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ORIGINAL ARTICLE

Post-mortem computed tomography assessment of medical support device position following fatal trauma: a single-center experience

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Abstract

Purpose To evaluate the percentage of misplaced medical support lines and tubes in deceased trauma patients using post-mortem computed tomography (PMCT).

Methods Over a 9-year period, trauma patients who died at or soon after arrival in the emergency department were candidates for inclusion. Whole body CT was performed without contrast with support medical devices left in place. Injury severity score (ISS) was calculated by the trauma registrar based on the injuries identified on PMCT. The location of support medical devices was documented in the finalized radiology reports.

Results A total of 87 decedents underwent PMCT, of which 69% (n = 60) were male. For ten decedents, the age was unknown. For the remaining 77 decedents, the average age was 48.4 years (range 18–96). The average ISS for the cohort was 43.4. Each decedent had an average of 3.3 support devices (2.9–3.6, 95% CI), of which an average of 1 (31.3%, 0.8–1.2, 95% CI) was malpositioned. A total of 60 (69.0%) had at least one malpositioned medical support device. The most commonly malpositioned devices were decompressive needle thoracostomies (n = 25/32, 78.1%). The least malpositioned devices were intraosseous catheters (n = 7/69, 10.1%). Nearly one quarter (n = 19/82, 23.2%) of mechanical airways were malpositioned, including 4.9% with esophageal intubation.

Conclusion Malpositioned supportive medical devices are commonly identified on post-mortem computed tomography trauma decedents, seen in 69.0% of the cohort, including nearly one quarter with malpositioned mechanical airways. Post-mortem CT can serve as a useful adjunct in the quality improvement process by providing data for education of trauma and emergency physicians and first responders.

Keywords Post-mortem computed tomography · Trauma · Medical support devices

Introduction

Trauma is a leading cause of death in persons under the age of 44, surpassing heart disease and malignant cancer combined [1]. Advanced trauma life support (ATLS) is a standardized protocol for the rapid triage of the injured patient, aimed at injury identification and the expedited administration of lifesaving treatments in both the hospital and the prehospital setting [2]. Commonly in the treatment of injured patients, medical support devices, such as mechanical airways and chest tubes, are placed to alleviate the potential of mortal injury. These devices are often placed rapidly as patient physiology dictates, but due to austere circumstances in the field, patient injury burden leading to altered anatomy, and patient specific factors independent on trauma (e.g. morbid obesity), device placement may occur in suboptimal conditions. While in the alive patient, medical imaging through x-rays and computed tomography can confirm appropriate device placement, trauma decedents historically have been excluded from such confirmation as they die before confirmatory imaging is obtained. This is a huge opportunity loss as one could argue these patients represent the more severe circumstances that require swift and accurate placement of supportive medical devices. Quality improvement processes that educate the treating physician

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and emergency medical services on the correct placement of these devices would be invaluable to any trauma system.

Post-mortem computed tomography (PMCT) is a relatively underutilized adjunct to categorize not only injury severity in trauma decedents but instruct on the efficacy and accuracy of provider interventions. Previous work has demonstrated that PMCT can accurately characterize patient injury patterns and bolster trauma registry capture of clinically unsuspected injuries [3]. To date, there is sparse data on trauma decedents and utilization of PMCT to inform practice patterns, and what literature exists has focused primarily on airway device misplacement [4].

The depth of information to be gained from the holistic view of trauma decedents and the importance of informing providers on the precision and accuracy of procedures and devices applied cannot be overstated. Therefore, the purpose of this study is to quantify the rate of medical device misplacement in trauma decedents who have undergone PMCT. Our hypothesis is that a significant number of devices are malpositioned as seen on PMCT.

Materials and methods

This was a retrospective, single-center cohort study evaluated post-mortem CTs obtained from trauma decedents conducted over a 9-year period spanning January 1, 2013, to December 31, 2021. Patients were eligible for inclusion into the study if they were aged 18 years or older and died within 1 h of presentation to the emergency room. Decedents who underwent lifesaving resuscitative interventions such as resuscitated thoracotomy within the emergency room remained candidates for PMCT. Patients were excluded from analysis if they (1) underwent antemortem computed tomography or (2) underwent any surgical intervention (e.g., a laparotomy) other than resuscitative procedures performed in the trauma bay.

Imaging protocol

The PMCT protocol consisted of a non-contrast scan from the head to toes without contrast on either a 64, 128, or 256 multi-detector CT scanner (Philips Healthcare, Best, The Netherlands). A reference mAs of 240 and kVp of 120 was used with *z*-axis dose modulation. Images through the head, face, and cervical spine were reconstructed at 2-mm slice thickness in three planes (axial, sagittal, and coronal), while images through the chest, abdomen, pelvis, and lower extremities were reconstructed at 4-mm slice thickness in 3 planes (axial, sagittal, and coronal). Images were transferred to a clinical PACS system (Fuji Synapse, Stamford, CT). Scans were performed within two hours of death. All medical support devices were left in place but were disconnected from any other medical equipment such as intravenous pumps or ventilators.

Reporting and data analysis

All PMCT exams were interpreted by one of two board certified radiologist with 12 to 14 years of trauma and emergency radiology experience. For each decedent in the cohort, all medical devices and their positioning were noted within the finalized report, which was included in the decedent's permanent medical record. An anonymized database was created for all decedents in the study cohort. Every line, tube, and/or medical device for each decedent was extracted from the finalized radiology report and documented as being correctly or incorrectly positioned per the criteria listed in Table 1. Criteria for appropriate positioning of medical devices were then approved by two board certified trauma surgeons. The percentage of each malpositioned support medical device was calculated for each decedent and for the entire cohort. Malpositioned support medical devices were then re-confirmed on imaging by a post-graduate year 6 (PGY-6) emergency radiology fellow. Injury severity score (ISS) was calculated by the trauma registrar based on the injuries identified on PMCT. Injury severity score mean and standard deviation were calculated for the cohort.

Results

A total of 87 decedents underwent PMCT during the study period, with an average age of 48.4 years (range 18–96 years) and 69% ($n = 60$) being male. For ten decedents, age was unknown. The most common mechanism of injury was motor vehicle collision ($n = 47$, 54.0%), followed by pedestrian vs. vehicle ($n = 15$, 17.2%), motorcycle collision ($n = 8$, 9.2%), crush injury ($n = 5$, 5.7%), gunshot wounds ($n = 4$, 4.6%), falls ($n = 3$, 3.4%), and other (motor scooter accident, jet ski accident, all-terrain vehicle accident, suicide, and found down ($n = 5$, 5.7%). The 4 gunshot victims evaded PMCT eligibility criteria but were included as a part of this analysis. The mean injury severity score was 43.4 (±16.2) following injury identification on PMCT, with 1 having an ISS <15 and 86 having an ISS ≥15 (Table 2).

Each decedent had an average of 3.3 support devices (2.9–3.6, 95% CI) with an average of one (31.3%, 0.8–1.2, 95% CI) support devices being malpositioned. In all, a total of 60 decedents (69.0%) had at least one malpositioned line or tube with the most malpositioned device being decompressive needle thoracostomies (DNT; Fig. 1a). A total of 32 DNT were placed in 19 decedents, of which 25 (78.1%) were malpositioned. A total of 64 chest tubes were placed in 37 decedents ($n = 36$ on the right, $n = 28$ on the left) of which 27 (42.2%) were malpositioned.

Table 1 Support medical device optimal position and malpositioned location

Medical devices analyzed in our cohort		
Medical device	Optimal position	Malpositioned
Endotracheal tube	Above carina and below vocal cords	Esophageal, mainstem bronchus, above vocal cords
Dual lumen airway device	Distal tube in the esophagus and proximal balloon inflated in the hypopharynx	Balloon inflated within the oropharynx; tube folded on itself
Laryngeal mask airway device	Cuff inflated around the airway opening	
Intravascular device	Intravascular	Extravascular; within surrounding subcutaneous tissues/muscle
Intraosseous catheter	In medullary bone of humeral head or tibial plateau	In bone cortex; in overlying subcutaneous tissues/muscles
Chest tube	Posterior pleural space	In overlying extra-thoracic soft tissues/muscles; in lung parenchyma; in lung fissure
Decompressive needle Thoracostomy	Pleural space	In overlying extra-thoracic soft tissues/muscles; in lung parenchyma
Nasogastric/orogastric tube	In stomach	In mouth or esophagus
REBOA (resuscitative endovascular balloon occlusion of aorta)	In Zone 1 (Between left subclavian artery and intra-abdominal aorta) or Zone 3 (Below the renal arteries and above the aortic bifurcation) of the aorta	Outside of these zones of the aorta

Table 2 Demographics of decedents who received PMCT following fatal trauma

Age (years)	48.4 (18–96)
Sex	60 male (69%)
Mechanism of injury	
MVC	47 (54.0%)
Pedestrian struck	15 (17.2%)
MCC	8 (9.2%)
Crush injury	5 (5.7%)
GSW	4 (4.6%)
Fall	3 (3.4%)
Other	5 (5.7%)
Injury severity score	43.4 (±16.2)
ISS < 15	1
ISS ≥ 15	86

PMCT post mortem computed tomography, *MVC* motor vehicle collision, *MCC* motorcycle collision, *GSW* gunshot wound, *ISS* injury severity score

Airway devices were malpositioned in 19 out of a total of 82 decedents (23.2%). In patients with endotracheal tubes (n = 64), 16 (25%) were positioned in either the esophagus (n = 4; Fig. 2), were supraglottic (n = 4; Fig. 3), or positioned in a mainstem bronchus (n = 8; Fig. 1b). Amongst supraglottic airways (including dual lumen airways, laryngeal mask airways, and nasopharyngeal airways), only 3 out of 17 (17.6%) were misplaced, all of which were dual lumen airway devices (3 of 9 dual lumen airway devices, 33.3%; Fig. 3). Of the 8 laryngeal mask airways placed, all were in appropriate position. There was one correctly positioned nasopharyngeal airway in the cohort. A summary of the malpositioned devices can be seen in Table 3.

A total of 19 upper extremity intravascular access devices were placed (n = 9 on right, n = 10 on left), of which 5 were malpositioned (26.3%; Fig. 2). A total of 18 lower extremity intravascular access devices were placed (n = 11 on right, n = 7 on left), of which 3 were malpositioned (16.7%). The majority of malpositioned intravascular access devices were extravascular in the overlying subcutaneous tissues. A total of 69 intraosseous catheters (IOC) were placed in 53 decedents. A total of 29 upper extremity intraosseous catheters (IOC) were placed (n = 12 on the right, n = 17 on the left), of which 5 were malpositioned (17.2%). A total of 40 lower extremity IOCs were placed (n = 24 on right, n = 16 on left), of which 2 were malpositioned (5.0%). Most were malpositioned within the overlying subcutaneous tissues or within the bone cortex and did not reach the medullary space. Lower extremity IOCs were the least malpositioned medical device within the cohort.

Finally, a total of 18 nasogastric/orogastric devices were placed in 18 patients, of which two (11.1%) were malpositioned in the mid esophagus. There were three REBOA (resuscitative endovascular balloon occlusion of the aorta) catheters which were correctly positioned within the aorta.

Discussion

Life-saving resuscitative efforts following trauma are multifaceted, and often include the rapid administration of intravenous fluids and blood products, evacuation of blood or gas

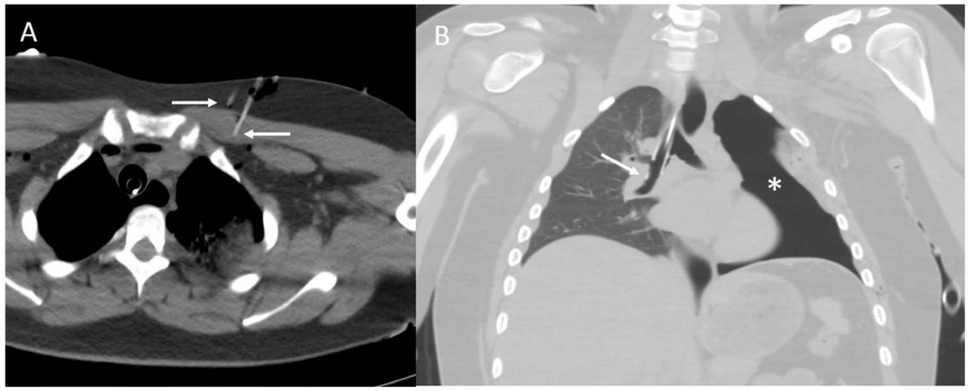

Fig. 1 **A** 18-year-old female following an abdominal gunshot wound. Axial non-contrast CT through the upper chest demonstrates decompressive needle thoracostomy tubes embedded in the left anterior chest wall and do not terminate in the pleural space (arrows). **B** Coronal non-contrast CT image through the chest demonstrates right mainstem intubation (arrow). There is a left sided pneumothorax (asterisk)

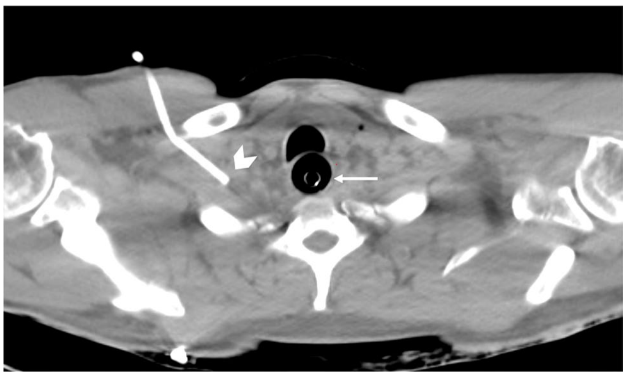

Fig. 2 Axial non-contrast CT through the neck base of a 49-year-old male following a motor vehicle collision. There is esophageal intubation (arrow) and a right subclavian vascular sheath in the neck soft tissues (arrowhead)

from the pleural space, and securing of the airway [5]. Thus, the proper placement of vascular catheters, chest tubes, mechanical airways, and other support medical devices are critical during these efforts. Our study is the largest series to date of PMCT in trauma decedents and demonstrates many these supportive devices are incorrectly positioned with a preponderance of misplaced vascular access devices and mechanical airways. PMCT has been previously used to investigate support line placement following trauma, finding that 31.3% and 56% of patients had malpositioned support devices in prior studies [3, 6]. In this study, 69% of decedents had at least one malpositioned medical support device. The significance of this finding is salient as there is a large body of literature that malpositioned lines and tubes may have detrimental effects on survival [7–9].

Securing a patent airway is a central tenant of advanced trauma life support (ATLS); therefore, accurate placement of any mechanical airway in the obtunded patient is critical for resuscitative success. While a variety of advanced mechanical airway devices may be employed in the emergent setting, the most common are endotracheal tubes (ETTs) and supraglottic airway devices such as dual lumen King airways, and variants on laryngeal airway masks. Our study found that

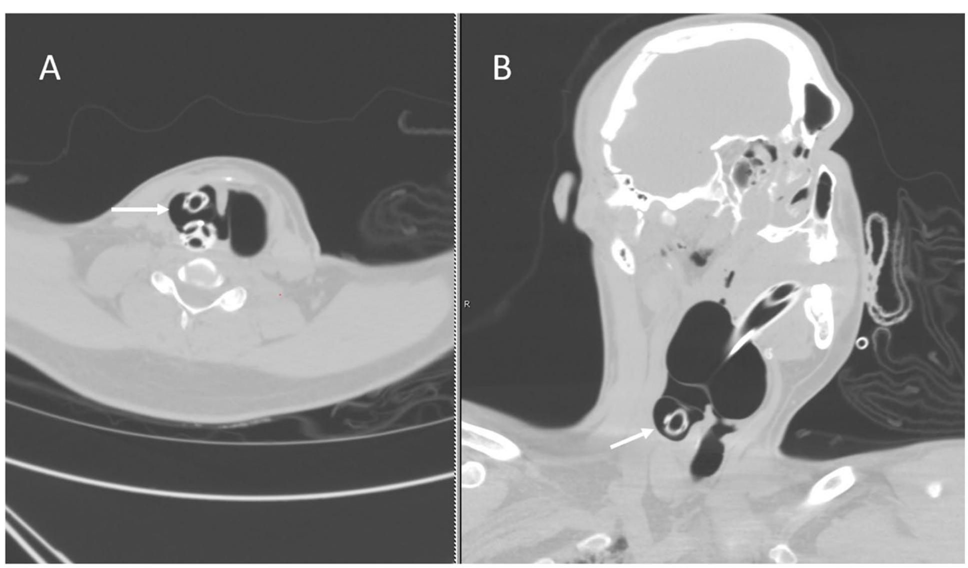

Fig. 3 23-year-old man struck by a motor vehicle. Axial (**A**) and coronal (**B**) non-contrast CT images of the neck demonstrate a malpositioned dual lumen pharyngeal airway device folded in the hypopharynx (arrows)

Table 3 Malpositioned supportive medical devices on post-mortem CT

Device	Total number of devices placed	Total number of devices malpositioned	Percentage malpositioned	Most commonly malpositioned location
Malpositioned airway devices on post-mortem CT				
Mechanical airway devices	82	19	23.2%	Esophageal intubation = 4 Right mainstem intubation = 8 Within hypopharynx/balloon inflated above vocal cords/in oral cavity = 7
Endotracheal tube	64	16	25.0%	Esophageal intubation = 4 Right mainstem intubation = 8 Within hypopharynx/balloon inflated above vocal cords/in oral cavity = 4
Dual lumen airway device	9	3	33.3%	Balloon inflated within the oropharynx and tube folded on itself within oral cavity = 3
Laryngeal mask airway device	8	0	0%	All were correctly positioned
Nasopharyngeal airway	1	0	0%	Correctly positioned
Malpositioned IV/IO devices on post-mortem CT				
Right upper extremity intravascular access	9	2	22.2%	Extravascular
Left upper extremity intravascular access	10	3	30.0%	Extravascular
Right lower extremity intravascular access	11	1	9.1%	Extravascular
Left lower extremity intravascular access	7	2	28.6%	Extravascular
Right upper extremity Intraosseous catheter	12	4	33.3%	Overlying subcutaneous tissues/muscle = 3 In bone cortex = 1
Left upper extremity intraosseous catheter	17	1	5.9%	In humeral metaphysis as opposed to the head = 1
Right lower extremity intraosseous catheter	24	1	4.2%	Overlying subcutaneous tissues/muscle = 1
Left lower extremity intraosseous catheter	16	1	6.3%	Overlying subcutaneous tissues/muscle = 1
Malpositioned DNT/tube thoracostomy/NG tubes on post-mortem CT				
Right chest tube	36	15	41.7%	Folded and kinked at side port = 3 Side port in extra-thoracic soft tissues = 2 Suboptimally positioned/terminates within a fissure = 6 Not in pleural space/incorrect positioning = 4
Left chest tube	28	12	42.9%	Folded and kinked at side port = 3 Side port in extra-thoracic soft tissues = 2 Suboptimally positioned/terminates within a fissure = 4 Not in pleural space/incorrect positioning = 3
Right decompressive needle thoracostomy	14	10	71.4%	In lung parenchyma = 1 In overlying chest wall soft tissue/muscle = 9
Left decompressive needle thoracostomy	18	15	83.3%	In lung parenchyma = 4 In overlying chest wall soft tissue/muscle = 11
Nasogastric/orogastric tubes	18	2	11.1%	Coiled within esophagus = 2
REBOA catheters	3	0	0.0%	All correctly positioned within the aorta

REBOA resuscitative endovascular balloon occlusion of the aorta

25.0% of endotracheal tubes were incorrectly positioned with 4.9% of ETTs incorrectly placed in the esophagus. The consequences of esophageal intubation have been well established with the potential for anoxic brain injury and mortality. Esophageal intubation is the most likely to cause irreversibly neurological sequelae in trauma patients compared to mainstem intubation or supraglottic intubation [7].

Dual lumen supraglottic airway devices are designed for easier placement in austere environments. Our study demonstrated nearly a third of patients with dual lumen airway devices had radiographic evidence of incorrect placement. This is similar to prior studies which have reported 14.4% of all supraglottic airway devices and 13.8% of King airway devices were placed incorrectly [4]. This places doubt into the assumption that supraglottic airways can be "easily" placed as the consequences of malpositioning include ventilatory obstruction, esophageal perforation, pharyngeal perforation, and hyoid bone fracture [4].

In all, our study demonstrated 23.2% of all mechanical airways were malpositioned including esophageal intubation, bronchial intubation, and malpositioned supraglottic devices. This high rate of incorrect positioning mirrors the published literature. A prior study showed that in a cohort of 239 trauma patients who received emergency airway management, 16.7% of airway devices were malpositioned, and a 2016 meta-analysis of 42,081 emergency department in-hospital intubations showed a first pass success rate of only 81.8% [10, 11].

Emergent chest decompression through needle (DNT) or tube thoracostomy (DCT) can be a definitive resuscitative and life-saving measure, but the consequences of incorrect DNT/DCT are dire. In our study, 78% of DNTs were incorrectly positioned which mirror prior work by Kaesrer et al. [12]. In their retrospective review, 72% of DNT attempts resulted in insufficient decompression of tension pneumothorax. In our study, all malpositioned DNTs were placed anteriorly which suggests anterior placement of DNTs may be suboptimal. A cadaver study on optimal DNT positioning showed increased chest wall depth during an anterior approach as opposed to the lateral mid-axillary approach [13]. This may account for the degree of malpositioned DNTs observed in our cohort.

Large bore chest tubes are often placed as the definitive modality of pneumothorax and hemothorax evacuation, but accurate placement into the chest cavity is paramount for success. Our cohort had a total of 64 chest tubes placed with 42% showing radiographic evidence of malposition either within the subcutaneous tissues or in the lung fissures. Different studies report a range of tube thoracostomy malpositioning from 22 to 77%, but regardless the consequences of incorrect positioning portend significant morbid and mortal implications [6, 8, 9].

Timely and accurate vascular access is the bastion of effective resuscitation, but unrecognized misplacement of intravenous or interosseous catheters can have dire consequences. In our study, one out of every five (21.6%) intravenous catheters were incorrectly positioned with more left-side catheters being malpositioned than right-sided catheters (29.4% vs 15%). Likewise, 10% of interosseous catheters were not appropriately positioned, with a higher rate of malpositioning in the right shoulder compared to all other extremities (33.3% vs 5.3%). These findings are similar to prior studies which demonstrate high rates of both intravascular and interosseous catheter misplacement though at lower rates than presented within our work [10, 14]. Our finding of differences in successful placement based on laterality has not been previously described and suggests there may be anatomic or system issues contributing to device misplacement.

Study limitations

Our study has several limitations of note. First, this is a single institution retrospective cohort study with limitations inherent to its design. Specifically, we were only able to study device malposition in those decedents who underwent PMCT. Since the ordering of a PMCT was at the discretion of the treating trauma surgeon, there may have been cases not captured. Second, we only evaluated device malposition in decedents, but presumably similar malpositioning can occur in survivors which is a cohort uncaptured by this study. Third, the circumstances of prehospital device placement and patient handling/transport are not well evaluated in our study, but future investigation into this is planned. Lastly, there is the possibility of support lines, tubes, and medical devices being moved or dislodged during transportation, resuscitation efforts, and during the scan acquisition, and therefore, our findings may not accurately reflect device positioning at the time of initial placement. Nevertheless, our study does demonstrate that a significant number of devices are malpositioned. Regardless of how, this is an important finding which should give pause to any provider and prompt them to be curious whether the devices placed are accomplishing their goal.

Conclusions

Malpositioned supportive medical devices are commonly identified on post-mortem computed tomography trauma decedents, seen in 69.0% of the cohort, including nearly one quarter with malpositioned mechanical airways. Post-mortem CT can serve as a useful adjunct in the quality improvement process by providing data for education of trauma and emergency physicians and first responders.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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