Guns and Daggers: A Pictorial Review of the Imaging Features and The Management of Penetrating Thoracic Injury Presenting to a Level 1 Trauma Centre.

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Objectives

Thoracic injuries are responsible for up to 25% of deaths due to trauma and there is an increasing prevalence of penetrating chest injuries associated with knife and gun-crime. Thoracic penetrating injuries tend to be associated with significant morbidity and mortality rates due to the vital vascular structures housed within the thoracic cavity. Although the majority of penetrating chest trauma seen in our level 1 trauma centre is the result of knife stabbings or gunshot wounds, industrial accidents and sporting activities are also contributory.

Our aim is to provide a pictorial review of the broad spectrum of injuries sustained in patients with penetrating thoracic trauma and emphasize the value of multidetector computed tomography (MDCT) in the initial assessment of such injuries using optimal CT protocols and techniques.
Materials and Methods

The images used to illustrate our pictorial review are of patients presenting to our Level 1 trauma centre with penetrating thoracic injuries, the majority of which were secondary to stabbings and gunshot wounds.

All patients were scanned either with a split bolus iv contrast protocol or arterial phase imaging with MDCT (750 Gemstone GE scanner). Multiplanar reformats were performed in all cases.

Trauma to the chest usually involves multiple organ systems and different anatomic sites. For the sake of simplicity, we have divided our images under the following injury categories: chest wall, pleural cavity, lung and airway, mediastinum and diaphragmatic injuries.
Results

Chest Wall Injuries

Isolated chest wall injuries (eg rib fractures, sternal fractures etc) are much less common in penetrating trauma than in blunt trauma and there will usually be other underlying intra-thoracic injuries such as pneumothorax or haemothorax. Structures at risk include intercostal and internal mammary vessels. As with all penetrating injuries, contrast enhanced CT (CECT) plays a vital role in assessing vascular integrity at the site of the injury. Internal mammary artery injuries in particular can frequently be missed and can be a 'occult' cause of exsanguination. If there is arterial involvement with ongoing bleeding, then operative intervention may be required. Otherwise, isolated chest wall injuries are usually managed conservatively.

Figures 1-4 illustrate a 15 year old patient who presented following a javelin injury to the chest wall in sports class. In this case, this was an isolated injury and CECT with multiplanar reformats was used to look for underlying vascular injury and to delineate the trajectory of the javelin for surgical planning. The patient was very fortunate that none of the major intra-thoracic structures were injured; the foreign body was removed in theatre and a thorough wound wash-out was performed. The patient was discharged from hospital within 48 hours.

Pleural Cavity Injuries

Pleural cavity injuries include pneumo/haemothoraces and pneumo- and haemomediastinum.

A pleural effusion presenting after penetrating trauma is usually due to a haemothorax. Haemothorax in penetrating trauma may result from an injury to the visceral or parietal pleural, injury to intercostal or internal mammary arteries or direct laceration of the lung parenchyma. CT attenuation values of hemathorax tend to have a density of 35-70 HU. Active haemorrhage into the pleural space may be seen as high density extravasated contrast agent within the pleural cavity. The significant difference in the attenuation value extravasated contrast material (Range 85-350 HU) and haematoma (40-70 HU) is helpful in determining active bleeding from clotted blood.

Chylothorax resulting from interruption of the thoracic duct is another aetiology that should be considered in the setting of penetrating trauma. The common site of injury is within the superior mediastinum at the junction of the thoracic duct and the left subclavian
vein. The injury is suggested following injury to this region and low or negative pleural fluid attenuation values.

Pneumothorax occurs commonly after penetrating chest trauma with air entering and collecting within the pleural space from outside the chest, or from a leak in a damaged proximal or distal airway. Compared with radiography, CT is much more sensitive in detecting pneumothoraces. Its main advantage, however, is in aiding assessment of major airway injuries and in evaluating correct positioning of chest tubes.

Pneumomediastinum in penetrating trauma may occur as a result of tracheal or oesophageal rupture (less than 1% of cases of penetrating trauma) and secondary to penetrating injuries of the deep fascial planes of the neck. Furthermore, air in the mediastinum may rupture the mediastinal parietal pleural resulting in an associated pneumothorax.

Figures 5-6 Demonstrate imaging findings in a patient following a stabbing injury to the left chest. Note the left pneumothorax, pneumomediastinum and haemothorax. Active bleeding is evident from the left internal mammary artery identified on the arterial phase CECT as pooling of high density contrast (Fig 6). At surgery the patient was found to have a laceration to the left ventricle and injuries from concomitant abdominal stab wounds resulted in a jejunal perforation and a psoas haematoma. He was taken to theatre for combined cardiothoracic and abdominal surgical repair.

Figure 7 demonstrates imaging findings from another stabbing patient with active bleeding into a left-sided haemothorax evidenced by layering of high density within the left chest. In this case, the exact point of bleeding was not visualised on CECT but was found at surgery to be from an intercostal artery.

Lung and Airway Injuries

Pulmonary lacerations and tracheo-bronchial injuries are usually found in association with pleural cavity injuries. CT is a valuable tool in assessing the extent of the pulmonary injuries. Tracheobronchial injuries should be suspected in all patients with penetrating wounds to the neck or chest. Penetrating trauma generally involves the anterior aspect of the cervical trachea (75-80% of cases). Soft tissue and mediastinal emphysema usually results which is extensive and progressive and not relieved by chest tube placement.

In large airway injuries MDCT may demonstrate the extent of surgical emphysema and correct line placement. It may also pinpoint the exact point of the injury (Figures 16-17). This 44 year old man was stabbed in the neck and the wound tract and degree of
surgical emphysema combined with the irregularity of the tracheal wall strongly indicated a tracheal laceration which was confirmed on bronchoscopy.

Bronchial wall tears can be more difficult to diagnose radiologically.

Pneumothorax is more likely to be seen in distal bronchial tears than tracheal injuries and may result in persistent pneumothorax (despite adequately sited chest drains, due to the major air leak) and distal atelectasis from obstruction of a ruptured bronchus.

Pulmonary lacerations occur following a disruption of the alveolar spaces with subsequent formation of a cavity which fills with blood or air. They are often ovoid or elliptical in shape and surrounded by pulmonary contusion which in the early stages post trauma may mask the laceration. They may communicate with the visceral pleural and result in the presence of a pneumothorax.

Figures 8, 9, 13, 14 and Figure 27 all demonstrate pulmonary lacerations secondary to stabbing and gun shot wounds.

**Mediastinum**

Transmediastinal wounds are associated with great potential for injury to vital structures including the heart and great vessels. These are once again usually associated with other intra-thoracic injuries. The right atrium and right ventricle are the most commonly injured chambers of the heart as they lie anteriorly and myocardial rupture is the most rapidly fatal cardiac injury. Radiology plays a limited role in diagnosis of penetrating injuries to the heart, given the high mortality rate (70-80%) and often urgent need for surgical intervention. However, newer scanners now tend to be associated with minimal misregistration and motion artefacts and can help raise suspicion of injuries which are not immediately obvious at presentation.

Penetrating wounds to the chest which penetrate the lungs may be associated with 'occult' major vessel and cardiac injuries, such as the pneumomediastinum secondary to a right ventricular laceration seen in Figure 5 or the mediastinal haematoma secondary to a thoracic gunshot injury in Figure 10. Great care must be taken in looking for these often subtle secondary signs of injury in these cases.

On another note, it is important to note that care of penetrating thoracic injuries nowadays frequently involves 'damage control' procedures at the time of presentation (the so-called 'resuscitative' thoracotomy). This is usually utilised in peri-arrest patients or in patients who are already in cardiac arrest. Chest tube output can be an indicator for the need for
A thoracotomy with an immediate output of 1.5L of blood or a steady output of 250mls/hour indicating the need for resuscitative thoracotomy. It is important for the radiologist to be aware if such procedures have been performed prior to imaging.

**Diaphragmatic Rupture**

Traumatic diaphragmatic rupture is due to penetrating trauma in approximately 30-35% of cases. The majority (>90%) will have other associated injuries and patients with penetrating injuries to the thoracoabdominal region or radiographic evidence of a wound trajectory in close proximity to the diaphragm are at significant risk of diaphragmatic injury. Few fatalities are directly associated with the diaphragmatic rupture itself and fatalities are usually as a result of the concomitant injuries.

In penetrating trauma the laceration to the diaphragm may be small and hence CT findings may be very subtle. Diagnostic signs of diaphragmatic injury include the CT "collar sign" (constriction of a hernating viscus at the site of defect) or the presence of direct injuries on either side of the diaphragm following a single penetrating injury.

More subtle signs include focal irregularity or thickening of the contour of the diaphragm as a result of haematoma, or haematoma or stranding of the adjacent fat. Use of multiplanar reformats is essential in evaluating diaphragmatic injury. Magnetic resonance imaging optimally demonstrates the diaphragmatic collar and herniation, but, for practical purposes, is best confined to confirming a suspected rupture in a clinically stable patient and is not utilised in an acute setting.

Figures 18-22 and Figures 26-27 demonstrate patients with gunshot wounds to the upper abdomen associated with intra-thoracic injuries. In all cases the diaphragm had been breached. One patient (Fig 26 & 27) had conservative management of a liver laceration and diaphragmatic injury whilst the other two had surgical diaphragmatic repair.
Fig. 1: Admission CXR: 15 year old boy with javelin injury to the chest wall

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Fig. 2: Sagittal reformats through the thorax demonstrate the javelin traversing the space between the 1st rib and clavicle. There was no involvement of the left subclavian artery or vein.

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Fig. 3: Sagittal reformat on mediastinal windows of the javelin injury through the chest
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Fig. 4: 3D Reconstruction of the previously demonstrated javelin injury to the upper chest wall

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**Fig. 5:** 26yr old male stabbing to the left side of the chest. Axial CT demonstrates soft tissue disruption at the site of stabbing (red arrow). Left pneumothorax (blue arrow) And pneumo-mediastinum(yellow arrow). Note surgical emphysema tracking through the left chest wall.

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Fig. 6: 26 year old male with stabbing injury to the left 5th intercostal space. Axial CT demonstrates active contrast extravasation from the left internal mammary artery (red arrow). Note the left haemothorax with active bleeding demonstrated as a blush of high density contrast material within the pleural space.

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**Fig. 7:** CT of the lower chest showing a large, mixed density, left haemothorax in another stabbing victim.

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Fig. 8: Patient with multiple chest and abdominal stab wounds. Axial CT on lung windows demonstrates a small left pneumothorax and a left upper lobe laceration.

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Fig. 9: Axial CT images on lung windows. The patient presented with gunshot wounds to the chest and abdomen. There is a pulmonary laceration on the right (red arrow). Bilateral thoracostomy tubes are in-situ.

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Fig. 10: Mediastinal haematoma in a patient with a gunshot wound to the posterior chest.

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**Fig. 11:** Patient with multiple gunshot wounds to the posterior chest (same patient as in figure 10). Axial CT images on bony windows show multiple bullet fragments within the chest, notably within the mediastinum adjacent to the aorta, anterior to the right pulmonary artery and within the thoracic spinal canal. Note the associated thoracic spine fractures.

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Fig. 12: Coronal reformats of the patient with multiple gunshot wounds to the chest demonstrate that there is associated hepatic injury with a right subphrenic haematoma, elevation of the right hemidiaphragm and associated right lower lobe collapse.

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**Fig. 13:** Patient with a stabbing injury to the right posterior chest wall. Axial CT image through the lower thorax on lung windows. demonstrates a right pneumothorax and pulmonary laceration.

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Fig. 14: Coronal reformats of the right chest wall stabbing victim with right pneumothorax and pulmonary laceration.

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**Fig. 15:** Sagittal upper abdominal reformats of the patient with the right posterior chest wall stabbing wound (Figures 13 & 14) demonstrate an associated hepatic laceration at the dome of the liver (segment 7-red arrow).

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Fig. 16: 44 year old man stabbed to the right side of the neck. Axial CT (lung windows) through the neck shows extensive surgical emphysema and a focal mural thickening with a defect in the trachea at the 11'o'clock position. Bronchoscopy confirmed a laceration of the trachea.

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**Fig. 17:** 44 year old man with tracheal laceration-Axial CT images on mediastinal windows.

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**Fig. 18:** Patient presented with a gunshot wound to the right upper quadrant with no exit wound identified on examination. Coronal CT images through the abdomen demonstrates a liver laceration extending from the porta to the dome of the liver (red arrow). Figure 19 shows the bullet lodged within the sternum.

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Fig. 19: Patient with gunshot wound to the right upper quadrant which has traversed the liver into the thorax; the bullet is lodged in sternum (red arrow).

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**Fig. 20:** Scout image of the gun shot victim from Figures 18 and 19 demonstrates the bullet lodged in the sternum and also shows a second bullet in the left lower quadrant of the abdomen.

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Fig. 21: Splenic laceration secondary to a gunshot wound to the left upper quadrant. Bullet trajectory extends though the spleen into the lower left chest.

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**Fig. 22:** Patient with gunshot wound to be the left upper quadrant with the bullet traversing the diaphragm and resulting in a left haemothorax (red arrow).

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**Fig. 23:** Patient presenting with multiple stab wounds to the chest and abdomen. Axial CT on mediastinal windows shows the right haemothorax. A hepatic laceration is just visible as a low density at the posterior aspect of the liver.

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Fig. 24: Patient with multiple stab wounds to the chest and abdomen (as in Figure 23). Sagittal reformats better demonstrate the right haemothorax and underlying hepatic laceration (grade 3). The patient had an associated right diaphragmatic laceration with no herniation.

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Fig. 25: Axial CT on bony windows of stabbing victim demonstrated in Figures 23 & 24. There is an associated fracture of the right transverse process of T9 (red arrow).

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Fig. 26: Coronal reformats of a patient with gunshot wounds to the right upper quadrant of the abdomen associated with a hepatic laceration (segment 7), right diaphragmatic injury (red arrow) and right lower lobe pulmonary laceration.

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**Fig. 27:** Coronal reformats on lung windows of the patient (previously demonstrated in Fig 26) with gunshot wound-related right diaphragmatic injury and right lower lobe pulmonary laceration (red arrow).

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Conclusions

Conclusion

Contrast-enhanced CT (CECT) is a vital diagnostic tool in the evaluation of penetrating thoracic injuries and can reduce the incidence of invasive diagnostic procedures providing the right sequences and reformats are utilized. We have illustrated some of the common injuries and CECT findings associated with penetrating thoracic trauma that are important to recognise at presentation. Patients can be successfully triaged using CECT findings and early diagnosis and immediate appropriate treatment has been shown to increase overall survival; this is particularly pertinent in the case of gun shot wounds where outcomes are directly related to the extent of the injury and the timing of the initiation of treatment.

References


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