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Non-lethal weapon: Injury patterns and imaging correlates for firearm alternatives

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ABSTRACT

Law enforcement officers have adopted the use of non-lethal weapons to mitigate civilian casualties incurred by firearm use over recent years and decades. These weapons include, but are not limited to, TASER, beanbag rifles, pepper spray, tear gas, and Flash-ball guns. Nonetheless, severe injuries and even deaths do occur with use of these weapons, in rare instances. This review aims to comprehensively discuss these cases and associated injuries, as well as their according findings on imaging studies. It will also examine how often injuries occur in situations with non-lethal weapons.

1. Introduction

Law enforcement officers have employed several types of non-lethal weapons in altercations with civilians for decades, which include TASER weapons, pepper spray, tear gas, beanbag-loaded rifles, and Flash-Ball guns. All of these weapons have been manufactured and utilized as relatively safe alternatives to firearms with the specific intent of subduing, rather than killing, individuals. Nonetheless, these weapons have been associated with serious injuries and even death [1]. For example, conducted energy devices (CEDs) appear to be relatively safe when tested on healthy individuals in clinically controlled settings [2–10]. However, CEDs can increase the risk of secondary head injuries from falls [11–13]. Pepper spray-related deaths have even been recorded, but they were usually due to “positional asphyxia, pre-existing health conditions, or drug-related factors.” [14] Despite these rare occurrences, these weapons prove to be non-lethal in most interactions with healthy individuals. To that point, a review of police and medical records for suspects detained with CEDs during a two-year period showed that <1% experienced moderate injuries and only one individual (0.1%) sustained a severe injury [15]. Nevertheless, as previously mentioned, exceptions do occur. Imaging has been used to elucidate the extent of the damage inflicted by these weapons. This review will discuss several cases, focusing on the pattern of injuries associated with various non-lethal weapons, as well as the associated imaging correlates. In particular, this article will more closely examine CEDs and their related complications. Furthermore, we aim to bolster medical knowledge about injuries associated with non-firearm weapons, in order to improve clinical management of these cases.

2. Conducted energy devices (CEDs) - TASER

Conceived in 1960 by an American physicist and commercialized in

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1974, the TASER device was employed by law enforcement with the intent to subdue individuals without causing significant harm. It is used to incapacitate someone with an electrical discharge. The TASER X26 is the most common variant of this non-lethal weapon that is favored by law enforcement due to its small size, making it easy to carry on an officer's person. The TASER uses "compressed nitrogen to propel barbed electrodes, which penetrate light clothing and skin." These electrodes remain attached to the TASER by copper wires, which deliver up to 50,000 V at 19-Hz. This results in extreme discomfort and skeletal muscle tetany, as well as convulsions and other adverse effects, in some cases [16,17]. In fact, many TASER encounters have resulted in visits to emergency rooms and hospitalizations.

2.1. Penetrating Injury

In one case, a 16-year-old male presented to the Emergency Room with a TASER electrode penetrating his right forehead, after resisting arrest. He complained of a mild headache, but was otherwise grossly neurologically intact upon physical examination. The lodged electrode dart was immobile, so the patient underwent computed tomography (CT) of the head, which showed intracranial penetration of the dart and possible perforation of the dura mater. The patient was admitted for surgery, to remove the electrode, which had indeed penetrated the dura and brain parenchyma. Surgeons observed discoloration of the dura, likely resulting from the electric current. The patient had an uneventful post-operative course and was discharged without focal neurologic deficits [18].

An inebriated 27-year-old male, resisting arrest, became incapacitated after law enforcement struck him with a TASER X26. He was allowed to return home, but decided to go to a hospital a few hours later because of a headache. Upon arrival to the Emergency Department, he was conscious. However, examination revealed a barbed electrode in his right frontal skull along with a periorbital bruise. The patient's GCS (Glasgow Come Scale) was 15 and neurological examination was normal. Head x-ray confirmed that the electrode was lodged in the frontal bone. Subsequent CT Head studies revealed that the patient sustained an encephalic injury to the right frontal lobe. More specifically, the injury was localized to the squama frontalis, a smooth convex surface of the lateral right frontal bone. Imaging revealed a squama thickness of 5.6 mm and that the probe had penetrated a few millimeters deeper, through the dura and into the right frontal cortex. The patient was admitted to neurosurgery to remove the probe from the frontal parenchyma, which revealed a "minor hemorrhage at the tip." The patient was eventually discharged without major complications. However, he endorsed persistent, throbbing frontal headaches associated with physical activity and head extension for more than five months after surgery. In addition, the patient endorsed sleep disturbances, anxiety, irritability, and difficulty with concentrating, although these symptoms resolved after a few months [19].

2.2. Cerebrovascular accident

It is especially important to take note of the cases that involve damage to extremely vital organs, such as the brain and heart. As described by *Bell* et al. (2014), the TASER has the ability to reach very high currents, which can induce spasms in vessels along with endothelial lesions. This in turn can serve as a focal point for arterial ischemia and can ultimately lead to catastrophic cerebrovascular accidents and myocardial infarctions [20].

A 32-year-old male presented to the Emergency Department with right-sided weakness, altered mental status, dysarthria, and forehead abrasions after a confrontation with law enforcement officers, who fired a TASER. CT Head revealed an acute, ischemic infarct involving the left MCA (Middle Cerebral Artery) territory with surrounding edema and mass effect. Subsequently, CTA (Computed Tomography Angiography) and MRI/MRA (Magnetic Resonance Imaging/Magnetic Resonance Angiogram) of the head and neck were performed. These studies revealed filling defects in the distal M1 and proximal M2 segments of the MCA, "with restricted diffusion in the MCA territory." EKG, TTE (Transthoracic echocardiogram), and TEE (Trans-esophageal echocardiogram) were all performed to rule out a cardio-embolic etiology, but all studies were negative [20].

2.3. Myocardial infarction

A 20-year-old male presented to the Emergency Department with TASER probes lodged in his posterior upper right thorax following an altercation with police. Thirty minutes after arrival, the patient endorsed burning, retrosternal chest pain, described as "5/10 in intensity," along with associated dyspnea. His symptoms resolved after receiving aspirin and nitroglycerin. EKG showed ST segment elevation in the inferior leads and troponin levels were elevated, consistent with evolution of an acute, inferior wall infarct. The patient was admitted for emergent coronary angiography, which revealed patent coronary arteries that were "angiographically normal." Finally, left ventriculography showed "hypokinesis of the distal inferior wall, with an ejection fraction of 60%." The remainder of the patient's admission was unremarkable, except for some instances of elevated blood pressure. The patient was discharged with aspirin, an ACE inhibitor, a statin, and a beta-blocker [21].

2.4. Limb injuries

An 18-year-old male presented to the Emergency Department with a finger injury following an attempt to evade French law enforcement. In order to detain the subject, an officer discharged a TASER, penetrating the middle phalanx of his left index finger. Physical examination revealed no sensory or motor deficits in the left upper extremity. AP (anterior & posterior) and lateral radiographs confirmed penetration of the dart at the base of the left middle phalanx. Physical examination revealed that active flexion of the distal phalanx was compromised. Surgery was performed to remove the dart and address the injuries. The patient was given a course of antibiotics after surgery and discharged. On post-operative day 15, the patient was re-evaluated and found to have recovered all range of motion, with no motor or sensory deficits [22].

2.5. Vertebral compression fractures

A 38-year-old law enforcement officer was participating in CED-use training when he volunteered to be shocked in the shoulder and hip. Following this incident, he experienced persistent, severe, thoracic muscle spasms, so he went to the Emergency Room for medical evaluation. Physical examination revealed diffuse tenderness over the thoracic spine, but no point tenderness. Thoracic and lumbar x-rays showed compression fractures at T6 and T8 (with "30% loss of vertebral body stature") and anterior wedging at L2. CT imaging confirmed these findings along with several posterior disc bulges of the lumbar spine. The patient endorsed no risk factors for pathological fracture. He was admitted to the hospital for fitting of a Jewett hyperextension orthosis for comfort and was discharged the next day. At a 9-week follow-up, he was still experiencing significant pain and was not able ambulate properly [23].

A 23-year-old employee at the Department of Corrections volunteered as a test subject for a CED demonstration. TASER leads were placed on his right shoulder and ankle and the device was discharged. The patient began complaining of muscle contractions in his bilateral flanks along with severe mid-back pain. He then presented to the Emergency Department for medical evaluation. On physical examination, he appeared in severe distress with elevated blood pressure of 168/100. The patient had diffuse thoracic midline and bilateral paravertebral tenderness, as well as limited range of motion due to the pain. CT Chest with contrast showed acute compression fractures of the "superior endplates of the sixth, seventh, and eighth thoracic vertebrae without retropulsion of any of the spinal fragments." He was transferred to a Level I trauma center where a neurosurgeon consulted on the case. Ultimately, non-operative management was pursued, using a thoraco-lumbar-sacral orthosis device, physical therapy, and pain medication. After five days, the patient was discharged with a plan for outpatient follow-up [24].

3. Tear gas

Tear gas contains chemicals such as oleoresin capsicum (OC), *ortho*-chlorobenzylidene malononitrile (CS), or chloro-acetophenone (CN), which induce acute irritation of mucus membranes, leading to irritation of the eyes, rhinorrhea, skin inflammation, and respiratory distress. It is used by law enforcement to quell riots and can be fired in the form of canisters from tear gas guns. In addition to the aforementioned chemical effects, tear gas capsules can cause blunt force trauma, if fired incorrectly. [25]

3.1. Multisystem hypersensitivity reaction

An incarcerated 30-year-old man presented to the Emergency Department with moderate respiratory distress, eight days after an altercation with prison guards, who sprayed the individual with tear gas. On physical exam, diffuse bilateral rhonchi were auscultated and bilateral conjunctival injection and icterus were present. The patient's abdominal exam was also significant for guarding. Chest x-ray showed "inhomogeneous ground glass and linear opacities in the left lower lobe and lingula, as well as increased reticulonodular markings in the right base." Abdominal ultrasound was unremarkable.

The patient was diagnosed with "bronchoconstriction and pneumonitis" secondary to a tear gas-mediated hypersensitivity reaction. A repeat chest x-ray showed improvement four days after the first radiograph. The patient was discharged with prednisone; however, after he finished his course, his dyspnea and cough recurred, so he returned to the Emergency Department. He was subsequently admitted to the ICU for severe asthma exacerbation. He also complained of severe pruritis. After improvement of his symptoms, he was again discharged and followed up after six months in the outpatient setting. Results of allergy skin testing showed "marked sensitization to CS," the chemical ultimately determined to be the culprit of his illness [26].

3.2. Maxillofacial trauma

Three men (32, 38, and 41 years of age) all presented to the hospital with gun shot wounds sustained in the Syrian Civil War. All three men had irregular maxillofacial wounds, including ecchymoses ranging from 2 to 4 cm in diameter. The 32 and 41-year-old both had unremarkable brain CT scans. CT scans of the maxillofacial region in the 32-year-old showed "severe soft tissue damage" and multiple fractures with a foreign body lodged inside, which was deemed to be a tear gas capsule fragment. He underwent reconstructive surgery and was ultimately discharged. Maxillofacial CT of the 41-year-old was essentially the same as that of the 32 year old. Unfortunately, he developed septic shock and died on his 10th day of admission. The 38-year-old man deteriorated into cardiopulmonary arrest and was intubated after successful CPR and ROSC (Return of Spontaneous Circulation). Brain CT was performed, which showed "a foreign body in the deep maxillofacial region." Unfortunately, the patient's condition continued to deteriorate into cardiac arrest, again, and he ultimately expired despite ACLS (Advanced Cardiac Life Support) measures [25].

4. Flash-ball

The Flash-Ball is an alternative, non-lethal weapon that fires large rubber balls, rubber bullets, rubber buckshot, and pellets containing "coloring or irritating chemicals." These projectiles fire with up to 200 J of kinetic energy. In comparison, a major league fast ball reaches up to 50 J [27,28]. Although the gun is not designed to penetrate skin, it can cause significant damage to it, as well as severely damage internal organs, rarely. For this reason, it is not surprising that the use of flash-ball is the ultimate step before the use of deadly force [29].

4.1. Soft tissue contusions

A 22-year-old man presented to the Emergency Department with multiple bruises after losing consciousness during a political demonstration, where riot police fired rubber bullets. Physical examination revealed ten contusions on the abdominal wall and thighs. CT Abdomen, EKG, and labs were unremarkable. The patient rejected analgesic treatment and was discharged [28].

4.2. Cardiac and pulmonary contusions

A 25-year-old man was mutilating himself with a knife when police subdued him, using a Flash-Ball gun. Upon arrival to the Emergency Department, he complained of severe lower thoracic pain. The patient was mildly hypoxic with oxygen saturation of 91% and his chest x-ray was unremarkable. CT of the head, neck, and chest revealed a pulmonary contusion. Although an EKG was unremarkable, troponin was slightly elevated, indicative of cardiac contusion, as well. The patient's cardiac enzymes and blood gases normalized over the day and he was discharged the following morning with analgesics [28].

4.3. Craniocerebral trauma

A 34-year-old man in France presented to the Emergency Department with a severe left-sided headache after being shot in the side of the head by police using a Flash-ball gun at a riot. The patient endorsed a loss of consciousness immediately after being shot. He was admitted to the hospital under the care of neurosurgery. Physical examination demonstrated a large left frontotemporal hematoma with a "severe contusion mark 60 mm in diameter with an abrased ring 10 mm wide." CT Head confirmed the hematoma, as well as a left temporal bone fracture extending towards the left temporomandibular joint. Imaging also showed "a moderate cerebral edema" and "a pneumocephalus associated with a left fronto-temporal hemorrhagic contusion accompanied by extra-axial and subarachnoid hemorrhage." [29] The right side of the head was unremarkable. The patient's hospital course was non-operative, primarily consisting of rehabilitation. One week after admission, the patient had a generalized tonic-clonic seizure, which was treated with Levetiracetam. After two months, the patient had sustained significant complications, including circular alopecia scarring in the frontotemporal area, left destructive vestibular syndrome, and subjective syndrome of brain injury (a neuropsychological disorder). He also experienced dysarthria and right-handed weakness secondary to left motor cortex damage [29].

CT Head imaging is the standard of care in such cases of craniocerebral trauma, in order to rapidly and efficiently evaluate for soft tissue and bone damage, as shown in another case involving globe rupture and orbital bone fracture secondary to a rubber bullet injury (Fig. 1).

5. Beanbag

A shotgun is typically used to fire a beanbag – a synthetic bag that contains 40 g of lead pellets. It is similar to the Flash-ball gun and it is designed to inflict painful, superficial injuries [30]. It is recommended for an individual to stand 3 to 10 m away from his or her intended target when firing this weapon, which can discharge projectiles up to 90 m/s. In 2004, the National Institute of Justice reviewed 373 injuries caused by "less lethal weapons." Among the less lethal munitions, the beanbag

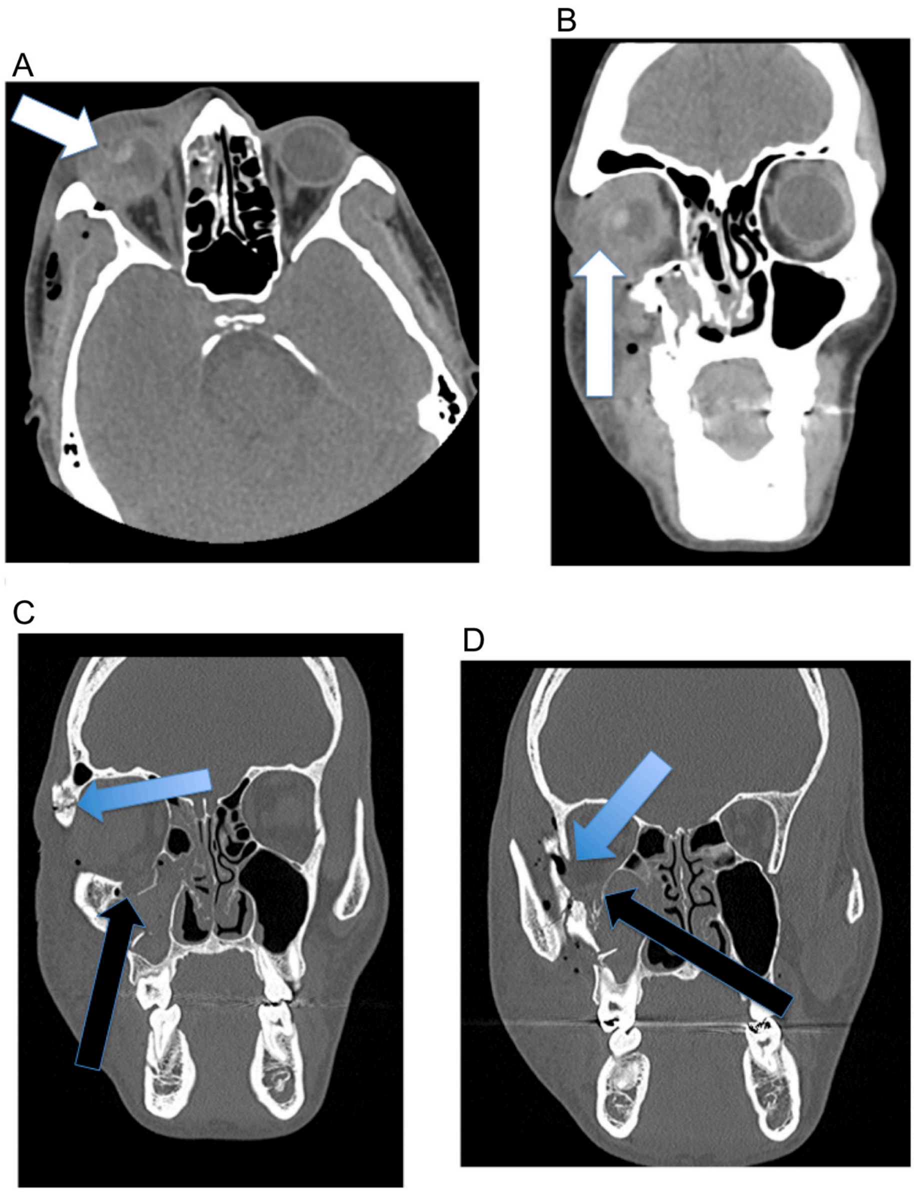

Fig. 1. A (axial), 1B, 1C, 1D (coronal) show the non-contrast CT Maxillofacial of a 35-year-old male who shot in the right eye by law enforcement with a rubber bullet. Imaging reveals, rupture of the right globe (white), right orbital floor fracture extending to the orbital rim (black), and right zygomaticomaxillary complex comminuted fracture (blue) [33]. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

was most commonly used and was responsible for 65% of injuries. This same study noted eight beanbag-related deaths, mostly due to thoracic injury, with one death caused by a penetrating neck wound [31].

As discussed in the following sections, beanbags can become embedded in the body, in rare instances. Two examples include an individual involved in an altercation with law enforcement, with an embedded beanbag in the left elbow on x-ray (Fig. 2) and another individual who sustained cranial fractures and pneumocephalus secondary to a beanbag rifle while resisting arrest (Fig. 3).

6. Penetrating thoracoabdominal injury

A 46-year-old male presented to the Emergency Department with severe right-sided chest pain and dyspnea after an altercation with the police. After verbal resolution failed, the police shot the individual in the chest with a beanbag. On physical exam, the patient was tachypneic and there was a 3.0 × 3.5 cm entry wound on the right parasternal border. A chest x-ray showed a right hemopneumothorax and a radiopaque foreign body. The patient underwent a right thoracotomy, which revealed a beanbag pellet in the right lung with a surrounding hematoma of the middle lung. The foreign body was extracted and the surrounding area was irrigated and debrided. The patient's postoperative course was uneventful and he was discharged after five days [30].

Police escorted another male of unknown age to an Emergency Department after an altercation. Law enforcement had shot him twice with a TASER and once in the left lateral chest with a beanbag, from approximately 6 ft away. The patient's blood pressure was elevated at 159/99 mmHg and he was tachycardic at 106 bpm (beats per minute). Physical examination showed a 2 cm wound of the chest wall anterior and medial to the left axilla with crepitus. The patient was admitted for cardiac evaluation and possible surgery. CT Chest with contrast revealed a 3.6 × 1.4 cm foreign body bordering the pericardium with a small left pulmonary contusion. Imaging also showed a left apical pneumothorax and hemothorax. The patient underwent surgery to remove the beanbag. There were no postoperative complications [32].

CT Thorax or Abdomen are first-line diagnostic modalities in

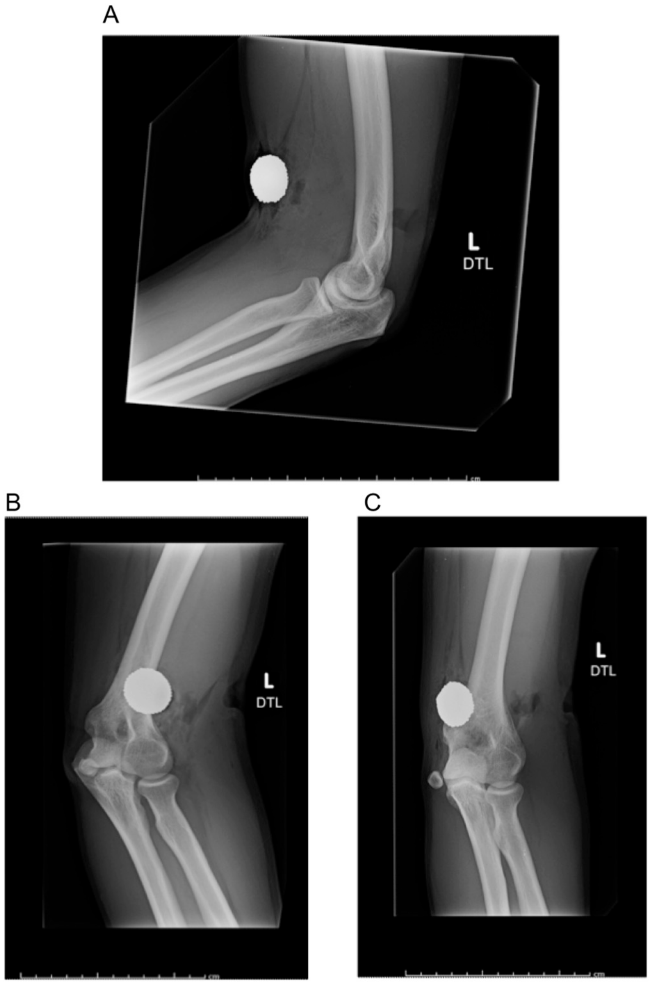

Fig. 2. A (lateral), 2B (oblique), and 2C (AP) show the complete left elbow x-ray of a 27-year-old male presenting after an altercation with law enforcement. A 3.0 × 2.3 cm lobular well circumscribed metallic density is visualized. Additionally, a 2.1 cm skin laceration with soft tissue swelling and subcutaneous emphysema in the lateral soft tissues at the level of the distal humerus reveals the entry wound.

evaluating for penetrating body injuries, such as in the case of a 50-year-old male involved in an altercation with law enforcement, who sustained pulmonary injuries due to a beanbag (Fig. 4).

De Brito et al. (2001) discuss several cases of anterior injuries to patients by law enforcement using beanbag weapons. One such case involves a 45-year-old man who was struck in the right chest with a beanbag. Physical examination revealed a 4 cm laceration just below the right nipple. CT Chest showed a large pulmonary contusion with the beanbag lodged in the right posterior chest cavity. He underwent surgery, which revealed that the beanbag had ruptured into approximately 100 pieces, requiring removal from the pleural cavity. Another case involves a 32-year-old male who was struck by a beanbag in the right upper quadrant and genitals. CT Abdomen/Pelvis revealed a subcapsular hematoma of his left liver lobe and contrast extravasation within the scrotum. The patient sustained right testicular hemorrhage and fracture, requiring surgical removal [27].

Of note, penetrating injuries often require CT Angiography to assess the patency of vasculature, to rule out traumatic hemorrhage or occlusion of vessels, such as in compartment syndrome (Fig. 5).

6.1. Penetrating ocular trauma

Another patient of unknown age, involved in an altercation during civil unrest, presented to the Emergency Department after being shot in the eye with a beanbag. He endorsed right facial pain and vision loss. A head CT showed a "3 cm hyperintense mass" in the nasopharynx "lodged against the anterior skull base." Due to the proximity of the object to the cavernous carotid artery, an angiogram was performed, which showed no damage to the arterial system. The patient was admitted for surgery to extract the foreign body. Complications included a tattered right eyelid, which was ultimately not viable [31].

While the TASER uses electromagnetic energy, the Flash-ball and beanbag deliver kinetic energy. As such, the resulting injury profiles can be quite different. In some cases, the TASER can cause thromboembolic and vasospastic ischemic events due to the electric current it generates. In contrast, the Flash-ball and beanbag inflict more blunt trauma due to fired projectiles. Therefore, it is logical that weapons predicated on kinetic energy have caused more serious structural injuries, such as various types of contusions and fractured bones. Cranio-cerebral blunt trauma secondary to a Flash-ball weapon (discussed above) produced a fracture and devastating, lasting neurological side effects that the patient endured well beyond the hospital stay. If they strike a precise location, kinetic energy-driven weapons can potentially be fatal, as demonstrated by a case of *commotio cordis*-related death after chest trauma from a Flash-ball gun, in an otherwise healthy middle-aged male [29]. *Commotio cordis* describes a fatal ventricular fibrillation secondary to blunt force trauma to the anterior precordium directly overlying the heart, at a specific time of the cardiac cycle (i.e. early T wave) [32].

6.2. Subject resistance and police use of force (UOF)

Aforementioned cases describe different types of injuries using non-lethal weaponry that usually involved altercations with law enforcement (Table 1). It is also relevant to discus how often officers use particular types of weapons, as well as the frequency of significant injuries.

Mesloh et al. (2008) analyzed information from two law enforcement agencies in Florida over a five-year period (2000–2005). During this time period, there were 4303 "first altercations" with suspects where law enforcement pursued a particular UOF before escalating or deescalating UOF ("second altercation"). 2775 of these encounters involved aforementioned modalities (i.e. CED, tear gas, and beanbag), as well as non-physical (i.e. verbal) intervention. 49.11% of this cohort involved use of CED, 11.88% involved use of chemical agents (i.e. tear gas and pepper spray), 3.35% involved use of verbal intervention, and 0.16% involved use of beanbag [33]. (Table 2).

Bozeman et al. (2018) examined three-midsized police agencies over two years and concluded that police UOF rarely results in significant injuries. Out of 914 suspects, 898 (98.2%) did not experience significant injury from UOF. Moderate to severe injuries, most of which were associated with canines and firearm use, occurred in the remaining 16 suspects (1.8%). In this study, use of CED caused no significant injuries [34].

7. Discussion

Over several decades, law enforcement has used non-lethal weapons to subdue individuals, in order to reduce mortality and morbidity in altercations with the public. Most altercations result in minimal injury. *Ordog* et al. (1987) compared CED injuries by the police to firearm injuries by police using 0.38 Smith & Wesson Special handguns. The authors reviewed 218 patients who were shot by TASER and 22 who were shot by the 0.38 Special. The long-term morbidity of the TASER cohort was 0% compared to 50% ($p < 0.05$) in the 0.38 Special group. Therefore, TASERs appear to be relatively safe in terms of potential morbidities when compared to conventional firearms [35]. This same conclusion for other non-lethal weapon is supported by the aforementioned study by *Bozeman* et al. [34] Thus, these aforementioned weapons provide effective and safer alternatives than firearms for law enforcement.

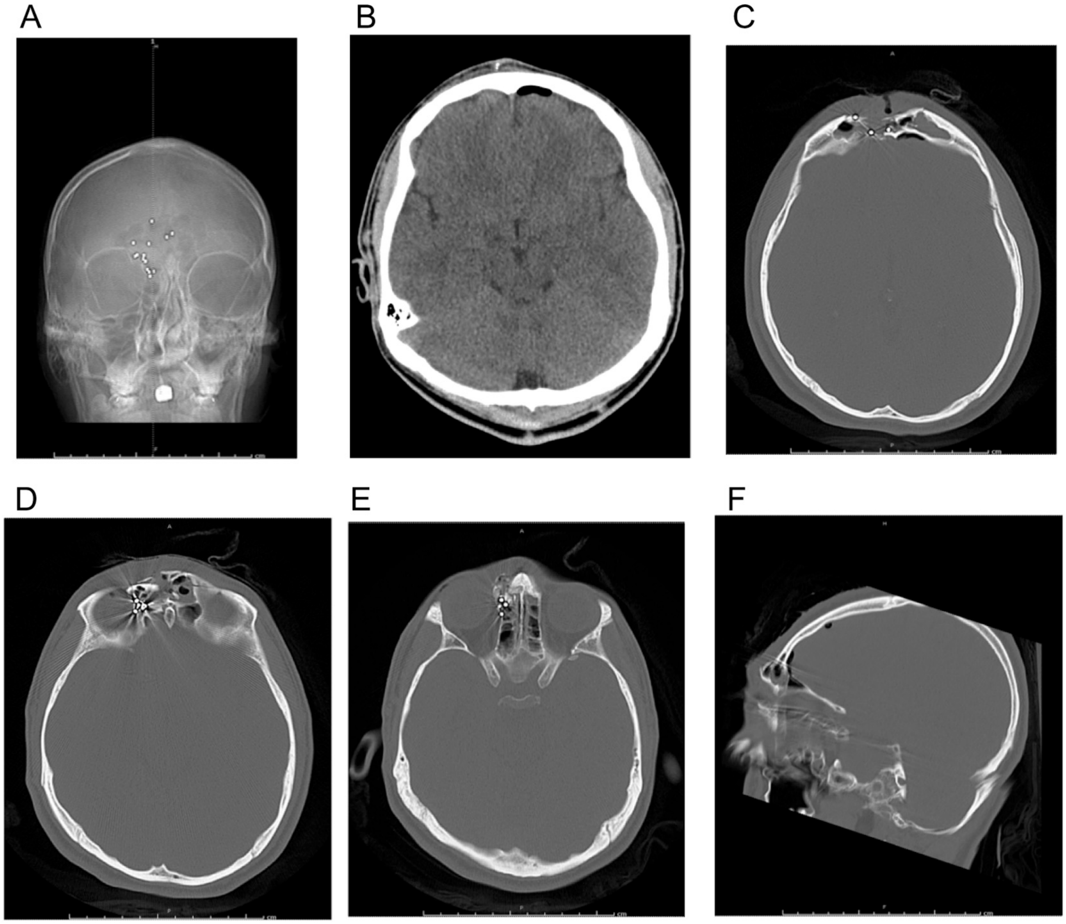

Fig. 3. A (coronal), 3B, 3C, 3D, 3E (axial), and 3F (sagittal) show the CT Head without contrast of a 21 year-old-male who was evading the police and shot in the head with a beanbag. Finding shows comminuted frontal calvarial fractures with metallic fragments extending into the right and left orbits, as well as lamina papyracea and bilateral nasal bones. Small pockets of pneumocephalus are also visible.

However, this does not negate the fact that non-lethal weapons can indeed cause moderate or severe injuries in some instances, such as with previously discussed cases of CED-triggered vertebral fractures or fatal injuries associated with tear gas canisters. *Tyagi* et al. (2017) state there have only been two reported cases of vertebral fractures secondary to CED use over a ten-year period [24]. Interestingly, in both aforementioned cases, each volunteer had two leads: one on the shoulder and another on the lower half of the body [24]. Theoretically, this balanced placement across the spine could have stimulated the paraspinal muscles enough to elicit a contraction intense enough to cause compression fractures, even in patients that are not at risk of pathologic fractures (i.e. osteoporotic patients).

Although the only two fatalities discussed in prior cases both occurred with tear gas, these injuries were sustained in the Syrian Civil War. As such, it's possible they did not receive the standard of care patients in the other cases received. One of the patients succumbed to septic shock, an indirect outcome. Additionally, both patients had already sustained gunshot wounds, so it's likely firearms contributed significantly to their deaths (e.g. via hemorrhagic or hypovolemic shock). Thus, these cases are statistical outliers and not representative of the most likely outcomes with non-lethal weapons.

It can be difficult to ascertain the extent of non-lethal weapon injuries by clinical examination alone, as physical damage is often not externally visible. Thus, imaging is invaluable in diagnosing inconspicuous, yet significant injuries, which could otherwise remain undetected on clinical examination, such as electrical damage to the superficial brain parenchyma by TASER. Moreover, imaging is pivotal in dictating medical decision-making, as well. For example, in an aforementioned case of a suspect who presented with a beanbag lodged in his nasopharynx, an angiogram was performed to rule out an arterial bleed. A positive study would have required an immediate embolization; however, since the angiogram was negative, the patient was admitted to surgery for removal of the foreign body. Therefore, appropriate use of imaging facilitates timely recognition, diagnosis, and treatment of life-threatening injuries.

8. Conclusion

Non-lethal weapons rarely cause significant injuries; however, exceptions do occur and changes can still be implemented to improve outcomes. For example, officers using kinetic-energy devices (e.g. beanbag and flash ball weapons), as well as TASERs, could aim to avoid vital organs (e.g. brain, heart, and lungs), if possible, which portend more severe injuries and potential surgeries. Aiming for the abdomen or extremities would likely result in less severe injuries and outcomes.

Moreover, certain modalities appear to be more effective in resolving altercations than others. *Mesloh* et al. found that 69.1% of CED encounters were resolved (30.9% of CED cases required additional interventions), 64.4% of chemical agent encounters were resolved, 0.7% of verbal encounters were resolved, and 28.6% of beanbag encounters were resolved. Therefore, an officer might consider using a TASER instead of a beanbag rifle in certain situations, as it appears to be 40.5% more effective in resolving altercations [33].

However, research on injuries due to non-lethal UOF is limited and requires further investigation [36]. Future studies should accrue more clinical data and imaging correlates in order to better understand the

Fig. 4. A (axial) and 4B (coronal) show CT thorax w/ contrast of a 50-year-old male with history of schizophrenia brought in by the police after he was found swinging large pipes in public. After law enforcement attempted verbal resolution, police shot five beanbags at his torso. Imaging reveals right middle lobe pulmonary laceration and contusion (white arrow), as well as a small right pneumothorax (black arrow).

extent of harm and injury patterns non-lethal weapons can cause, which will in turn decrease the necessity for firearms. Imaging provides a crucial link between sustained injuries and injury patterns, in order to more effectively evaluate and manage such patients upon initial presentation. Additionally, radiology studies can guide which areas of the body law enforcement targets and avoids, as well as which non-lethal weapons are employed, in order to effectively and safely subdue suspects in various situations.

Author contributions

NSM conducted the case literature review and drafted the manuscript, with support from AG, who conceived the concept. DS contributed to the case literature review and revised the manuscript. MS collaborated in conceiving the concept and contributed to the case literature review. AG also provided feedback, guidance, and supervised.

IRB

N/A

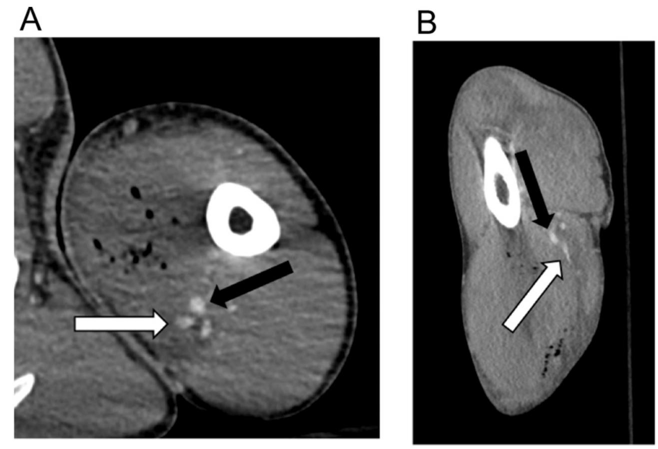

Fig. 5. CT Angiography left upper extremity (A, axial, and B, sagittal) for a 31-year-old male, who was shot in the arm with a beanbag by police, as well as bitten on the right thigh by a police dog. The beanbag remained lodged in the arm and was removed on the scene, revealing arterial injury and requiring hemostasis. The patient was also diagnosed with compartment syndrome in the Emergency Department. Soft tissue laceration and a left brachial sheath hematoma with active extravasation (white arrow) at the upper antecubital fossa with associated subcutaneous gas are visualized. The black arrow points the brachial artery.

Table 1
Law enforcement UOF modality and type of injuries

UOF modality	Injuries inflicted (x Number of cases)
Conducted Energy Devices (CED)	Intracranial Dart Penetration (x2), Cerebrovascular Accident (x1), Myocardial Infarction (x1), Left Middle Phalanx Penetration (x1), Vertebral Compression Fracture (x1)
Tear Gas	Hypersensitivity Reaction (x1), Maxillofacial Capsular Penetration (x3)
Flash Ball	Abdominal and Thigh Contusions (x1), Cardiac and Pulmonary Contusions (x1), Left Sided Hematoma & Temporal Bone Fracture (x1)
Bean Bag	Hemopneumothorax (x2), Pulmonary Contusions (x2), Subscapular Injury of Liver & Scrotal Hemorrhage (x1), Penetrating Ocular Trauma (x1)

Table 2
Florida police department UOF modalities for “first altercation incidents” adapted from *Mesloh* et al. (2008).

UOF modality	Incidents	Percent
Bean bag	7	0.16%
CED	2113	49.11%
Tear gas & pepper spray	511	11.88%
Non-Physical (i.e. verbal intervention)	144	3.35%

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Declaration of competing interest

None.

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