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Characterization of fatal blunt injuries using post-mortem computed tomography

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J.L., study design and was primary contributor to study conception, data acquisition, analysis and interpretation as well as manuscript drafting

A.P., data interpretation and critical revisions of the manuscript

T.O. was involved in data acquisition and analysis

A.M., data interpretation and critical revisions

S.S., study design and conception and aided in data acquisition, interpretation, and critical revisions

P.H., study conception, data interpretation, and critical manuscript revisions.

Study Quality Guidelines: STROBE

Social Media: Post-mortem CT can reliably aid in injury identification and inform resuscitation algorithms in blunt agonal patients. Our data demonstrate a high rate of airway device misplacement and pneumothoraces which should mandate empiric confirmation of ETT position. and chest decompression. @jeremyhlevin, @iu_surgery, @dr_meagher, @radiology911, @iuradiology, #pmct #trauma # #emergencyradiology

Abstract

Introduction

Rapid triage of blunt agonal trauma patients is necessary to maximize survival, but autopsy is uncommon, slow, and rarely informs resuscitation guidelines. Post-mortem computed tomography (PMCT) can serve as an adjunct to autopsy in guiding blunt agonal trauma resuscitation.

Methods

Retrospective cohort review of trauma decedents who died at or within 1 hour of arrival following blunt trauma and underwent non-contrasted PMCT. Primary outcome was the prevalence of mortal injury defined as potential exsanguination (e.g., cavitary injury, long bone and pelvic fractures), traumatic brain injury, and cervical spine injury. Secondary outcomes were potentially mortal injuries (e.g., pneumothorax) and misplacement airway devices. Patients were grouped by whether arrest occurred pre-/in-hospital. Univariate analysis was used to identify differences in injury patterns including polytrauma injury patterns.

Results

Over a 9-year period, 80 decedents were included. Average age was 48.9 ± 21.7 years, 68% male, and an average ISS of 42.3 ± 16.3. The most common mechanism was motor vehicle accidents (67.5%) followed by pedestrian struck (15%). Of all decedents, 62 (77.5%) had traumatic arrest prehospital while 18 (22.5%) arrived with pulse. Between groups there were no significant differences in demographics including ISS. The most common mortal injuries were traumatic brain injury (40%), long bone fractures (25%), moderate/large hemoperitoneum

(22.5%), and cervical spine injury (25%). Secondary outcomes included moderate/large pneumothorax (18.8%) and esophageal intubation rate of 5%. There were no significant differences in mortal or potentially mortal injuries, and no differences in polytrauma injury patterns.

Conclusions

Fatal blunt injury patterns do not vary between pre- vs in-hospital arrest decedents. High rates of pneumothorax and endotracheal tube misplacement should prompt mandatory chest decompression and confirmation of tube placement in all blunt arrest patients.

Level of evidence: III, prognostic and epidemiological

Keywords: Blunt trauma, post-mortem computed tomography, injury, death

Introduction

Blunt agonal trauma patients are highly complex and require swift decision-making through utilization of effective triage and resuscitation algorithms to improve survival.[1] Despite maximal resuscitative efforts, many blunt agonal patients arrive and soon perish in the trauma bay.[2] Dogma would dictate that most of these patients should die from hemorrhagic shock; however, without robust injury identification through formal autopsy, it is unclear what the predominant modality of death is within this patient population.[3,4]

Post-mortem computed tomography (PMCT) may add value in identifying unrecognized injuries in blunt agonal trauma decedents. Though formal autopsy may provide a high sensitivity and specificity for injury identification, they can be time consuming and autopsy rates may be significantly delayed or declined depending on municipality or region.[5,6] Prior work at our institution has demonstrated that utilization of PMCT improves trauma registry data fidelity by potentiating more accurate assessments of injury severity.[6] Likewise, work with PMCT has suggested that a significant number of supportive lines and devices like tubes and decompressive chest catheters may be malpositioned.[7] Since blunt agonal trauma patients have a dwindling margin of success with resuscitative efforts, garnering a better understanding of the injury mechanisms contributing to their demise may inform future resuscitative algorithms.

We aim to determine the prevalence of mortal injuries found in blunt agonal trauma decedents through use of PMCT. Our hypothesis is two-fold: 1) that most of these patients do not die from exsanguinating injuries, and 2) that there are potentially intervenable injuries that could either avert or mitigate death. By better defining the primary modality of death in these decedents and the injury burden which accompanies them, we hope to provide equipoise for better resuscitative algorithms that are data informed to be targeted and efficacious.

Methods

This is a retrospective cohort review of trauma decedents who died at or within 1 hour of arrival following blunt mechanisms of injury and who subsequently underwent PMCT. Following exempt approval by the Institutional Review Board, patients who underwent resuscitative surgical interventions (e.g., resuscitative thoracotomies, chest tube thoracostomies, REBOA placement, etc.) were included for analysis. Decedents were excluded if they were admitted to the inpatient setting prior to death, had undergone CT imaging prior to arrival, had any surgery for hemorrhage control excluding resuscitative thoracotomy in the trauma bay, had suspected non-accidental death (e.g., penetrating trauma) or suspicion of interpersonal violence, or were under the age of 16 (Supplemental Digital Content, http://links.lww.com/TA/C979).

Our primary outcome was the prevalence of having any mortal injury defined as potential exsanguination, traumatic brain injury, and/or cervical spine injury. Potentiality of exsanguination was defined as presence of moderate-to-large hemoperitoneum, high grade pelvic fractures (i.e., grade III anterior-posterior compression fractures and lateral compression fractures, as well as vertical shear), retroperitoneal hematoma, and moderate-to-large hemothoraces. Secondary outcomes included potentially mortal injuries, defined as injuries which could either be addressed in the field by pre-hospital providers or rapidly in the trauma bay and included pneumothoraces, misplaced airway devices, and long bone fractures. As this study was interested in potentially intervenable injuries that would avert death, patients were grouped by whether arrest occurred pre-hospital vs trauma bay.

All images were obtained following the ordering provider, typically a trauma surgeon or a member of the trauma team, obtaining verbal or written consent from the decedent's family or significant other as part of routine practice. CT scans were performed without the use of iodinated contrast from the top of the head to the toes using scanners located adjacent to the emergency department. All lines, tubes, and other support medical devices, if present, were intentionally left in place but disconnected from their respective devices (e.g., intravenous pumps, ventilators, etc.).

Images of the head, face, and cervical spine were reconstructed at 2mm slice thickness in the axial, sagittal, and coronal planes while images of the chest, abdomen, and pelvis were reconstructed at 4mm slice thickness in the axial, sagittal, and coronal planes. Images obtained were sent to sequestered worklist on a clinical production PACS system (Fuji Synapse, Stamford, CT) and archived in perpetuity. All studies were interpreted by one of two board certified radiologists. PMCT reports were generated prior to formal autopsy reports, if possible, and the finalized radiology report was included within the medical record. Injuries were tabulated to assess differences between groups. Interpretation of degree of solid organ injury was not possible due to the lack of iodinated contrast, but the presence of a solid organ injury was inferred from the presence of adjacent hemoperitoneum, or obvious deformity or destruction of the organ in question. For semi-quantifiable variables including size of pneumothorax, amount of hemothorax, and amount of hemoperitoneum, characterization of "moderate" or "large" was left to the discretion of the interpreting radiologist. Vascular injuries, and specifically blunt aortic injuries, could not be graded but similarly were inferred if peri-aortic hematoma was present or if there was gross irregularity to the contour of major vessels.

The relevance of certain injury patterns was determined by two attending trauma surgeons and injuries were placed into a dichotomized framework of mortal vs potential mortal injury. The heuristic guiding injury characterization fell to injuries that either could or could not be managed in the prehospital setting – for example, cavitary injuries with evidence of noncompressible hemorrhage, evidence of traumatic brain injury, and cervical spine injuries. Potentially mortal injuries were therefore relegated to pneumothoraces, issues with airway management, and long bone fractures as these injuries and issues can be addressed or mitigated in the field by pre-hospital providers. Several factors led to a consideration of pelvic fractures as mortal injuries: they are highly associated with complex multisystem trauma and represent a noncompressible form of hemorrhage, as binders cannot compress arterial bleeding.

Univariate analysis was performed to assess for significant differences between injury patterns and demographics between groups. Multicavitary injury patterns with or without brain or cervical spine injury were created to assess whether there were any significant differences in multisystem injury patterns between groups. A p-value less than 0.05 was considered significant.

Results

Over a 9-year study period, 91 patients underwent PMCT with 11 patients excluded either because they were victims of violence, had penetrating mechanisms of injury, or had already undergone a procedure for hemorrhage control (e.g., laparotomy) prior to obtaining imaging. Patients were subsequently grouped by loss of vital signs in the pre-hospital setting or in the trauma bay to help determine if these differences may represent injury patterns with potential for salvage. This left 80 patients for analysis with 62 patients losing vital signs pre-hospital (77.5%) and 18 patients losing pulses in the trauma bay (22.5%). Groups were similar in demographics and injury severity score with a minority of patients being above the age of 65 in both groups (overall 20%, 21% vs 16.7%; table 1). The mechanism of injury differed significantly between groups with falls and crush injuries predominating in patients arriving with a pulse and pulseless, respectively. However, the most common modality of injury, motor vehicle collision, was not significantly different between the two groups (67.7% vs 66.7%, p = 0.93).

Our primary outcome, the prevalence of mortal injury, did not differ between groups with an overall mortal injury rate of 51.3% (n = 41), with 50% (n = 31) in the pulseless group and 55.6% (n = 10) in the with pulse group (p = 0.68). Between groups, there were no significant differences in individual categories of mortal injuries – any traumatic brain injury, any cervical spine injury, or injuries with potential for exsanguination including moderate-to-large hemothoraces (22.5%) and hemoperitoneum (22.5%), with few to no significant pelvic or retroperitoneal injuries (see table II).

Potentially mortal injuries did not differ with a rate of 57.5% (n = 46) overall, 58.1% (n = 36) rate in pulseless patients, and 55.6% (n = 10) in the with pulse group (p = 0.85). Notably, while airway device malpositioning was similar between groups, the rate of malpositioning for endotracheal tubes was high (13.7% overall, 12.9% vs 16.7%, p = 0.68). Esophageal intubation rate was particularly high at 5% overall (n = 4), 4.8% (n = 3) in pulseless patients, and 5.5% (n = 1) in patients with pulse (table III). Chest trauma was prevalent with 47.5% of patients (n = 38) incurring at least 1 chest injury. Prehospital needle decompression only occurred in 17.5% of the entire cohort (n = 14) with no significant difference in needle decompression rate between the two groups (17.7% vs 16.6%, p = 0.92). The rate of moderate to large pneumothoraces was similar between groups (36.3% overall, 37.1% vs 33.3%, p = 0.82). Of these pneumothoraces, a large contingent of decedents had unevacuated pneumothoraces (18.8% overall, 19.4% vs 16.7%, p = 0.8).

When examining multicavitary injury patterns, groups did not differ in the rate of abdominal (p = 0.73), retroperitoneal or pelvis (p = 0.39), thoracic (p = 0.17), long bone (p = 0.44), or no cavitary injury (p = 0.9, table IV). Cavitary injury patterns were grouped to assess the prevalence of multicavitary injury patterns. There was a fair split between solitary and two cavitary injury patterns overall (32.5% and 33.8%, respectively) with no differences between groups in the rate of solitary vs bi-cavitary injuries (p = 0.63 and p = 0.97, respectively). Isolated traumatic brain injury or cervical spine injury was uncommon (7.5% and 1.3%). Likewise, the prevalence of multisystem injury was low (e.g., traumatic brain injury and cavitary injury). When cavitary injury was combined with traumatic brain injury, the overall prevalence was 11.3% (n = 9) and did not differ between groups.

Discussion

In this study, we utilized PMCT to identify injury patterns in blunt trauma decedents and dichotomized them by location of death in order to identify the predominating injury patterns, and the patients in whom life-preserving interventions may have been efficacious. Our presumption was that decedents would have largely succumbed to mechanisms of exsanguination, but concurrently there would be a subset of decedents who possess rapidly addressable life-threatening and that these data would inform future resuscitation algorithms. We therefore dichotomized patients by location of death (pre-hospital vs trauma bay) with the thought that decedents who arrived at the hospital with vital signs may have potential for salvage and differ in injury pattern. Within our analysis, we found a plurality of injury patterns without a discernable difference of any one mechanism of death over another. Specifically, when examining different mortal injuries, mechanisms of exsanguination, including abdominal, pelvic, or chest, were no more prevalent than neurological injuries. Of our defined potentially mortal injuries, we did not demonstrate a majority of any one modality; however, we did observe a high prevalence of rapidly correctable issues such as pneumothoraces or malpositioned airway devices. These findings are critical to create and implement data-informed improvements in resuscitation practices in areas where autopsy rates may be low for non-violent deaths.

Post-mortem CT has been repeatedly shown to reliably increase the identification of injuries in trauma decedents across multiple studies, including work within our own institution.[8–11] Likewise, the accuracy of injury identification compared to formal autopsy shows high sensitivity for identifying most injury patterns, though specificity is lacking.[12] Our study is one of the few which links injury patterns in blunt decedents with potential of death and offers actionable data to inform resuscitation algorithms.

A surprising finding of our study is that most decedents did not have evidence of cavitary sources of exsanguination, but a large contingent did have unevacuated pneumothoraces or malpositioned airways. Multicavitary injury was uncommon with 33.8% having two cavitary injury while only a combined 12.5% having three or four cavitary injury, and significant pelvic injury was a rarity with only 6 patients (7.5%) in the entire cohort having a grade III anterior-posterior compression or lateral compression pelvic fracture. While we feel hemorrhage or the potential thereof needs to be a grave concern in any blunt agonal resuscitation, it cannot steal focus away from actionable and correctable modalities of death during the rapid triage and treatment of patients. As such, we identified to major areas of concern which we feel require mandatory addressal in any blunt agonal resuscitation. First, the rate of esophageal intubation was high at 5% and overall airway malpositioning of 13.7% including an 11.3% rate of malpositioned endotracheal tubes. While these findings are consistent with existing literature, we feel their prevalence should prompt mandatory confirmation of correct placement through either video or direct laryngoscopy.[13–15] Second, we identified a large group of decedents with unevacuated pneumothoraces despite roughly 17% of patients undergoing prehospital needle decompression. Prior work has demonstrated that needle decompression may either be inadequate to reach and evacuate the intrathoracic cavity or carry the risk of inadvertent iatrogenic injury including cardiac injury.[16,17] We believe our findings support empiric surgical decompression of the chest via tube or finger thoracostomy in all blunt agonal trauma patients.

The interpretation of our results in the context of their limitations is important and worth noting. First, the retrospective nature of this review carries with it the limitations inherent to its design. Perhaps most notably is selection bias as uniformly obtaining PMCT in blunt decedents was not enforced and left to the discretion of the attending trauma surgeon. This may also have contributed towards a low sample size over nearly a decade's worth of practice, which may hamper the power of our results and potentiate type II error. Second, as all PMCTs are non-contrasted, the grade of solid-organ injury severity is severely limited. However, while prior studies have demonstrated PMCT is inferior to formal autopsy for organ injury severity grading, PMCT is highly sensitive for identification of hemoperitoneum and has high sensitivity to identifying solid organ injury in a binary yes-no manner. Interestingly, there are some preliminary data suggesting PMCT angiography is feasible, but its nascency and utility makes its practical application unknown. [18] Fourth, at this time we do not have the transport times of decedents from the site of injury to when they arrived at our institution. This makes interpreting the dichotomization of pre-hospital vs trauma bay mortality difficult and is likely significant. Work to incorporate these times into our analysis of PMCT is ongoing. And finally, it would be impossible based on our findings to determine the cause of death in any decedent based on PMCT alone without corroborating autopsy findings. Though there is equipoise within the literature that PMCT may be suitable for determination of death, it is our opinion that this needs to be individualized on a locoregional basis in a multidisciplinary manner between medical examiners, trauma surgeons, and radiologist. Nevertheless, in areas with low autopsy rate, PMCT may provide an avenue for better and more expeditiously defined forensic analysis as has been demonstrated in other fields.[6]

Conclusion

Fatal blunt injury patterns do not vary between pre- vs trauma bay arrest in blunt trauma decedents. Injury patterns with potential for significant hemorrhage do not predominate but the high rate of pneumothorax and endotracheal tube misplacement should prompt mandatory surgical chest decompression and confirmation of tube placement in all blunt agonal trauma patients. Multi-institutional research of PMCT in trauma decedents will aid in understanding the prevalence of significant injury patterns, augment locoregional autopsy data, and help inform best practices for the resuscitation of the blunt agonal trauma patient.

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SUPPLEMENTAL DIGITAL CONTENT

SDC 1. STROBE Checklist

Table I: Demographics

	Overall (N = 80)	Pulseless (n = 62)	Pulse (n = 18)	p
Age (years)	48.9 +/- 21.7	49.9 +/- 20.5	45.8 +/- 25.6	0.5
Sex (M)	56 (68.3)	43 (69.4%)	13 (72.2%)	0.82
Mechanism of Injury				0.03
Fall	3 (3.8%)	0 (0%)	3 (16.7%)	
MVC	54 (67.5%)	42 (67.7%)	12 (66.7%)	
MCC	5 (6.3%)	4 (6.5%)	1 (5.6%)	
ATV	1 (1.5%)	1 (1.6%)	0 (0%)	
Ped Struck	12 (15%)	10 (16.1%)	2 (11.1%)	
Crush/Machinery	5 (6.3%)	5 (8.1%)	0 (0%)	
Pre-PMCT ISS	5.9 +/- 9.2	5.9 +/- 9.2	6.0 +/- 9.2	0.51
Post-PMCT ISS	42.3 +/- 16.3	42.1 +/- 16.4	42.6 +/- 16.3	0.09
Mortal Injury	69 (86.3%)	54 (87.1%)	16 (88.9%)	0.84
Potentially Mortal Injury	54 (67.5%)	43 (69.4%)	12 (66.7%)	0.83
Arrived Pulseless	62 (77.5%)			

*M = male, MVC = motor vehicle collision, MCC = motorcycle collision, ATV = all-terrain vehicle, Ped = pedestrian, PMCT = post-mortem computed tomography, ISS = injury severity score

Table II: Mortal Injuries

	Overall (N = 80)	Pulseless (n = 62)	Pulse (n = 18)	p
Traumatic Brain				
Any Traumatic Brain Injury	32 (40%)	28 (45.2%)	4 (22.2%)	0.08
Epidural Hematoma	0 (0%)	0 (0%)	0 (0%)	---
Subdural Hematoma	6 (7.5%)	6 (9.7%)	0 (0%)	0.17
Subarachnoid Hemorrhage	19 (23.8%)	17 (27.4%)	2 (11.1%)	0.15
Intraparenchymal Hemorrhage	5 (6.3%)	3 (4.8%)	2 (11.1%)	0.33
Intraventricular Hemorrhage	10 (12.5%)	9 (14.5%)	1 (5.6%)	0.31
Diffuse Axonal Injury	3 (3.8%)	2 (3.2%)	1 (5.6%)	0.65
Any Parenchymal Herniation	9 (11.3%)	9 (14.5%)	0 (0%)	0.09
Cervical Spine				
Any Cervical Spine Injury	18 (22.5%)	14 (22.6%)	4 (22.2%)	0.97
Listhesis	6 (7.5%)	6 (9.7%)	0 (0%)	0.17
C1 fx	9 (11.3%)	9 (14.5%)	0 (0%)	0.09
C2 fx	6 (7.5%)	5 (8.1%)	1 (5.6%)	0.72
C3 fx	1 (1.3%)	1 (1.6%)	0 (0%)	0.59
C4 fx	2 (2.5%)	1 (1.6%)	1 (5.6%)	0.35
C5 fx	2 (2.5%)	1 (1.6%)	1 (5.6%)	0.35
C6 fx	3 (3.8%)	3 (4.8%)	0 (0%)	0.34
C7 fx	1 (1.3%)	1 (1.6%)	0 (0%)	0.59
Atlanto-Occipital Dissociation	5 (6.3%)	4 (6.5%)	1 (5.6%)	0.89
Chest				
Moderate/Large Hemothorax	18 (22.5%)	16 (25.8%)	2 (11.1%)	0.35
Abdomen				
Splenic laceration	15 (18.8%)	11 (17.7%)	4 (22.2%)	0.67
Liver laceration	6 (7.5%)	3 (4.8%)	3 (16.7%)	0.09
Moderate/Large Hemoperitoneum	18 (22.5%)	11 (17.7%)	7 (38.9%)	0.06
Pelvic/Retroperitoneum				
Any pelvic fracture	26 (32.5%)	19 (30.6%)	7 (38.9%)	0.51
APC I	0 (0%)	0 (0%)	0 (0%)	---
APC II	4 (5.0%)	3 (4.8%)	1 (5.6%)	0.9
APC III	1 (1.3%)	1 (1.6%)	0 (0%)	0.59
LC I	9 (11.3%)	6 (9.7%)	3 (16.7%)	0.41
LC II	10 (12.5%)	8 (12.9%)	2 (11.1%)	0.82
LC III	5 (6.3%)	4 (6.5%)	1 (5.6%)	0.89
Vertical Shear	0 (0%)	0 (0%)	0 (0%)	---
Renal laceration	7 (8.8%)	5 (8.1%)	2 (11.1%)	0.69

Zone I Hematoma	2 (2.5%)	2 (3.2%)	0 (0%)	0.44
Zone II Hematoma	10 (12.5%)	6 (9.7%)	4 (22.2%)	0.16

*CX fx = Cervical spine fracture with x denoting level, APC = anterior-posterior compression, LC = lateral compression

Table III: Potentially Mortal Injuries

	Overall (N = 80)	Pulseless (n = 62)	Pulse (n = 18)	p
Airway				
King Airway	11 (13.8%)	10 (16.1%)	1 (5.6%)	0.25
Laryngeal Airway Mask	13 (16.3%)	12 (19.4%)	1 (5.6%)	0.16
Pre-hospital ETT	34 (42.5%)	26 (41.9%)	8 (44.4%)	0.85
Endotracheal Intubation	26 (32.5%)	18 (29%)	8 (44.4%)	0.22
Emergent Cricothyroidotomy	3 (3.8%)	1 (1.6%)	2 (11.1%)	0.06
All malpositioned airways	11 (13.7%)	8 (12.9%)	3 (16.7%)	0.68
Malpositioned LMA	0 (0%)	0 (0%)	0 (0%)	---
Malpositioned King Airway	2 (2.5%)	2 (3.2%)	0 (0%)	0.82
Malpositioned ETT	9 (11.3%)	6 (9.7%)	3 (16.7%)	0.41
Esophageal intubation	4 (5%)	3 (4.8%)	1 (5.6%)	0.9
Chest				
Moderate/Large Pneumothorax	29 (36.3%)	23 (37.1%)	6 (33.3%)	0.82
Pre-hospital Needle Decompression	14 (17.5%)	11 (17.7%)	3 (16.7%)	0.92
PTX, No chest tube	15 (18.8%)	12 (19.4%)	3 (16.7%)	0.8
Potential Aortic Injury	12 (15%)	10 (16.1%)	2 (11.1%)	0.6
Hemopericardium	7 (8.8%)	6 (9.7%)	1 (5.6%)	0.59
Extremity				
Any long bone	20 (25%)	13 (21%)	7 (38.9%)	0.12
Unilateral femur	14 (17.5%)	10 (16.1%)	4 (22.2%)	0.55
Bilateral femur	3 (3.8%)	3 (4.8%)	0 (0%)	0.34
Traumatic amputation (UE)	1 (1.3%)	1 (1.6%)	0 (0%)	0.62
Humerus	4 (5%)	2 (3.2%)	2 (11.1%)	0.18

*ETT = endotracheal tube, LMA = laryngeal airway mask, PTX = pneumothorax, UE = upper extremity

Table IV: Multicavitary Injury Patterns

	Overall (N = 80)	Pulseless (n = 62)	Pulse (n = 18)	p
Abdominal	24 (30.0%)	18 (29%)	5 (27.85)	0.73
Retroperitoneum/Pelvis	33 (41.3%)	24 (38.7%)	9 (50%)	0.39
Thoracic Cavity	38 (47.5%)	32 (51.6%)	6 (33.3%)	0.17
Long Bones	17 (21.3%)	12 (19.4%)	5 (27.8%)	0.44
No Cavitary Injury	17 (21.3%)	13 (21%)	4 (22.2%)	0.9
Solitary Cavitary Injury	26 (32.5%)	21 (33.9%)	5 (27.8%)	0.63
Two Cavitary Injury	27 (33.8%)	21 (33.9%)	6 (33.3%)	0.97
Three Cavitary Injury	8 (10%)	5 (8.1%)	3 (16.7%)	0.28
Four Cavitary Injury	2 (2.5%)	2 (3.2%)	0 (0%)	0.44
TBI, no cav	6 (7.5%)	4 (6.5%)	2 (11.1%)	0.51
Cervical spine, no cav	1 (1.3%)	0 (0%)	1 (5.6%)	---
TBI & C-spine, no cav	4 (5%)	4 (6.5%)	0 (0%)	---
TBI & One Cav	9 (11.3%)	6 (9.7%)	3 (16.7%)	0.44
TBI & 2 Cav	11 (13.8%)	10 (12.5%)	1 (5.6%)	0.25
TBI & 3 Cav	3 (3.8%)	2 (3.2%)	1 (5.6%)	0.65

*TBI = traumatic brain injury, Cav = cavitary injury, C-spine = cervical spine injury

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2
Objectives	3	State specific objectives, including any prespecified hypotheses	2
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	3
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4-5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*4-5*
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	3
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	

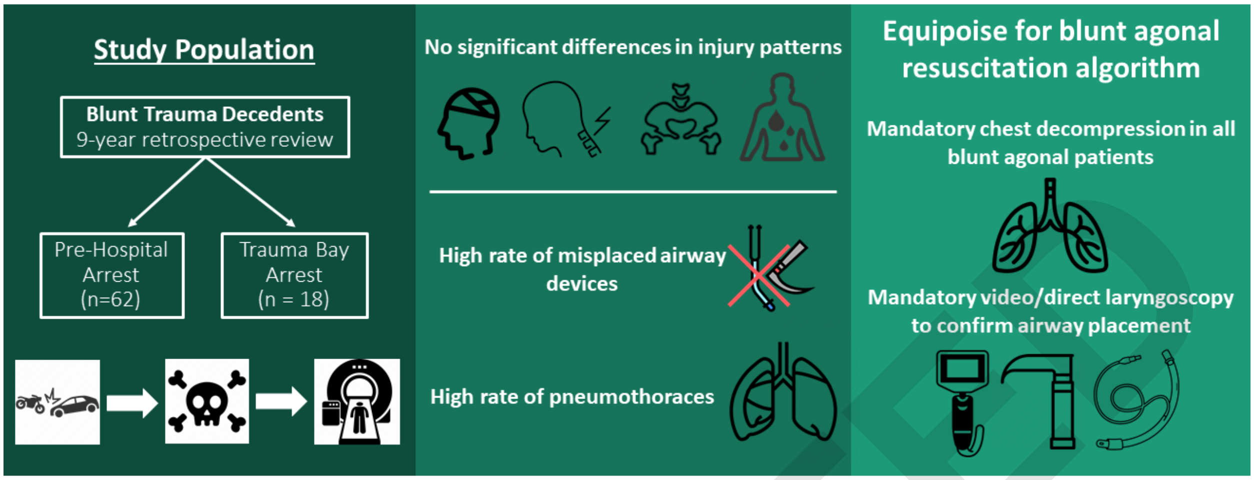
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5-6
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	*6*
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6-7
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	

Discussion			
Key results	18	Summarise key results with reference to study objectives	7-8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	9-10
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	7-10
Generalisability	21	Discuss the generalisability (external validity) of the study results	8-9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Characterization of Fatal Blunt Injuries Using Post-Mortem Computed Tomography



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