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ORIGINAL ARTICLE

# Pneumomediastinum and pneumopericardium following blunt thoracic trauma: much ado about nothing?

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## Abstract

**Purpose** Pneumomediastinum is the hallmark of intrathoracic aerodigestive trauma, but rare following blunt injury. Aim: review of blunt thoracic trauma (BTC) for the incidence and outcome of patients with pneumomediastinum or pneumopericardium (PM/PC) on Computerised Tomographic scanning.

**Methods** Admissions to the level I trauma ICU at IALCH, Durban, ZA following BTC from April 2007 to March 2014. Patients with Chest-CT-scan were analysed. Variables included age, sex, mechanism of injury, and Injury Severity Score (ISS). Specific injury patterns: isolated thoracic trauma, flail chest, bilateral injury and presence of haemothorax or pneumothorax were analysed.

**Results** Three hundred and eighty-nine patients were included. Males (70.9%) accounted for the majority of patients. The median Injury Severity Score was 32 (IQR 24-41). Motor vehicle collisions accounted for 94% of injury mechanisms. Twenty-three (5.9%) were identified with pneumomediastinum, 6 (1.5%) with both pneumomediastinum and pneumopericardium, and 1 (0.2%) with isolated pneumopericardium. No patient required surgery for thoracic trauma. Increasing age ($p < 0.001$) and a flail chest ($p = 0.005$) were significant associations. The mortality rate was almost identical in those with or without air within the mediastinum. No patient died from a missed mediastinal aero-digestive injury.

**Conclusion** The presence of PM/PC following BTC is incidental and benign. Increased injury severity with a flail chest is associated with a significant increase in the presence of free gas within the mediastinum. In the absence of complications, no obvious injury to the intrathoracic aero-digestive tract on CT scanning, and no difference in mortality, a conservative management policy is warranted.

**Keywords** Pneumomediastinum · Pneumopericardium · Chest trauma · Blunt · Severe · Outcome

## Introduction

Anatomically, the mediastinum is defined as the space containing those structures which lie between the right and left pleural sacs, extending from the thoracic inlet to the diaphragm. The superior mediastinum lies between the thoracic inlet and thoracic plane, a horizontal division at the level of the sternal angle and T4/5 intervertebral disc. Inferior to this the mediastinum is divided into the anterior, middle and posterior compartments relative to the pericardium. A number of tissue planes within the mediastinum communicate with extrathoracic structures both cranially and caudally. Pneumomediastinum may arise, therefore, from injury to air-filled structures within the head and neck, the thorax, or abdomen [1].

Following trauma subcutaneous gas extending from the thoracic outlet into the neck is the commonest sign of pneumomediastinum. If present in large amounts it is suggestive of a considerable air leak but does not necessarily indicate an injury to the major airways and may arise from a pneumothorax [2]. Dyspnoea and chest pain are less frequent occurring in approximately one-third of patients. Auscultation

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of the chest in the presence of air within the mediastinum may reveal Hamman's sign, a crunching or clicking noise synchronous with the cardiac cycle. Pneumopericardium may produce the water wheel sound or "bruit de moulin" described by Bricketeau in 1844 [3].

Gas within the mediastinum outlines the anatomic structures contained within and there are a number of classical radiological findings [1]. Compared to chest X-ray computerised tomography is far more sensitive in detecting pneumomediastinum and the frequent use of computed tomography for blunt trauma has led to an increased recognition [4, 5] which may result in unnecessary investigations. In the context of thoracic trauma, pneumomediastinum following a penetrating wound is highly suggestive of injury to the airways or oesophagus and appropriate investigations are essential. Delays in the diagnosis of oesophageal injury are associated with a high mortality rate. Following blunt thoracic trauma, the value of such an aggressive approach has been challenged. Blunt oesophageal and major airway injuries are exceptionally rare [2, 4, 6, 7] and gas within the mediastinum or pericardium may arise from alveolar rupture with air tracking along the perivascular and peribronchial fascial sheaths, the Macklin effect named after the author who first described the phenomenon [8]. Rupture of the peribronchial sheath at the lung root will result in pneumomediastinum, whereas gas within the perivascular sheath may be released into the pericardium. On rare occasions, a tension pneumopericardium may result. Given the minimal incidence of injuries to the aerodigestive tract following blunt trauma a more conservative approach with selective imaging has been advocated [2, 4].

In view of the suggested benign nature of pneumomediastinum, we reviewed our experience of patients admitted to a Level I Trauma Centre who had suffered major blunt thoracic injury. We adopt a conservative imaging and management approach and the aim was to determine the incidence and outcome of pneumomediastinum and pneumopericardium identified by computed tomography.

## Patients and methods

The study was approved by the Biomedical Research Ethics Committee of the University of KwaZulu-Natal (BCA 207/09). Patients admitted to the level I trauma unit and requiring ICU admission at Inkosi Albert Luthuli Central Hospital (IALCH) in Durban, South Africa who had sustained blunt thoracic trauma during the 7 year period April 2007 to March 2014 were identified from a computerised database. Computed tomography was performed on a Siemens Somatom 64, or 128 slice scanner (Siemens, Munich, Germany) and included angiography, portal venous, and delayed exposure if indicated. All scans were reported by the radiology staff and reviewed by the senior trauma surgeons. Patients who had not undergone computed tomographic imaging were excluded from the study. Data collection included age, sex, mechanism of injury, and Injury Severity Score (ISS). Specific injury patterns such as isolated thoracic trauma, flail chest, bilateral injury and the presence of a haemothorax or pneumothorax were assessed for association. Statistical analysis for continuous data was performed using the unpaired Student's $t$ test and for categorical data either Chi-squared or Fisher's exact test if the cell frequencies were $<5$. A $p$ value of $<0.05$ was regarded as significant.

## Results

A total of 431 patients were admitted following blunt thoracic injury during the study period. Forty two were excluded from analysis (23 underwent plain radiology only, 9 died in the emergency room and 5 on the operating table without imaging, and the remaining 5 were admitted for renal replacement therapy following severe beatings and rhabdomyolysis). The remaining 389 patients formed the study cohort of whom 30 (7.7%) were identified as having pneumomediastinum and/or pneumopericardium. Of these 30 patients pneumomediastinum was identified in 23 (76.7%), combined pneumomediastinum and pneumopericardium in 6 (20%) and one patient (3.3%) had isolated pneumopericardium. Figures 1, 2 and 3 illustrate the pathology on plain chest X-ray and CT scanning. Ages ranged from 2 to 84 years with a mean of 30.1 (SD = 16 95% CI 28.5–31.7) and median age of 30 years (IQR = 19–40). The median ISS for the entire cohort was 32 (IQR = 24–41). Mechanism of injury is listed in Table 1 and demographics and specific anatomical derangements of the two groups are illustrated in Table 2. Motor vehicle related collisions were responsible for 93.8% of injuries with pedestrians accounting for almost 50% of injury mechanism. There was no significant association between the mechanism of injury and the presence of pneumomediastinum or pneumopericardium. Of the specific anatomical derangements only flail chest was associated significantly with pneumomediastinum or pneumopericardium. The mean age of those with a flail chest was 42.1 years (SD = 15.2) versus 27.9 years (SD = 15.4) in those without ($p<0.001$ 95% CI 10.50–17.82). Although the presence of a pneumothorax or haemothorax per se was not significantly associated with pneumomediastinum or pneumopericardium, of the 66 patients with a flail chest 54 (81.8%) had a pneumothorax and/or haemothorax compared to 168 (51.7%) of the 323 patients without a flail chest ($p<0.001$ OR 4.15 95%CI 2.14–8.05). The ISS was non-significant between the groups but increasing age was associated significantly with pneumomediastinum and/or pneumopericardium. Mortality rates were almost identical

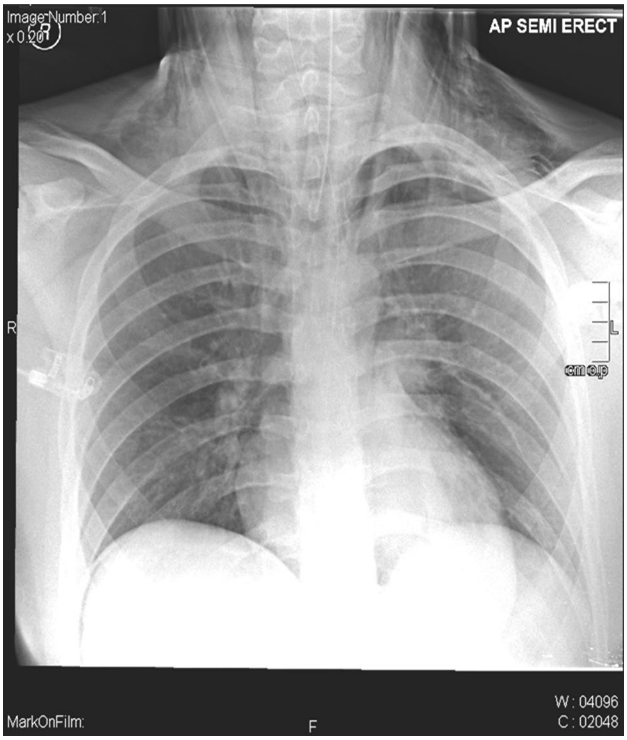


Fig. 1 Chest X-ray demonstrating pneumomediastinum and surgical emphysema of the chest-wall

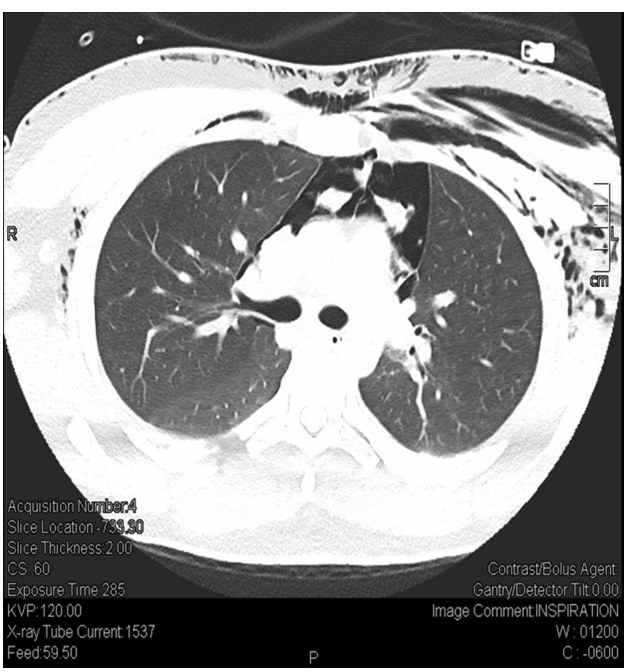


Fig. 2 Mid-thoracic CT-slice in lung window phase showing pneumomediastinum and surgical emphysema and no pneumothorax

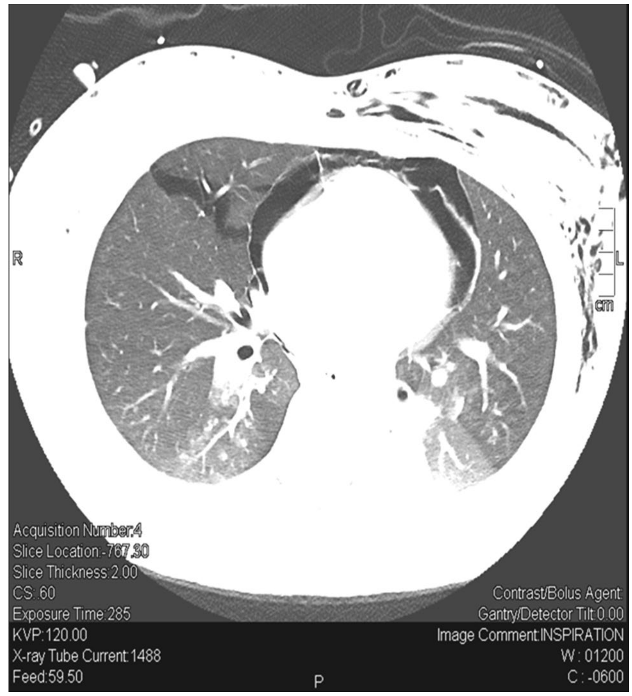


Fig. 3 Ct-slice of thorax in same patient as Fig. 2. Demonstrating pneumopericardium and the Macklin effect with air-tracking around the arterioles of the right lung and leaking back into the pericardium

Table 1 Injury mechanism amongst those with and without mediastinal involvement

| Injury mechanism | No PM/PPC, *n* (%) | PM/PPC, *n* (%) | Total, *n* (%) |
|---|---|---|---|
| MVC pedestrian | 168 (46.8) | 14 (46.7) | 182 (46.7) |
| MVC passenger | 96 (26.7) | 9 (30) | 105 (26.9) |
| MVC driver | 61 (17) | 4 (13.3) | 65 (16.7) |
| MVC motorcyclist | 12 (3.3) | 1 (3.3) | 13 (3.3) |
| Non-vehicular blunt | 22 (6.1) | 2 (6.6) | 24 (6.2) |
| Total | 359 (92.3) | 30 (7.7) | 389 (100) |

*MVC* motor vehicle collision, *PM/PPC* pneumomediastinum/pneumopericardium

between the groups. No patient underwent either oesophagoscopy or bronchoscopy for investigation of pneumomediastinum and all deaths were unrelated to a missed injury of the aerodigestive tract.

## Discussion

Iatrogenic trauma causes the majority of aerodigestive tract injuries within the thorax [9]. Both penetrating and blunt non-iatrogenic injuries to the major airways and oesophagus presenting to the hospital are uncommon with the

**Table 2** Demographics, specific anatomical derangements, and association between groups

| | No PM/PPC, *n* (%) | PM/PPC, *n* (%) | Total, *n* (%) | |
|---|---|---|---|---|
| Total cohort | 359 (92.3) | 30 (7.7) | 389 (100) | |
| Males | 253 (70.5) | 23 (76.7) | 276 (70.9) | |
| Females | 106 (29.5) | 7 (23.3) | 113 (29.1) | |
| Age (mean:SD) | 29.2 (15.6) | 40.4 (19.7) | 30.1 (16) | $p<0.001$ (95% CI = 5.25–17.17) |
| ISS (median:IQR) | 32 (25–41) | 29 (21–38) | 32 (24–41) | $p=0.31$ (95% CI = 2.41–7.50) |
| Deaths | 81 (22.6) | 7 (23.3) | 88 (22.6) | $p=1.0$ (OR = 0.96 95% CI = 0.39–2.31) |
| Flail chest | 55 (15.3) | 11 (36.7) | 66 (16.9) | p = 0.005 (OR = 3.2 95% CI = 1.44–7.09) |
| HTX/PTX | 232 (64.6) | 24 (80) | 256 (65.8) | $p=0.11$ (OR = 2.19 95% CI = 0.87–5.49) |
| Bilateral injury | 109 (43.4) | 9 (30) | 118 (30.3) | $p=0.54$ (OR = 0.98 95% CI = 0.45–2.21) |

*SD* standard deviation, *IQR* interquartile range, *HTX* haemothorax, *PTX* pneumothorax

latter being exceptionally rare [7]. This low prevalence is most likely due to the small size of these structures, their relatively protected position, and if damaged, the high pre-hospital mortality rates due to associated injuries to major vascular structures [10].

Pneumomediastinum is the hallmark of intrathoracic aerodigestive trauma. Although many injuries of the major airways may be managed non-operatively [11], those of the oesophagus fare badly if the diagnosis and surgical intervention are delayed. As such, given that penetrating trauma accounts for the majority of injuries, all transmediastinal penetrating injuries require imaging of the oesophagus using contrast radiology or endoscopy. Given the extremely rare occurrence of oesophageal injury following blunt trauma, however, routine imaging has been questioned, even in the presence of pneumomediastinum [2] which has been recognised as a poor predictor of aerodigestive tract injury by this mechanism [4]. The most likely cause of pneumomediastinum is due to the Macklin effect [12] where alveolar compression and rupture results in air tracking along the peri-bronchial sheath to the lung root which if breached releases air into the mediastinum.

CT scanning is superior to plain radiology for blunt thoracic trauma, especially in detecting pneumomediastinum [2], and in up to 20% of patients will result in a change in management [13]. Tracheal injury results in a vertical tear usually about 2 cm above the carina. Bronchial injuries, which are parallel to the cartilaginous rings, are more common on the right and arise about 2–3 cm from the carina. Suspicious CT findings are irregularity or a defect within the airway wall, focal thickening, or cut-off of the tracheal or bronchial wall surrounded by extraluminal air. A large and persistent pneumothorax despite adequate intercostal drainage is a common association [14]. The development of three-dimensional scanning has further increased the diagnostic accuracy where thin slice reconstruction allows a virtual bronchoscopy [6]. Of major importance is the accuracy of CT scanning to detect those injuries which require surgical intervention with a reported 100% true positive rate [2]. In addition to pneumomediastinum, CT findings of oesophageal injury include extra-luminal air in more than 90% of patients, a left pleural effusion, left lower lobe collapse, and the V-sign of Naclerio consisting of gas outlining the lateral margin of the descending aorta, and extra-pleural air between the parietal pleura and diaphragm in the inferior mediastinum, most commonly on the left [6, 14]. Gas may also be seen surrounding the extrapericardial portion of the right pulmonary artery, the "ring around the artery" sign [15]. On plain chest radiology, a medial pneumothorax may be mistakenly diagnosed as pneumopericardium. CT scanning allows a definitive diagnosis. Although most cases of pneumopericardium are asymptomatic, some may progress to a tension pneumopericardium causing life-threatening tamponade, especially during positive pressure mechanical ventilation [16].

We could find no association with mortality in our patient cohort. Although Lee et al [5] report a significantly higher mortality rate in patients with pneumomediastinum following blunt thoracic trauma, only one of the nine deaths had a documented airway injury, which was deemed non-survivable. Of the other eight deaths, three were declared brain dead, two had incomplete hospital records, one died from sepsis, one from uncontrolled haemorrhage and one from unknown causes. Excluding these patients would make the results non-significant and no other study has reported a significant association with outcome.

In contrast with other authors, we could not demonstrate an association of haemothorax or pneumothorax with pneumomediastinum. This is unlikely due to a limited number of patients as almost two-third of the total of 389 patients had blood or air within the pleural cavity. Of note is the strong association of flail chest with pneumomediastinum. The presence of a flail chest in a predominantly young patient population signifies major energy transfer, increased injury severity, and a higher risk of major lung trauma as evidenced by the significantly higher incidence of haemothorax and pneumothorax in those suffering a flail chest.

Although we could find no difference in ISS between the groups less than 10% of our patients had suffered isolated thoracic trauma which may confound the interpretation of injury severity. Lee at al documented that the ISS in those with pneumomediastinum was twice that of those without [5].

Unlike other authors, we found a significant association of pneumomediastinum with increasing age. Increased stiffness of the pulmonary interstitium with age has been suggested to prevent air leaks and subsequent tracking along the peribronchial and perivascular sheaths [14]. We would suggest otherwise and that increasing fragility of the chest wall with age would result in more severe disruption and underlying lung damage. This supposition is confirmed by the significantly greater age in those patients who sustain a flail chest which we found to be strongly associated with the presence of pneumomediastinum. In addition, flail chest is associated with more severe underlying lung injury and the presence of hyperinflation in the elderly would predispose to a more severe air leak.

Our data confirm that the presence of pneumomediastinum or pneumopericardium following blunt thoracic trauma is an incidental benign finding. Increased injury severity in the form of a flail chest is associated with a significant increase in the presence of free gas within the mediastinum. In the absence of complications, no obvious injury to the intrathoracic aerodigestive tract on CT scanning, and no difference in mortality a conservative investigation and management policy is warranted.

## Compliance with ethical standards

**Conflict of interest** No conflict of interest reported for any of the authors.

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