Is there a role for planned serial chest radiographs and abdominal ultrasound scans in the resuscitation room following trauma?

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ABSTRACT

INTRODUCTION Despite advances in trauma care, significant morbidity and mortality exists which could be reduced if all injuries were immediately identified. Two treatable factors are hypoxia and hypovolaemia which may occur secondary to haemorrhage into the chest and abdomen. Pneumothorax is also a frequent cause of preventable trauma death. Clinical examination is limited and we often rely on imaging. Anecdotally, it seemed some patients were investigated too quickly because their injuries had not evolved sufficiently enough to become detectable. In these patients, repeated assessments and imaging would, therefore, be necessary.

PATIENTS AND METHODS This was a retrospective study looking at all patients over a 15-month period with significant chest and abdominal injuries. Patients with a chest or abdominal Abbreviated Injury Score (AIS) of 3 or above were identified. As a cross reference, those patients who required at least one chest drain, or a laparotomy within 24 h of admission were also identified. Case notes and films were reviewed with particular attention to the presence of initial 'normal' imaging.

RESULTS A total of 1036 patients were eligible for entry into the trauma database; of these, 170 patients had chest and/or abdominal injuries coded as AIS 3 or more. We were able to identify 7 cases (4%) where initial clinical examination and imaging failed to detect either bleeding (pleural space or abdomen) or a pneumothorax. A further 5 cases were potential missed injuries, but the data were incomplete making confident inclusion in this group impossible.

CONCLUSIONS Occult injuries are reported to have an incidence of around 2–5%. Serial imaging in the resuscitation room may enable early identification of chest and abdominal injuries. However, only 12 cases were identified making interpretation of suitable candidates for repeat imaging difficult. The question is which group of patients would benefit from planned repeat imaging before leaving the resuscitation room.

KEYWORDS

Imaging – Trauma – Missed diagnosis – Delayed diagnosis

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Advances in trauma care continue to improve outcomes in patients following injury. Yet, despite even the best efforts, major or multisystem trauma still carries significant morbidity and mortality which, arguably could be reduced further if all injuries were immediately identified on arrival in the resuscitation room. Even patients with apparently minor injuries can quickly deteriorate, the only clue to the underlying severe injuries being initially the mechanism of injury and superficial markings such as bruising, lacerations and abrasions. For this reason, frequent reassessment is advocated by the American College of Surgeons Advance Trauma Life Support course.¹

Unfavourable outcomes increase with increasing severity of trauma, as determined by a number of current scoring

systems. Two measurable factors, which are well known to influence outcome significantly, are hypoxia and hypovolaemia, although many others are also known to exist. Hypoxia and hypovolaemia have many possible causes. Two common (and often treatable) causes are haemorrhage into the chest and abdomen. Pneumothorax is also a frequent cause of preventable trauma death. Early identification and effective management of these conditions should, therefore, improve survival and reduce morbidity.

Unfortunately, the most rapid assessment tool, clinical examination, can be very limited, particularly in the presence of distraction (either to the patient or the attending clinician). It is said that a pneumo- or haemothorax can be diagnosed with a thorough physical examination and, in

ideal circumstances (*i.e.* a detailed history, quiet surroundings and fully co-operative patient), this may be possible. It has also been suggested that following blunt trauma, patients who are haemodynamically normal with a normal physical examination do not require a routine chest X-ray (CXR).² However, ideal examination conditions rarely exist in the resuscitation room. Although large pneumo- or haemothoraces may be detected clinically, smaller ones can be easily missed and, in most cases, diagnosis usually relies on chest radiography. In the multiply injured patient, chest radiographs are taken in the supine position and can be difficult to interpret.

Computed tomography (CT) scanning has been reported to detect otherwise undiagnosed injuries⁵ including air or blood in the pleural space.⁴ Assessment of the abdomen is also fraught with difficulty and it is well known that examination alone is unreliable in excluding injuries. In the unconscious or analgesed patient, clinical assessment is even more problematic.

We, therefore, often rely heavily on investigations in the initial assessment of these body regions. Choice of imaging is determined by local circumstances and protocols. Modalities shown to be of use include CXR, thoracic ultrasound,^{5,6} abdominal ultrasound,⁷ CT scan and diagnostic peritoneal lavage.

In our institution, anecdotally it seemed that, on occasion, performing an investigation too quickly resulted in an initial negative finding, which later became positive either clinically or on subsequent imaging. Although the value of early imaging is clear in patients with major injuries, particularly with significant haemo- or pneumothorax or abdominal bleeding, there appeared to be a cohort of patients whose injuries had not evolved sufficiently enough on arrival to become detectable by clinical examination or very early imaging. Deterioration may have been partly iatrogenic in origin following administration of intravenous fluids, as their blood pressure improved enabling uncontrolled haemorrhage to bleed further. In these patients, repeated assessments and imaging would, therefore, be necessary to pick up reactionary haemorrhage or enlarging pneumothorax.

Patients and Methods

This was a retrospective study looking at all patients over a 15-month period (May 2002 to August 2003) who attended the trauma unit at the University Hospital of North Staffordshire. Using the trauma unit database, we identified those patients with chest and abdominal injuries either in isolation or as part of the multiple injuries.

The database collects and codes all information prospectively from arrival in the emergency department (including pre-hospital care) until discharge. Data collected include,

but are not restricted to, mechanism of injury, pre-hospital care, times of arrival and any intervention(s) in the emergency department, injuries identified, length of stay and outcome. Patients eligible for entry into the database included those whose length of stay was 72 h or more, those who required intensive care unit (ICU) admission and those who were transferred from another hospital or who died.

From the database, we identified those patients with an Abbreviated Injury Score (AIS) chest or abdominal score of 3 or above (which included all serious thoracic and abdominal trauma). As a cross reference, we also identified those patients requiring at least one chest drain, or a laparotomy as part of their treatment within 24 h of admission to the accident and emergency department. The original 'paper-work' (collected by the Trauma Research Office), admission records and casualty records were reviewed to identify potential cases where the diagnosis may have been delayed.

Exclusion criteria

Exclusion criteria for the study included:

1. Those patients in whom a chest drain was inserted or who required a laparotomy prior to imaging, based on clinical presentation.
2. Positive identification of haemothorax, pneumothorax or abdominal free fluid on initial imaging.
3. Clinical presence of surgical emphysema due to associated pneumothorax.
4. Radiographic presence of surgical emphysema due to associated pneumothorax.
5. Identification of haemothorax, pneumothorax or abdominal free fluid requiring no specific treatment.
6. Data inadequate for patient.

Inclusion criteria

From the database, we were able to review those cases where the initial chest radiograph or Focused Assessment with Sonography for Trauma (FAST) abdominal examination were considered to be 'normal' or 'NAD' by the examining physician, (either a trauma team leader, or experienced radiologist), but where the patient later: (i) required a chest drain; (ii) required a laparotomy; or (iii) was found to have haemothorax, pneumothorax or blood loss in the abdomen at post mortem. In these patients all case notes, plain radiographs and CT scans were reviewed. From this, the following data were collated: (i) mechanism of injury; (ii) all injuries sustained; (iii) delay in diagnosis; and (iv) management.

Results

Over a 15-month period, 1036 patients were eligible for entry into the trauma database. Of these, 170 patients were identified as having chest and/or abdominal injuries coded

Table 1 Cases where initial clinical examination and imaging failed to detect either bleeding (pleural space or abdomen) or a pneumothorax

Patient	Mechanism of injury	Injuries	Further imaging required	Delay	Change in management
14-year-old F	MVC with ejection	Multiple small and large bowel perforations/mesenteric tear	Repeat US	12 h (abdomen)	R hemicolectomy
16-year-old F	MVC with head-on collision (130 mph)	Ruptured jejunum	Repeat US	12 h (abdomen)	Repair
58-year-old F	MVC with head-on collision (50 mph)	Splenic/liver laceration/pulmonary contusions	CT	3 h (abdomen)	Splenectomy
20-year-old M	MVC with head on-collision (50 mph)	Surgical emphysema/pneumothorax #s – clavicle/mandible; lacerations – head/leg; tender epigastrium	Repeat CXR	2 h (chest)	Intercostal drain
49-year-old M	Stab wound to left side of chest	Left-sided pneumothorax	CT	12 h (chest)	Intercostal drain
38-year-old M	MVC (motorcycle vs car)	Bilateral haemothoraces; R pneumothorax; #s – pelvic/forearm/scapula/rib; small bowel mesenteric lacerations and bowel perforation; contusion frontal lobe; brachial plexus injury	Repeat CXR	8 h (chest)	Intercostal drains
34-year-old M	MVC with head-on collision (70 mph)	L haemothorax/pulmonary contusion; multiple rib fractures	Repeat CXR	1 h (chest)	Intercostal drain

MVC, motor vehicle collision; US, ultrasonography; #s, fractures.

as AIS 3 or more. From this group of patients, we were able to identify 7 cases (4%; Table 1) where initial clinical examination and imaging failed to detect either bleeding (pleural space or abdomen) or a pneumothorax (4 thoracic trauma and 3 abdominal trauma). A further 5 cases were 'potential' missed injuries, but the data were incomplete to include them confidently in this group (Table 2). In all 12 cases, the injuries were only diagnosed following further imaging. Of the 12 cases identified, there were 5 abdominal injuries where initial ultrasonography was 'NAD'. Repeat ultrasonography (2 cases) and CT scan (3 cases) subsequently demonstrated intra-abdominal injury. Seven patients had initial 'normal' CXRs. Intrapleural air or blood was detected following repeat CXR in 5 cases, and CT scan in 2 cases. Of the 170 patients, there were 5 deaths. However, these were not directly attributable to their chest or abdominal injury – all patients died from serious brain injuries.

Discussion

Pneumothorax, haemothorax and abdominal bleeding frequently accompany significant blunt or penetrating injuries to the chest and abdominal and are usually detected clinically, following plain chest radiography or on FAST scanning. Occult injuries are reported to have an incidence of around 2–5%.^{4,8} These are potentially serious in trauma patients, particularly if they contribute to hypoxia or hypovolaemia. A small, occult pneumothorax, if undetected, may rapidly become life-threatening after the administration of general anaesthesia or mechanical ventilation.⁹

Our observations are not new^{10,11} and the concept of repeated examination and investigations is well known.^{12,13} The purpose of this study was to see if we could identify a cohort of patients in whom serial investigations would be a planned part of management, rather than be prompted by a change in the patients condition.

Table 2 'Potential' missed injuries with incomplete data

Patient	Mechanism of injury	Injuries	Further imaging required	Delay	Change in management	Data unavailable/incomplete
32-year-old F	MVC	Multiple left rib fractures: 5–7 & 10–12; right haemothorax	Repeat CXR	ND	Intercostal drain	Initial CXR (only 'NAD' in notes), delay
27-year-old M	MVC	Bilateral anterior pneumothoraces	CT	3 h	Bilateral intercostal drains	Initial CXR (only 'NAD' in notes)
48-year-old M	MVC	Ruptured spleen	CT	ND	Splenectomy	CT (US NAD), delay
23-year-old M	Fall from > 12 ft	Bilateral haemothoraces	Repeat CXR	2h	Intercostal drain	Initial CXR (only 'NAD' in notes)
32-year-old M	MVC	Multiple tears to small bowel mesentery	CT	5 h	Laparotomy	CT (US NAD)

MVC, motor vehicle collision; US, ultrasonography; ND, no data available.

Other studies have highlighted the limitations of the A-P CXR to detect pneumo- or haemothoraces in the supine, multiply injured patient. Abdominal CT scanning has also been shown to detect prior unrecognised thoracic injuries, such as pneumothoraces, hemothoraces, rib fractures, and lung contusions, in the trauma patient undergoing abdominal evaluation. CT scanning, however, requires patient transfer, at least out of the trauma room, and possibly into a potentially unsafe environment (from a resuscitation viewpoint).

Small pneumo- or haemothoraces are well known to be difficult to detect clinically or on a supine A-P CXR. Erect CXRs are usually not performed in the primary survey as there are often concerns about potential spinal injury. Cadaver studies have shown that supine CXRs have low sensitivity and that 200–400 ml of air are required to enable a confident diagnosis of a pneumothorax.⁴ Similarly, a significant amount of blood must accumulate in the supine pleural space before it is confidently recognised.

Serial imaging in the resuscitation room may provide some benefit in early identification of chest and abdominal injuries. This is especially important if the patient needs to be transferred, notably between hospitals. We only identified 12 potential cases making interpretation of suitable candidates for repeat imaging difficult. Of the 170 patients (AIS chest or abdomen 3 or more) identified, 169 were felt to have been managed appropriately. All patients were either further investigated (repeat CXR, ultrasonography or

CT scan), or admitted for close observation. Although diagnoses were delayed in some of these, this was not due to clinical error but the result of late presentation of clinical findings. One patient (second patient in Table 1) was discharged and re-presented 12 h later. In this case, it could be argued that admission may have been more appropriate.

Although variable, patients spend an average time of 3–4 h in the resuscitation room, prior to transfer to theatre or a ward. This would allow time to repeat investigations if appropriate. The need for serial investigation is well established in medicine and serial electrocardiogram (ECG) recording is common practice in patients presenting with chest pain. Serial CXRs may also be carried out in the diagnosis of some medical conditions.

All tests are only a 'snapshot' of the patient's condition at the time the test was undertaken, and trauma is no different. It is important to remember that not all injuries may be immediately evident following trauma and that haemorrhage and pneumothorax are on-going processes which may be initially difficult to recognise. Where abdominal CT scanning has shown occult pneumothoraces, the question is whether it was 'missed' on the supine A-P CXR or developed following it during the transfer process. Planned serial imaging may, therefore, help in the early identification of pneumothorax, haemothorax and abdominal bleeding, before the patient clinically deteriorates or is transferred into a potentially unsafe environment. We identified 7 patients (4%) where the data were complete. Potentially,

there were 12 (7%) patients in whom planned serial imaging may have been of benefit, but the data were incomplete to include them confidently in this study. In other studies, the pick-up rate seems to be low¹⁴ and the question is which group of patients would benefit from planned repeat imaging before leaving the resuscitation room. This study does not answer this question in detail due to the small group size and considerable number of variables involved in each case. However, the mechanism of injury in all cases was severe and may be a useful indication. Further risk-benefit analysis and cost-effective analysis are needed.

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