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Point of care ultrasound and sub-xiphoid window reduce uncertainty in the management of potential dual-cavity injuries in patients with torso stab wounds

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ABSTRACT

Introduction: This paper reviews our experiences with the management of patients with torso stab wounds and potential injuries in both the chest and abdomen over the last decade. The aim of the project is to clarify our approach and provide an evidence base for clinical algorithms. We hypothesize that there is room for our clinical algorithms to be further refined in order to address the diverse, life threatening injuries that can result from stab wounds to the torso.

Methods: Patients with one or more torso stab wounds, and a potential injury in both the chest and the abdomen were identified from a local database for the period December 2012 to December 2020.

Results: A total of 899 patients were identified. The mean age was 29 years (SD = 9) and 93% of patients were male. Amongst all patients, 686 (76%) underwent plain radiography, 207 (23%) a point of care ultrasound assessment, and 171 (19%) a CT scan. Following initial resuscitation, assessment and investigation, a total of 527 (59%) patients proceeded to surgery. A total of 185 patients (35%) underwent a semi elective diagnostic laparoscopy to exclude an occult diaphragm injury. Of the 342 who underwent an emergency operation, 9 patients (1%) required thoracotomy or sternotomy exclusively, 299 patients (33%) required a laparotomy exclusively and 34 patients (4%) underwent some form of dual cavity exploration. In total, there were 16 deaths, a mortality rate of 2%. The use of laparoscopy, point of care ultrasound and subxiphoid pericardial window increased over the period of this study.

Conclusions: Patients with torso stab wounds and potential injuries above and below the diaphragm are challenging to manage. The highly structured clinical algorithm of the ATLS course should be complemented by the use of point of care ultrasound and sub-xiphoid window to assess the pericardium. These adjuncts reduce the likelihood of negative exploration and incorrect operative sequencing.

Introduction

Depending on the site and trajectory of the wound, stab wounds (SW) to the torso may injure structures in both the thorax and the abdomen. This creates a clinical dilemma as the managing surgeon needs to assess both body cavities and prioritise the injury which is most life threatening. This situation has been described in the literature as one of 'double jeopardy' [1–3]. This term, however, has been used in a restrictive fashion since it was first coined by Hirshberg, who confined it to patients who underwent exploration of both thoracic and abdominal cavity at the same sitting [3]. While other authors have focused on thoraco-abdominal wounds, they have usually confined their discussion to the problem of diaphragmatic injury. A more expansive view of the problem should include all patients with potential injuries above and below the diaphragm following either a single or multiple stab wounds. This cohort of patients includes those with thoraco-abdominal wounds along the costal margin, as well as patients with multiple stab wounds above and below the diaphragm. This cohort of patients are at risk for

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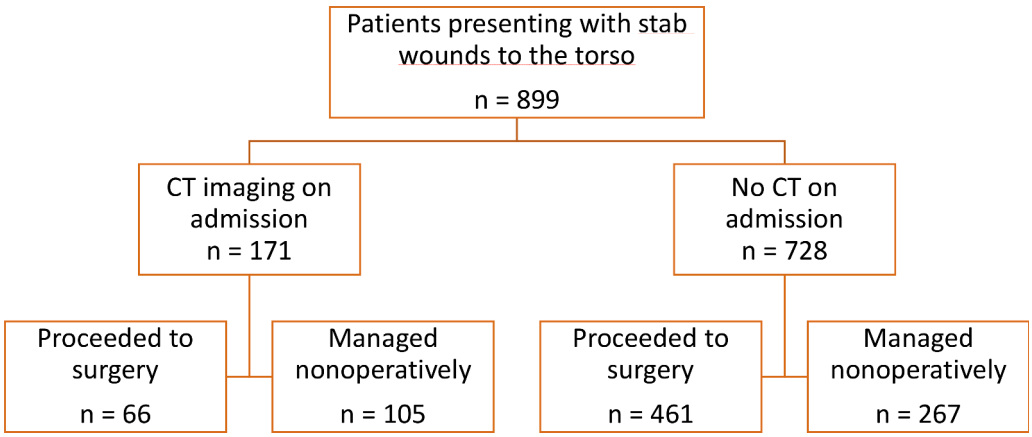


Fig. 1. Clinical course of torso stab wound patients in the context of CT imaging and surgical intervention.

double jeopardy as inappropriate management of a life threatening injury in the thorax, such as a tension pneumo-thorax or a cardiac tamponade, whilst attending to an intra-abdominal injury may be fatal [1–4]. This dilemma is recognized by the *Advanced Trauma Life Support (ATLS)* course, which proposes a highly structured clinical algorithm to actively exclude life threatening thoracic injuries during the primary survey [5]. The ATLS approach remains the gold standard in the assessment of patients with torso stab wounds. However, there is a degree of clinical inconsistency in the acute assessment and management of these patients. The development of new imaging techniques and operative strategies over the last three decades has improved our ability to assess and exclude injuries in the thorax, whilst managing intra-abdominal injuries. These modalities include the widespread availability of CT scan for penetrating torso trauma, point of care ultrasound and the increased use of sub-xiphoid pericardial window to actively exclude a traumatic cardiac tamponade [6–10]. Our centre follows the ATLS approach and has increasingly made use of the aforementioned modalities. This study reviews our experience with the management of patients with torso SWs and potential injuries in both the chest and abdomen over the last decade. The aim is to clarify our clinical approach and to provide a solid evidence base for our management algorithms. We hypothesise that the clinical approach emphasized by the ATLS course can be further refined to better address life-threatening injuries in the chest whilst avoiding non-therapeutic surgical explorations.

Materials and methods

Clinical setting

The Pietermaritzburg Metropolitan Trauma Service (PMTS) is a major trauma centre that covers the western part of the Kwa Zulu Natal (KZN) Province in South Africa, a low and middle income country (LMIC). The catchment population is over 3 million people and the service admits over 4000 patients annually. Penetrating injuries comprise of over 50% of all admissions. Clinical data on all trauma patients is recorded and maintained on an electronic registry called the Hybrid Electronic Medical Record (HEMR). Ethics approval for the HEMR database and this study was granted by the Biomedical Research Ethics Committee (BREC) of the University of KwaZulu Natal (Reference number: BE 207/19 and BCA 221/13).

Management protocol

All trauma patients who sustained a torso SW are managed according to the *Advanced Trauma Life Support (ATLS)* approach [5]. Cardiac tamponade and pleural collections are actively excluded using the ATLS approach. If a pleural collection is suspected clinically it is confirmed either on bed side X-ray or point of care ultrasound and managed by tube thoracostomy. If a cardiac tamponade is suspected this is assessed via a point of care ultrasound [6]. Cross sectional imaging, predominantly CT with intravenous contrast, is utilised when there is clinical uncertainty, provided the patient remains haemodynamic stable [9]. There are several permutations of operations that any given patient may undergo.

- If the source of the instability is suspected to be a cardiac tamponade or major intra-thoracic bleeding, the chest is accessed primarily [11].
- If the source of the instability or peritonitis is thought to be in the abdomen, the abdomen is accessed primarily.
- Dual cavity exploration is a blanket term that refers to patients who underwent both formal laparotomy and open chest exploration at the same index operation or patients who had a laparotomy and a sub-xiphoid window at the same index procedure.
- If there is clinical equipoise and the managing surgeon is uncertain as to the source of the instability, the abdomen is accessed d primarily and if necessary, a cardiac tamponade is excluded via a sub-xiphoid approach to visualize the pericardium [10,11].
- If there is concern that there may be a traumatic pericardial effusion and the patient is stable, a primary sub-xiphoid window is performed to exclude or confirm the presence of such an effusion. This may be definitive management in the case of low-grade cardiac injuries or may be converted to a formal sternotomy or thoracotomy as required [10–12].
- Patients with stab wounds to the left thoraco-abdominal region who are stable and who complete a period of observation will undergo laparoscopy to exclude an injury to the left hemi-diaphragm [13,14].

The study

The HEMR was reviewed for the period December 2012 to December 2020. All patients with one or more torso stab wound, and a potential injury in both the chest and the abdomen were identified. These included patients with multiple stab wounds above and below the diaphragm as well as those with stab wounds at the thoraco-abdominal junction. Patients with an obvious single cavity injury were excluded. Relevant demographic and clinical information was noted. The latter included vital signs on admission, imaging modalities used, operative management, complications and mortality. The Revised Trauma Score (RTS) and Clavien Dindo Classification were calculated accordingly. The Injury Severity Scale (ISS) was calculated by clinicians at the time of patient discharge and readily available on the HEMR. Data was analysed using IBM SPSS.

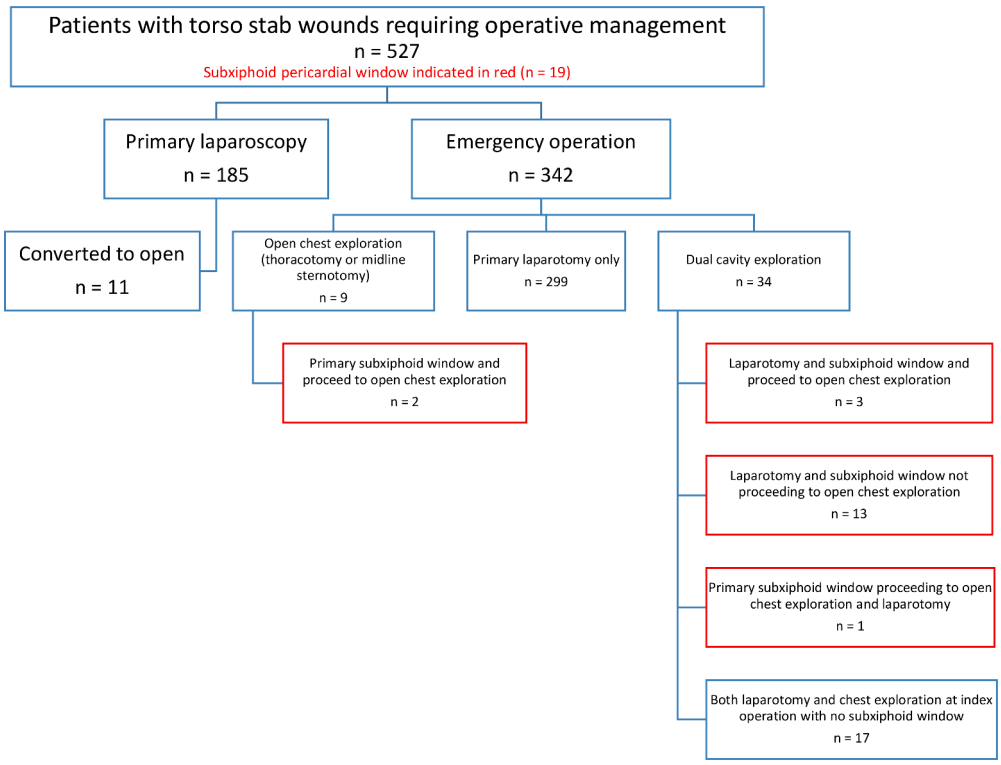


Fig. 2. Profile of operative approach to patients with stab wounds to the torso.

Results

Overview

A total of 899 patients were identified. The mean age was 29 years (SD = 9) and 93% of all patients were male. The median Glasgow Coma Score (GCS) was 15 (15, 15) and average admission vital signs and biochemistry were as follows: heart rate 90 bpm (SD = 18), systolic blood pressure 120 mmHg (SD = 19), temperature 36.3 °Celsius (36, 36.7), pH 7.37 (7.32, 7.42) and serum lactate 2.2 (1.2, 3.6). The median RTS was 8 (8, 8) and ISS 9 (4, 14).

Clinical management

Of the 899 patients, all had admission blood tests, whilst 686 (76%) underwent plain radiography, 207 (23%) a point of care ultrasound assessment of the thorax, and 171 (19%) a CT scan of the chest, abdomen and/or pelvis. A total of 59 patients (7%) underwent a CT angiogram and 24 patients (3%) underwent other investigations such as water soluble contrast study, upper endoscopy or a cystogram. Fig. 1 summarises the clinical course of patients in relation to CT imaging and operative management. Fig. 3 shows the increasing use of CT imaging in torso stab wounds over the period of this study.

Operative management

Following initial resuscitation and investigation, 527 (59%) patients proceeded to surgery. There were 342 emergency operations and 185 semi-elective laparoscopic procedures. Of the 342 emergency operations there were 299 laparotomy only procedures, 9 thoracotomy or sternotomy only procedures and 34 dual cavity procedures. The dual cavity group included 16 patients who had a primary laparotomy with a subxiphoid pericardial window and 17 patients who underwent dual cavity exploration at the index operation without use of a subxiphoid window. Out of the 299 laparotomy procedures there were 31 (10%) non-therapeutic or negative procedures. All 9 primary thoracotomy or sternotomy procedures were positive and therapeutic. In all 3 cases where a primary sub-xiphoid window procedure was followed by a sternotomy a cardiac laceration was repaired. In the 17 patients where both abdomen and chest were opened at the index operation without recourse to a sub-xiphoid window there were 5 (29%) negative procedures. These included 3 non-therapeutic laparotomies and 2 non-therapeutic thoracotomies. A total of 185 patients (35%) underwent a primary diagnostic laparoscopy to exclude an occult diaphragm injury and 110 (59%) were non-therapeutic. The operative management is summarised in Fig. 2.

Table 1
Profile of injuries sustained from torso stab wounds.

Type of injury sustained		Number of cases	Proportion of all torso stab cases (%)
Thoracic			
	Lung	349	39
	Musculoskeletal (e.g. ribs, sternum)	32	4
	Heart	14	2
	Oesophagus	1	0
Diaphragmatic		217	24
Abdominal			
	Liver	102	11
	Stomach	86	10
	Colon	75	8
	Spleen	66	7
	Small bowel	61	7
	Kidney	47	4
	Pancreas	32	4
	Duodenum	7	1
	Gallbladder	5	1

Analysis of the sub-xiphoid window cohort

A sub-xiphoid pericardial window was performed in 19 patients. In 3 patients the sub-xiphoid window was performed at laparotomy and the

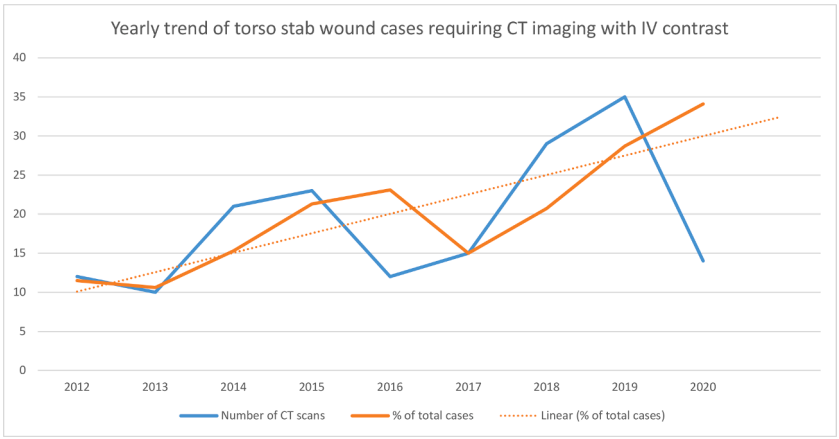


Fig. 3. Trend of CT imaging in patients with torso stab wounds, by year.

managing surgeon then proceeded to access the chest and repair a cardiac injury. In 13 patients the sub-xiphoid window was performed at laparotomy but the chest was not accessed as a cardiac injury had been excluded. In a single patient a subxiphoid window proceeded to both open chest exploration and laparotomy. In 2 patients, a primary subxiphoid window was performed and the surgeon then proceeded to access the chest cavity only to address a cardiac injury.

Spectrum of injuries

The spectrum of injuries sustained is summarised in Table 1. The most common injuries were hemo-pneumothoraxes, in 349 (39%) patients. Amongst these, 180 patients sustained a left-sided haemo-pneumothorax and 70 patients a right sided haemo-pneumothorax. 7 patients had a tension pneumothorax. The second most common injury was a diaphragmatic injury in 217 (24%) patients. Other injured structures included liver, stomach, large bowel, and spleen. A total of 14 patients sustained a cardiac injury. These included 6 cardiac lacerations requiring repair and 8 traumatic cardiac effusions. The average length of stay of TA SW patients was seven days. Of all patients with thoracoabdominal stab wounds, a total of 82 (9%) required admission to the intensive care unit (ICU). There were 16 deaths out of the 899 patients, a mortality rate of 2%. 5 patients died of hypo-volaemic shock. The proportion of patients requiring operative management remained stable, as did the need for laparotomy, chest exploration and dual cavity exploration. The use of laparoscopy and sub-xiphoid pericardial window

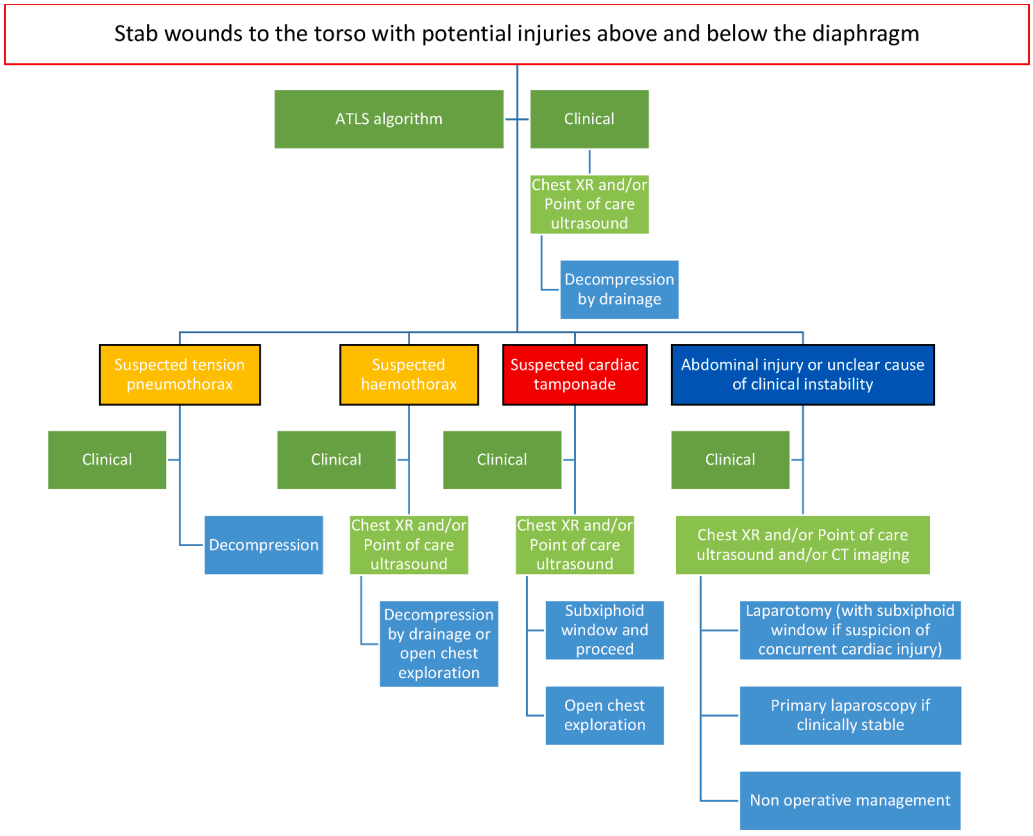


Fig. 4. A proposed algorithm for managing potential double jeopardy in thoracoabdominal stab wounds to prevent unnecessary opening of a body cavity. Note that in cases of significant clinical compromise, further investigations may be bypassed in favour of definitive surgical intervention.

increased over the period of this study.

Subgroup analysis

Of the 527 patients needing operative management, 66 (13%) underwent pre-operative CT imaging and 461 (88%) did not. There was no significant difference in demographic and clinical characteristics between the two groups of patients.

Discussion

Patients who present with potential injuries in both the chest and abdomen following a stab wound to the torso present significant challenges. These injuries may manifest as competing priorities and this situation has been described as one of double jeopardy [1–3]. A stab wound at the thoraco-abdominal junction, may injure structures above or below the diaphragm and a patient may have multiple SW's above and below the diaphragm. Intra-thoracic lesions such as haemopneumo-thoraces and tension pneumothoraces can be managed by tube thoracostomy as taught by the ATLS course [5]. Penetrating cardiac lesions, injuries to the great vessels of the thorax and lacerations to the lung parenchyma may require open surgery. Intra-abdominal injuries may also require operative intervention. Inappropriate prioritization may result in the incorrect body cavity being accessed or accessed unnecessarily and this is associated with increased morbidity and mortality [1–4].

The standard approach to torso stab wounds is a structured clinical algorithm to identify and treat all life threatening conditions in the chest prior to proceeding to surgery [11]. One such algorithm is suggested in Fig. 4. Tension pneumothorax, massive haemothorax and cardiac tamponade are addressed first before managing any abdominal injuries. Point of care ultrasound scan is a useful adjunct to clinical examination and can exclude or confirm the presence of a pericardial effusion [6]. We have shown an increased use of this adjunct over the last decade. The relatively low utilisation of cross sectional imaging reflects our view that CT scan is not helpful for the assessment of SW. This is in contradiction to its important role in the assessment of torso gunshot wounds [15].

A sub-xiphoid pericardial window procedure is a relatively minimal access type approach which can actively exclude the presence of a traumatic pericardial tamponade and help determine whether the chest needs to be opened. This procedure has been re-popularised by the Cape Town group and we have made increased use of it over the last decade [16,17]. It can be performed as an index procedure prior to opening the chest or in conjunction with a laparotomy. Our data shows that the use of sub-xiphoid pericardial window is associated with a reduced likelihood of a non-therapeutic exploration of chest.

Conclusions

Patients with torso stab wounds and potential injuries above and below the diaphragm are challenging to manage. The highly structured clinical algorithm of the ATLS course should be complemented by the use of point of care ultrasound and sub-xiphoid window to assess the pericardium. These adjuncts reduce the likelihood of negative exploration and incorrect operative sequencing.

CRediT authorship contribution statement

Jim Wang: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Victor Kong:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Conceptualization. **Jonathan Ko:** Resources, Methodology, Data curation. **Jonah Qi:** Software, Investigation, Data curation. **John Bruce:** Writing – review & editing, Validation, Supervision, Project administration, Conceptualization. **Grant Laing:** Writing – review & editing, Validation, Supervision, Project administration, Conceptualization. **Damian Clarke:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Investigation, Data curation, Conceptualization.

Declaration of competing interest

I, **Jim Hsu-Shun Wang**, the corresponding author for this paper, can confirm that to the best of my knowledge, we have no conflicts of interests to declare or disclose, including financial and personal relationships with people or organisations that may inappropriately influence our work.

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