortality. NDT patients were identified and analyzed to identify the injury patterns and etiology of hypotension. Subgroup analysis of the NDT group was performed to compare seriously injured patients and patient without serious injuries. Patients with minor orthopedic injuries or patients discharged without a diagnosis of severe traumatic injury were allocated to the "not severely injured" group. Data were compared using a Fisher's exact test for categorical variables and an unpaired tow-tailed *t*-test for continuous variables. $P < 0.05$ was considered significant. Data analysis was performed using GraphPad, Version 5 (GraphPad Software, San Diego, CA). This study was approved by our institutional review board (IRB) and followed all appropriate protocols.

RESULTS

We reviewed 649 patients with blunt abdominal trauma and hypotension between January 2016 and July 2018. As summarized in Table 1, a total of 47 patients (33 males, 14 females) with a mean age of 40.0 years (standard error of the mean (SEM) 2.5) had negative initial imaging and were allocated to the NDT group. In comparison, 602 patients (415 males, 187 females) had at least one positive initial imaging modality. The average Injury Severity Score (ISS) for the NDT group was 12.1 (SEM 1.9) compared to an average ISS of 13.9 (SEM 0.5) for the control group ($P = 0.34$). Injuries among the NDT group were as follows: 24/47 (51%) had peripheral orthopedic injuries; 15/47 (31.9%) had traumatic brain injury, and 8/47 (17%) had spinal fractures. Intoxication was present in 31/47 (61%) NDT patients. The NDT and control group had an average length of stay (LOS) of 6.6 (SEM 1.0) days and 7.7 (SEM 0.7) days, respectively ($P = 0.66$). There was a trend toward significantly lower blood pressure in the control group ($P = 0.06$). Among the NDT group, 2/47 (4.2%) patients died versus 110/602 (18.3%) patients in the control group ($P = 0.01$). Causes of death in the NDT group included: one hypoxic arrest due to lack of a secure airway; one retroperitoneal bleed.

The majority of the NDT group, 28/47 (59%), were thought to be hypotensive from causes other than direct trauma, including medical causes, dehydration, or intoxication. These patients ultimately were discharged without a diagnosis of severe traumatic injury contributing to their hypotension. Subgroup analysis of the NDT group was performed to compare seriously injured patients and patients without serious injuries (Table 2). There were 19/47 (40.4%) seriously injured patients and 28/47 (59.6%) not seriously injured patients. The seriously injured group had an ISS of 20.5 (SEM 3.6) compared to an ISS of 6.4 (SEM 1.4) in the not seriously injured group ($P = 0.0002$). Additionally, the seriously injured group had significantly lower SBP than the not seriously injured group, 80 mmHg (SEM 7) versus 97 mmHg (SEM 2), respectively ($P = 0.014$). Lactic acid was 4.2 (SEM 0.5) and 2.4 (SEM 0.3) in the seriously injured and not seriously injured group, respectively ($P = 0.002$). The seriously injured group was also more likely to have a significantly lower serum bicarbonate ($P = 0.048$). The seriously injured group had a significantly prolonged length of hospital stay ($P < 0.0001$).

Figure 1 illustrates the suspected source of hypotension in NDT patients. The etiology of hypotension was as follows: 1/47 (2.1%) patients were hypotensive from a blunt cardiac injury causing arrhythmia, 1/47 (2.1%) patients had hypoxic arrest, 15/47 (31.9%) patients had acute blood loss. Of the 15 patients with acute blood loss, 6/15 (40%) had intraabdominal bleeding (3 liver lacerations, 2 splenic lacerations, 1 mesenteric vascular injury), 5/15 (33.3%) had retroperitoneal bleeding (2 renal lacerations, 1 psoas muscle rupture, 2 unknown source), 4/15 (26.7%) had severe lower extremity orthopedic injuries. We identified 2/47 (4.2%) patients with thoracic aortic injury (TAI) despite an initially negative CXR. One TAI was a grade 3 injury that required a covered endovascular stent and the other TAI was a grade 1a intimal injury that required no intervention. Neither of these injuries had extravasation of contrast, and thus were not thought to directly contribute to the patients' hypotension at presentation.

Table 1 Demographics, admission information, and clinical outcomes of the NDT group and control group.

	NDT n = 47	Control n = 602	P value
Demographics and admission information			
Average age, years (SEM)	40.0 (2.5)	41.8 (0.8)	0.54
Male gender, *n* (%)	33 (70.2)	415 (68.9)	1.00
Caucasian, *n* (%)	23 (48.9)	323 (53.7)	0.55
African American, *n* (%)	21 (44.7)	217 (36.0)	0.27
Other race, *n* (%)	3 (6.4)	62 (10.3)	0.61
Injury Severity Score, avg (SEM)	12.1 (1.9)	13.9 (0.5)	0.34
Lowest systolic blood pressure, average (SEM)	96 (3)	87 (1)	0.06
Clinical outcomes			
Length of stay, average (days)	6.6 (1.0)	7.7 (0.7)	0.66
In-hospital mortality, *n* (%)	2 (4.3)	110 (18.3)	**0.01**

NDT, non-diagnostic triad; SEM, standard error of the mean; n, number. Numbers in bold represent statistically significant values with P < 0.05.

Table 2 Sub-group analysis of the NDT group

	Not seriously injured n = 28	Seriously injured n = 19	P value
Demographics			
Average age, years (SEM)	40.1 (3.6)	39.8 (3.4)	0.95
Male gender, *n* (%)	18 (64.3)	15 (78.9)	0.34
Caucasian, *n* (%)	12 (42.9)	11 (57.9)	0.38
African American, *n* (%)	13 (46.4)	8 (42.1)	1.00
Other race, *n* (%)	2 (7.1)	0	0.51
Injury Severity Score, average (SEM)	6.4 (1.4)	20.5 (3.6)	**0.00020**
Intoxicated, *n* (%)	18 (64.2)	13 (68.4)	1.00
Vital signs and labs on presentation			
Lowest systolic blood pressure, average (SEM)	97 (2)	80 (7)	**0.014**
Lactic acid, average (SEM)	2.4 (0.3)	4.2 (0.5)	**0.0020**
Bicarbonate, average (SEM)	23.1 (0.5)	21.4 (0.7)	**0.048**
Clinical work up			
CT scan, *n* (%)	25 (89.3)	19 (100.0)	0.26
Outcomes			
Length of stay, average (days)	2.7 (0.4)	12.2 (1.9)	**<0.0001**
In-hospital mortality, *n* (%)	0	2 (10.5)	0.16

NDT, non-diagnostic triad; SEM, standard error of the mean; n, number; CT, computed tomography. Numbers in bold represent statistically significant values with P < 0.05.

DISCUSSION

Hypotensive blunt trauma patients with NDT are a uniquely difficult population to diagnose and resuscitate. This analysis of 47 patients with NDT shows a much lower mortality compared to the control group. This is likely due to the high percentage of this group who were not diagnosed with a significant traumatic injury that could explain hypotension. We suspect dehydration, intoxication, and other medical causes were the reason for initial hypotension in these patients, as they improved after initial resuscitation and required no further intervention. Future studies could seek to eliminate this group by having a larger sample population and selecting out sicker patients, although it is of some value to note that most of our NDT patients may have better outcomes than patients with positive imaging in the trauma bay. A significant number of NDT patient were found to have major injuries, and we decided to sub-stratify the NDT group into those with and without significant traumatic

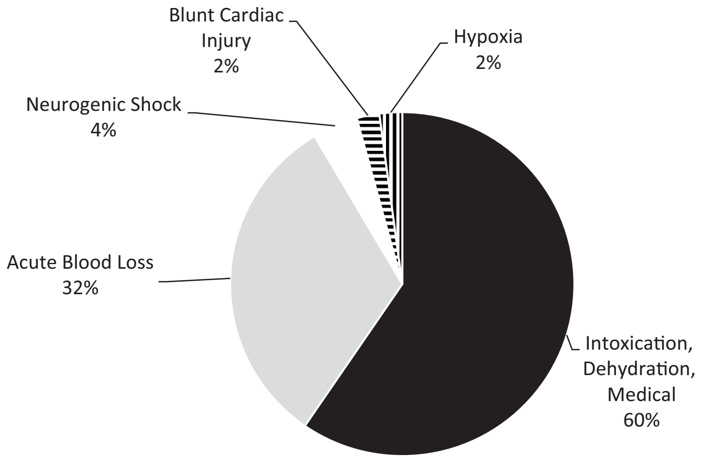

Figure 1 Etiology of hypotension among 47 NDT patients.

injury. A significant number of the seriously injured subgroup had acute blood loss (78.9%), while non-hemorrhagic shock was less common. Intra-abdominal, retroperitoneal, and severe lower extremity orthopedic injuries were found. This implies that these patients may benefit from aggressive resuscitative measures targeting hemorrhagic shock, including Massive Transfusion Protocol and consideration of REBOA placement.

The NDT population is inherently difficult to manage due to a lack of diagnosis or clear direction on where to proceed from the trauma bay. Existing algorithms fail to provide adequate disposition for these patients [1], and in the age of REBOA and hybrid Operating Rooms the decisions can become more complicated. It is perhaps more tempting to travel to the computed tomography (CT) scanner with the NDT population, even in the setting of hemodynamic instability. Surprisingly, only two of the NDT patients did not receive CT scans. This was not due to instability, but a low clinical suspicion for severe traumatic injury, and these patients were in the "not severely injured" sub-group. The obvious cost of delaying definitive treatment to obtain imaging is a concern known to most trauma surgeons. The conundrum that faces the physicians treating the NDT patient could be improved with modernized facilities, such as hybrid operating rooms with imaging, catheter-based, and surgical capabilities in one place. Some pioneering institutions have gone so far as to combine resuscitation, imaging, catheter, and operative capabilities in the trauma bay [2]. We believe the NDT population in particular may benefit from these advances.

The role of REBOA in the NDT population is unclear, and we began this study wanting to evaluate the NDT population with respect to the safety of REBOA. There were two patients who had thoracic aortic injuries without extravasation or free rupture, and hypotension was not thought to be due to these aortic injuries. Major thoracic hemorrhage is known to be the primary absolute contraindication for REBOA placement and most algorithms mandate thoracotomy [3] in these patients. It is unclear whether low-grade aortic injuries represent a contraindication to REBOA. The potential that distal occlusion could cause aortic injuries to progress, or result in direct damage from the device is an understandable concern. However, low-grade injuries will likely present with a negative CXR, requiring CT or angiography to diagnose. Therefore, most of these injuries will be found after the decision to place REBOA has been made. It is likely that the judicious use of REBOA to restore central blood pressure in the presence of a low-grade aortic injury may be worth the risk of the aortic injury progressing.

Two of the NDT group were hypotensive from neurogenic shock, and one patient was hypotensive from a suspected blunt cardiac injury. While most of the evidence regarding the safety and efficacy of REBOA is in hemorrhagic models, some studies suggest a benefit from increased coronary and cerebral perfusion in non-traumatic models [4]. This suggests that both neurogenic and blunt cardiogenic shock could potentially benefit from REBOA, and there is a lack of evidence to suggest REBOA would be unsafe in these patients. Furthermore, with the lower profile REBOA devices and decreasing vascular complication rates [5], it is likely that the risk-to-benefit ratio will continue to improve for all types of shock.

This study provides a limited but worthwhile view of a difficult patient population. We have attempted to characterize the injury patterns of the NDT population. However, further research is needed before creating formal recommendations and guidelines for resuscitating the NDT population.

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