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Impaled Knife in the Cardiac Box: Staged Surgical Management in a Hemodynamically Stable Patient

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Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Patient: Female, 29-year-old
Final Diagnosis: Penetrating stab injury of the left chest (cardiac box) with impaled knife and traumatic pneumothorax • epicardial contusion without pericardial penetration • no great-vessel or lung injury
Symptoms: Stab wound to the chest
Clinical Procedure: Median sternotomy with controlled removal of the impaled blade under direct vision, followed by video-assisted thoracoscopic surgery
Specialty: Cardiac surgery
Objective: Management of emergency care
Background: Penetrating cardiac box injuries risk cardiac, great-vessel, and pulmonary damage and usually present with hemodynamic instability. A knife impaled there in a stable, ambulatory patient is rare and raises decisions about imaging, surgical approach, and safe removal. This report describes such a patient, in whom blade trajectory and the positioning constraints of the impaled object dictated the operative sequence.
Case Report: A 29-year-old woman presented after self-inflicted injury. She was ambulatory and hemodynamically stable, with a knife impaled in the left hemithorax within the cardiac box. High-sensitivity troponin I was markedly elevated. Point-of-care ultrasound showed a left “barcode sign” (pneumothorax) without pericardial effusion; a chest tube was placed. Contrast-enhanced computed tomography (CT) localized the blade tip millimeters from the left hilum, abutting the left atrial appendage and pulmonary artery, without contrast extravasation. Because the tip abutted the hilum and the knife precluded lateral decubitus positioning, median sternotomy exposed the heart and proximal great vessels before the 9-cm blade was withdrawn under direct vision; no bleeding occurred. The pericardium was unpenetrated. Two small epicardial lesions consistent with contusion were found at the apex. Thoracoscopy after extraction confirmed no lung, hilar, or diaphragmatic injury. She was discharged on postoperative day 10.
Conclusions: In selected stable patients, contrast-enhanced CT trajectory assessment can inform a staged surgical approach sequenced by physiology, trajectory, positioning constraints, and the exposure needed for vascular control. An impaled blade should be removed only in the operating room, under direct vision, and after the structures along its track are exposed.
Keywords: Heart Injuries • Sternotomy • Thoracic Injuries • Thoracic Surgery, Video-Assisted • Wounds, Stab
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Introduction

Penetrating thoracic trauma accounts for a small proportion of trauma admissions but carries disproportionate lethality because of the vital structures at risk. Wounds overlying the cardiac box are particularly concerning for injury to the heart and great vessels [1-3]. The anatomical definition of the cardiac box is not standardized. In this report we use the definition of Jhunjunwala et al: the anterior chest bounded superiorly by the clavicles, laterally by the midclavicular lines, and inferiorly by a line joining the points at which the midclavicular lines meet the costal margins [4]. Other authors delimit the region by the sternal notch, the xiphoid process, and the nipples [5], and the origin and predictive validity of either set of borders are uncertain [4,5]. Whichever borders are used, stab wounds within the cardiac box carry a higher incidence of cardiac injury than stab wounds elsewhere on the thorax (14.3% vs 2.4% in a level I center series) and more often require thoracotomy or sternotomy (21.9% vs 6.4%) [5]. Stab wounds typically cause more localized tissue disruption than ballistic injuries, but their depth and trajectory are unpredictable, and a low-energy entry does not exclude a deep or critical track [6].

A retained or impaled object represents a distinct clinical entity: it may tamponade an underlying vascular or cardiac injury, and premature removal, particularly outside the operating room, can precipitate catastrophic hemorrhage [7,8]. Hemodynamic

stability after a penetrating cardiac box injury, even with an impaled object, is not in itself exceptional [5,9]. The educational contribution of the present case lies instead in its operative sequencing: a blade trajectory ending millimeters from the left hilum, together with the positioning constraints imposed by the protruding handle, dictated contrast-enhanced computed tomography (CT) trajectory mapping, median sternotomy to obtain proximal vascular control before the blade was moved, and thoracoscopy afterward to survey the regions that sternotomy cannot expose. This report describes the patient and the reasoning behind each of these decisions.

Case Report

A 29-year-old woman presented to the emergency department (ED) with a knife impaled in her left hemithorax following self-inflicted injury. There was no relevant medical history. The patient did not smoke, nor did she consume alcohol or illegal substances. After the injury, she contacted emergency medical services and was transported to the ED. On arrival, she was alert and ambulatory, with no respiratory distress. Three self-inflicted stab wounds were present over the left anterior chest within the cardiac box, with the knife remaining impaled (**Figure 1A, 1B**). At the ED, the entry point of the impaled wound was the fourth intercostal space, approximately 3 cm from the left sternal border. The knife handle pointed

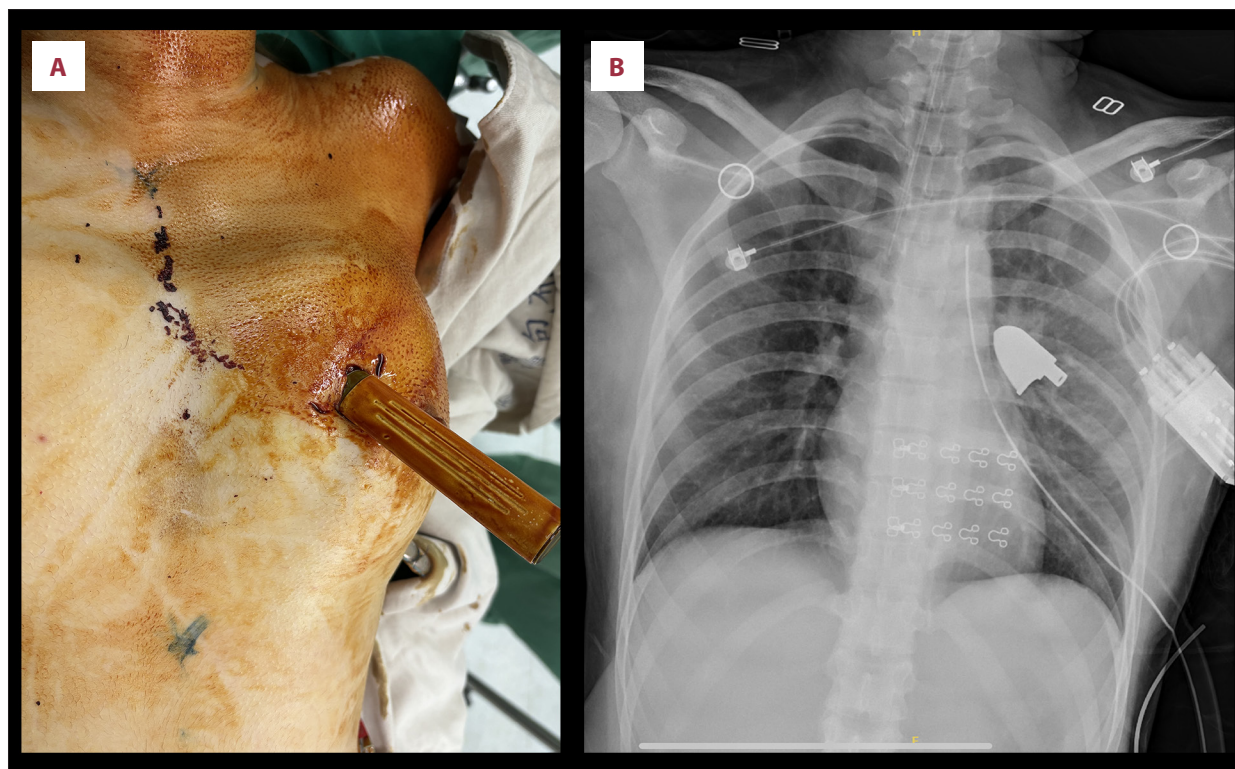


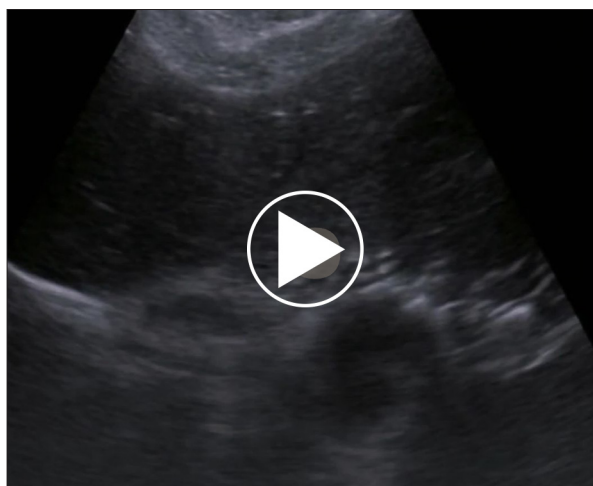
Figure 1. (A) Knife impaled in the left hemithorax on arrival. (B) Left chest tube in situ; residual pneumothorax.



Figure 2. Barcode sign suggesting pneumothorax.

to the patient's left, with the blade oriented from superior to inferior. Two additional wounds were present around the impaled knife. Each measured approximately 1 cm, and there was no active bleeding.

Her vital signs were stable: heart rate 78 beats/min, respiratory rate 16 breaths/min, blood pressure 102/55 mm Hg, temperature 37.4°C, and oxygen saturation 98% on room air. She was conscious and able to talk and walk without discomfort, and she remained hemodynamically stable throughout the primary survey. Peripheral intravenous access was established and blood was drawn. Initial laboratory test results showed hemoglobin level of 11.2 g/dL, white cell count of $27.5 \times 10^9/L$, platelet count of $486 \times 10^9/L$, international normalized ratio of 1.1, activated partial thromboplastin time of 25.3 seconds, fibrinogen level of 234 mg/dL, lactate level of 1.6 mmol/L, creatine kinase level of 134 U/L, and no acidosis on blood gas analysis (pH 7.37, bicarbonate 27.5 mmol/L, base excess +2.2 mmol/L). High-sensitivity troponin I was markedly elevated at 1.82 ng/mL (upper reference limit 0.012 ng/mL). Blood alcohol was undetectable and toxicologic screening was unremarkable. Tetanus toxoid 0.5 mL was given intramuscularly in accordance with national guidance for tetanus-prone wounds, and single intravenous doses of cefazolin 1 g and gentamicin 80 mg were given as prophylaxis. There was no airway compromise, hypoxemia, or respiratory distress, and the patient was calm and cooperative. Nevertheless, the ED team elected to perform endotracheal intubation before the secondary survey. This was an institution-specific decision rather than a routine step. It was performed in an operating-capable trauma bay with the surgical team present, because of the mechanism of injury and the position of the blade, to secure the airway before transfer and imaging in case the patient deteriorated. Induction followed the institutional protocol, with



Video 1. Extended focused assessment with sonography for trauma (e-FAST) demonstrating absence of pericardial effusion.

intravenous midazolam 5 mg followed by rocuronium 50 mg (additional midazolam in 5-mg increments as required), and the trachea was intubated with a video laryngoscope and a 7.5-mm endotracheal tube. Sedation was maintained with a propofol infusion. She remained hemodynamically stable after intubation, and no vasopressors or inotropes were required at any point during her care.

Initial extended focused assessment with sonography for trauma (e-FAST), including subcostal and parasternal cardiac views, demonstrated absent pleural sliding with a left-sided barcode sign (**Figure 2**), consistent with pneumothorax, and no pericardial effusion (**Video 1**). A 28-Fr chest tube was inserted by open technique through the fifth intercostal space in the anterior axillary line immediately after intubation, to offset the risk

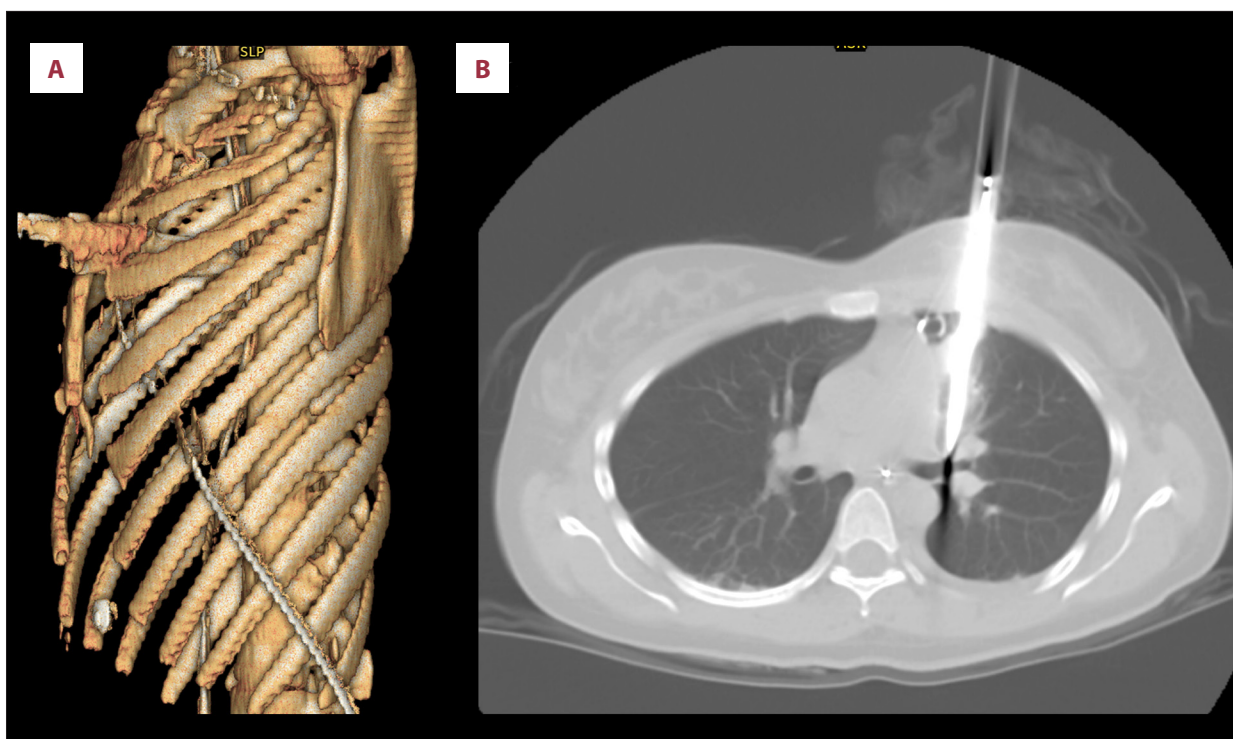


Figure 3. (A) Three-dimensional volume-rendered reformat of the contrast-enhanced whole-body computed tomography showing the blade trajectory, with the tip resting near the left hilum. (B) Axial chest computed tomography showing the intrathoracic course of the blade adjacent to the left hilum, abutting the left atrial appendage and pulmonary artery, without contrast extravasation.

of positive-pressure ventilation with a known pneumothorax. It drained air without blood, and the portable chest radiograph obtained after insertion showed the endotracheal tube and chest tube in position, an unremarkable mediastinum and cardiac silhouette, and only a small residual pneumothorax (**Figure 1B**). There was no ongoing air leak. The absence of bleeding or air leak from the chest tube supported proceeding to CT rather than to immediate operation. Whole-body CT was performed according to the institutional trauma protocol, which applies to all trauma patients (non-contrast acquisition followed by CT angiography and portal-venous phases after intravenous iodinated contrast, 5-mm reconstructions, and multiplanar and 3-dimensional volume-rendered reformats), to define the blade trajectory and for operative planning. The radiologist reported the blade entering through the left chest wall, with hemorrhage along the tract and possible involvement of the lung. The blade closely abutted the wall of the left atrial appendage and the pulmonary artery, with its tip directed toward the left pulmonary artery and the left superior pulmonary vein. There was no contrast extravasation, no aortic injury, and no pericardial effusion, and a left pneumothorax with a small pleural effusion or hemothorax was present with the chest tube in place (**Figure 3A, 3B**). CT therefore excluded active vascular bleeding and aortic injury and located the tip millimeters from the left hilum, but it could not exclude a contained injury to the

structures the tip abutted, and it left open whether the lung parenchyma was injured. During the operation, no parenchymal laceration and no hemothorax were found, and the pneumothorax was attributed to the chest-wall and parietal pleural wounds rather than to lung injury.

The structures at risk, as identified on CT, were the left atrial appendage and the pulmonary artery, which the blade abutted, and the left pulmonary artery and left superior pulmonary vein, toward which the tip was directed; the left ventricular apex, main pulmonary artery, and ascending aorta lay within a few centimeters of the track. Together with the elevated troponin level, which indicated that the heart had already been injured, these findings meant that an occult cardiac or great-vessel injury could not be excluded, and median sternotomy was selected. It exposed the heart, ascending aorta, and main pulmonary artery directly and, after pericardiectomy, the intrapericardial left pulmonary artery and pulmonary veins, so that proximal control could be obtained before the blade was moved, with the option of cardiopulmonary bypass through the same incision. Because sternotomy exposes the posterior hilum and posterior pleural space poorly, thoracoscopy was planned as a second stage. A left anterolateral thoracotomy and supine thoracoscopy were considered and rejected as the initial step for the reasons discussed below; the

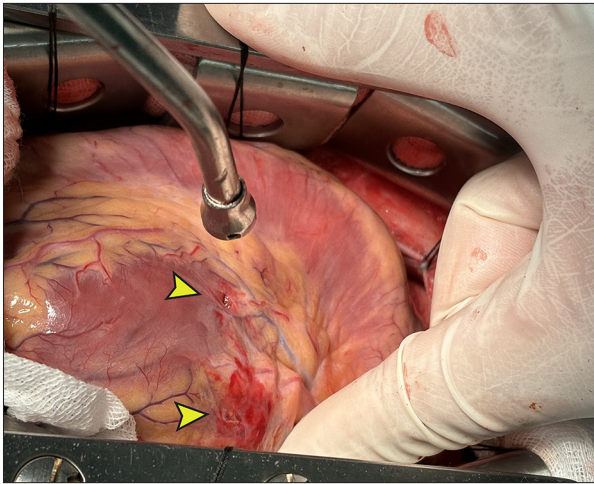


Figure 4. Two small superficial epicardial lesions at the cardiac apex (arrowheads), seen after surgical pericardiotomy and interpreted as pressure-related contusion; the overlying pericardium had not been penetrated.

projecting knife handle also precluded the lateral decubitus positioning that our institution uses for thoracoscopy.

The sternotomy was performed by the cardiovascular surgeon with care to avoid any manipulation of the blade. Before the pericardium was opened, its external surface was inspected and found to be intact, without laceration or hematoma; the knife tip could be palpated abutting and tenting the pericardium from outside without perforating it. On opening the pericardium, a trace of bloody effusion was noted. Inspection of the heart revealed 2 small superficial epicardial lesions (shallow, non-bleeding disruptions of the epicardial surface) near the apex, away from the coronary arteries, requiring no repair (**Figure 4**). They lay directly beneath the point at which the blade tip tented the pericardium. Because the pericardium was not penetrated, direct abrasion by the blade was excluded. Taken together with the troponin elevation measured before surgery, the lesions were interpreted as pressure-related epicardial and myocardial contusion produced by the beating heart against the pericardium tented over the fixed blade tip. This mechanism was presumed rather than proven, and manipulation during pericardial opening or cardiac inspection could not be excluded as a contributor to the surface appearance, although it could not account for the preoperative troponin elevation. With the pericardium open, the heart, ascending aorta, main pulmonary artery, and intrapericardial left pulmonary artery and pulmonary veins were exposed and available for immediate control.

The left pleura was then opened from the sternotomy, the full 9-cm blade was identified along its length, and its relationship to the hilum was inspected directly. Only then was the blade withdrawn along its track under direct vision, with the heart and proximal vessels exposed and instruments ready for immediate



Figure 5. Retrieved 9-cm blade.

control; no bleeding followed extraction (**Figure 5**). Once the risk of extraction-related hemorrhage had passed, the thoracic surgeon performed video-assisted thoracoscopic surgery (VATS) of the left hemithorax with the patient supine, directly inspecting the posterior pleural space, hilum, and diaphragm, to complete the evaluation of the regions poorly exposed by sternotomy. Aside from the entry wound, 2 additional parietal pleural lacerations were noted without active bleeding; there was no lung parenchymal injury, and a water-immersion test was negative for air leak (**Figure 6**). No transdiaphragmatic injury or communication with the abdominal cavity was identified.

The patient was transferred to the intensive care unit. No blood products, inotropes, or vasopressors were required. She was extubated within 6 hours and moved to the ward on postoperative day 1. The chest tube was removed on postoperative day 2. Psychiatric evaluation diagnosed a brief psychotic episode. After confirmation that she was not a danger to herself, she was discharged on postoperative day 10 and remained well at outpatient follow-up.

Written informed consent for publication of the clinical details and the accompanying images was obtained from the patient. The report was approved by the Institutional Review Board of Chang Gung Memorial Hospital (IRB No. 202402277B0), and patient information has been anonymized.

Discussion

Hemodynamic stability after a penetrating cardiac box injury is not unusual. Among 155 stable patients with penetrating cardiac box injuries in the Marseille area (88% stab wounds), only 54% underwent surgical exploration [9]; in a level I center series, stab wounds within the box caused cardiac injury in 14.3% of patients and required thoracotomy or sternotomy in 21.9%, with 1.9% mortality [5]. When the heart is injured, however, outcomes are poor: among 302 patients receiving emergency thoracotomy for penetrating cardiac wounds, survival was 58% after stab wounds and 13% with multiple-chamber or intrapericardial great-vessel injury [10]. Stability therefore does not exclude a track ending

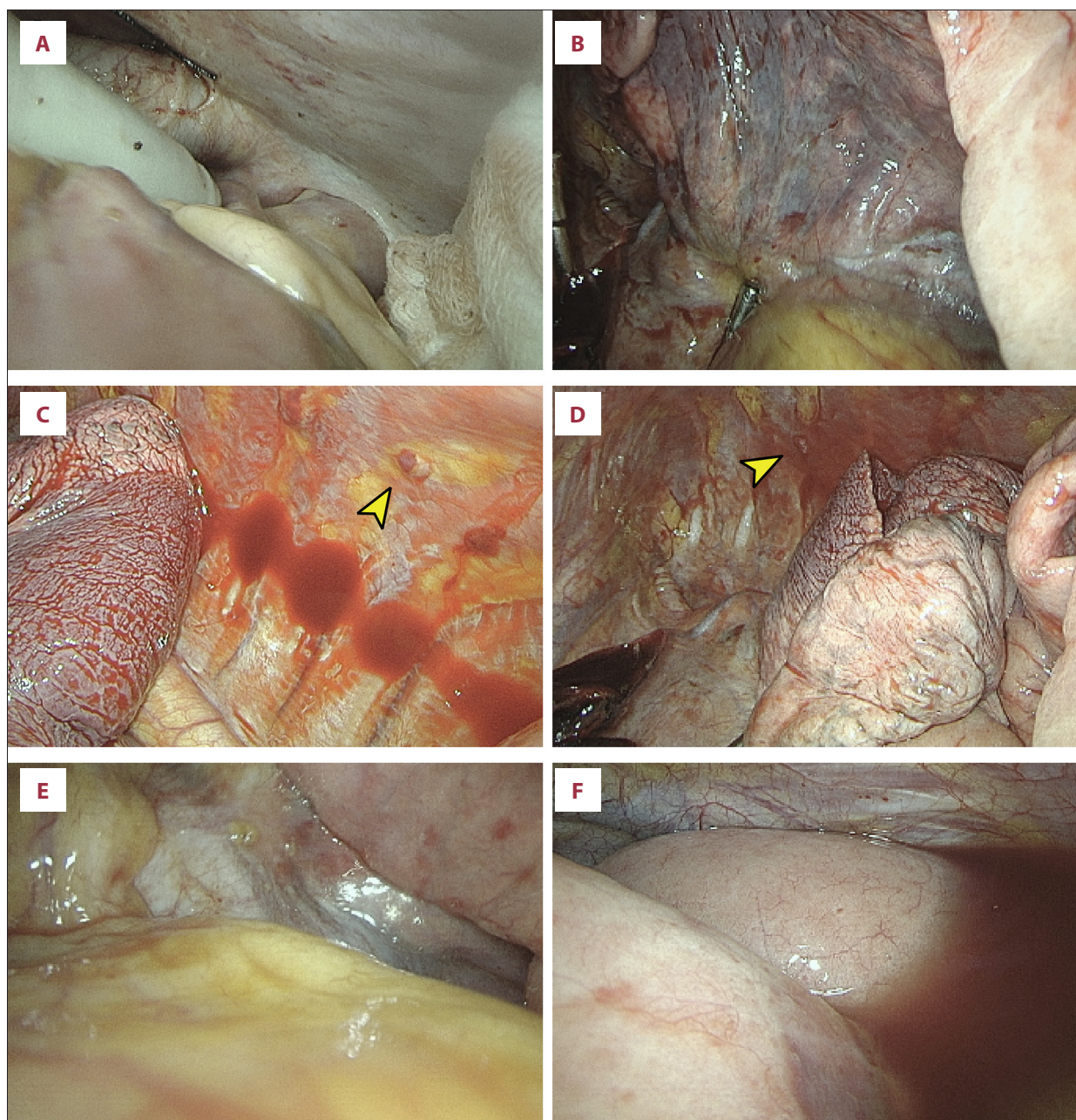


Figure 6. (A) Pericardium without traumatic penetration, viewed thoroscopically from the left pleural space after blade removal (the pericardiotomy for cardiac inspection had been performed through the sternotomy). (B) Normal left lung. (C, D) Two parietal pleural wounds without active bleeding (arrowheads). (E) Intact left hilum. (F) Negative water-immersion test confirming absence of air leak.

against a critical structure, nor does it exclude myocardial injury, as the troponin elevation in our patient showed. This residual risk shaped our decisions. Our contribution is accordingly confirmatory and operational, showing how established trauma tenets can be sequenced when an impaled object constrains positioning and exposure. The discussion below describes the 4 decisions that had to be made: physiological triage, imaging, selection of surgical exposure, and controlled removal of the object.

Physiological Triage

Management is driven first by hemodynamic status, beginning with the Advanced Trauma Life Support (ATLS) primary survey [11]. The Western Trauma Association algorithm separates unstable patients, who require immediate operative exploration, from stable patients, who can undergo focused imaging first [12]. The e-FAST examination identifies pneumothorax,

Table 1. A practical decision aid for the hemodynamically stable patient with a penetrating cardiac box injury.

Step	Action/decision
1. Physiologic triage	Apply ATLS primary survey. Unstable → immediate operative exploration. Stable → proceed to focused imaging (Western Trauma Association algorithm)
2. Do not disturb the object	Leave any impaled object in situ; stabilize it. Never remove in the prehospital setting or emergency department
3. Focused imaging	e-FAST for pneumothorax, hemothorax, and pericardial effusion; treat pneumothorax/hemothorax with tube thoracostomy; record chest-tube output and air leak, which inform the decision to image or to operate
4. Trajectory mapping	Contrast-enhanced CT with multiplanar reformats (when stability allows) to define the track and its relation to heart, great vessels, hilum, and diaphragm; 3-dimensional rendering is optional and may aid operative orientation
5. Select the exposure	Choose the exposure (Table 2) according to the structures at risk along the track, the positioning the object permits, the patient's physiology, and local expertise; the approach must permit control of the structures along the track before the object is moved
6. Controlled removal	Remove the object in the operating room, under direct vision, only after the structures along the track have been exposed and proximal/distal control is available; inspect the full track
7. Complete the survey	If a single approach leaves regions unexposed (eg, posterior hilum/diaphragm after sternotomy), add VATS to complete inspection once the moment of greatest hemorrhagic risk has passed

Abbreviations: ATLS, Advanced Trauma Life Support; CT, computed tomography; e-FAST, extended focused assessment with sonography for trauma; VATS, video-assisted thoracoscopic surgery.

hemothorax, and pericardial effusion. In the Marseille cohort, hemopericardium on e-FAST and chest-tube output discriminated patients who needed a therapeutic operation (median output 600 vs 300 mL), and e-FAST had a negative predictive value of 93% for cardiac injury [9]. Tube thoracostomy is both diagnostic and therapeutic [13]. Cardiac troponin level is a useful adjunct in this setting. In the largest cohort of stable patients with penetrating anterior chest injuries (n = 256, 65% stab wounds), troponin T had a sensitivity of 90.5% for occult cardiac injury against definitive modalities but a specificity of only 37.5% [14], so a normal value is reassuring, whereas an elevated value, as in our patient, means that cardiac injury must be excluded by imaging or direct inspection even when physiology is normal. Our decision to intubate an alert, oxygenating patient needs justification. In the INTUBE cohort, cardiovascular instability followed 42.6% of emergency intubations of critically ill patients [15], and intubation removed clinical examination as a monitor. It was an institution-specific judgement taken with surgical backup in the trauma bay, not a routine step, and proceeding to CT awake with the airway team present would have been equally defensible. **Table 1** integrates these steps into a decision aid.

Imaging

Contrast-enhanced multidetector CT is the established modality for defining the trajectory of a penetrating wound or retained object and its relationship to the heart, great vessels,

hilum, and diaphragm, and it reduces non-therapeutic exploration [6,16-18]. Three-dimensional rendering is a display derived from the same acquisition; it aided orientation in our case, but its incremental value over multiplanar contrast-enhanced images is not established and is case-dependent. CT also has to be read for what it can and cannot exclude. In our patient, it excluded active bleeding, aortic injury, and hemopericardium, but the radiologist could not settle whether the lung had been injured, and it was thoracoscopy that excluded parenchymal injury and attributed the pneumothorax to the chest-wall and pleural wounds. Most importantly, CT could not exclude a contained injury where the tip abutted the left atrial appendage and pulmonary artery; this residual uncertainty, reinforced by the troponin elevation, rather than the imaging findings themselves, determined the need for an approach allowing proximal vascular control.

Selection of Surgical Exposure

The exposure follows from the trajectory, structures at risk, positioning the object permits, and the patient's physiology rather than from habit or a fixed hierarchy. **Table 2** presents the options as anatomy- and physiology-dependent alternatives. In stable patients, VATS allows complete inspection of the pleural space, diaphragm, and lung, as well as treatment of retained hemothorax, air leaks, and diaphragmatic lacerations, with low morbidity. It can be converted to thoracotomy if instability develops or a major injury is identified [19-23]. In

Table 2. Surgical exposure options for penetrating chest trauma, presented as anatomy- and physiology-dependent alternatives.

Approach	Access/advantages	Limitations	Circumstances favoring this exposure
Diagnostic VATS (utility incision)	Inspects pleural space, diaphragm, lung; treats retained hemothorax, air leak, diaphragmatic injury; low morbidity; convertible	Usually performed in lateral decubitus (supine or semi-supine thoracoscopy is feasible for selected anterior injuries, depending on equipment and expertise); requires hemodynamic stability; limited for active great-vessel/cardiac bleeding; an impaled object may prevent positioning or port placement	Stable patient; imaging excludes major mediastinal injury; positioning compatible with the retained object
Anterolateral thoracotomy	Rapid entry; access to lung, hilum, pericardium; extensible to clamshell	Limited contralateral and posterior mediastinal access; less reliable control of the main pulmonary artery and ascending aorta	Instability; need for rapid one-sided control; track directed at the hilum or lung with the heart and proximal great vessels not at risk
Median sternotomy	Direct access to heart, ascending aorta, proximal great vessels, and (after pericardiotomy) the intrapericardial pulmonary artery and veins; proximal control; permits cardiopulmonary bypass	Poor exposure of posterior hilum, descending aorta, and posterior pleural space; insufficient alone for hilar evaluation	Suspected cardiac or proximal great-vessel injury; track abutting the heart, proximal great vessels, or anterior mediastinum; retained object that prevents lateral positioning
Clamshell (bilateral) thoracotomy	Widest exposure of both pleural cavities, heart, and great vessels	Most invasive; greatest morbidity	In extremis; bilateral or undefined major injury

Abbreviation: VATS, video-assisted thoracoscopic surgery.

the Marseille cohort, VATS accounted for 42% of explorations, with a conversion rate of 14% [9]. VATS is usually performed in the lateral decubitus position, although supine or semi-supine thoracoscopy is feasible for selected anterior injuries, depending on equipment and expertise. In our patient, the projecting handle prevented the lateral positioning our institution uses, and performing thoracoscopy first would have left the hilar vessels uncontrolled at extraction. Anterolateral thoracotomy gives direct access to the left hilum and lung and is extensible to a clamshell incision, but it controls the main pulmonary artery and ascending aorta less reliably. Median sternotomy provides direct access to the heart, ascending aorta, and proximal great vessels and, through the opened pericardium, to the intrapericardial left pulmonary artery and veins and to the left atrial appendage, the structures that CT showed the blade to abut or point toward; it also permits cardiopulmonary bypass. Its poor exposure of the posterior hilum, descending aorta, and posterior pleural space is real, and sternotomy alone is insufficient to evaluate the hilum. The 2 statements are compatible: sternotomy was chosen for the structures it controls during extraction, and VATS was added afterward to inspect what sternotomy could not show, once the moment of greatest hemorrhagic risk had passed.

Controlled Removal of the Object

Removal of the impaled object is where avoidable deaths occur. A retained blade may tamponade an underlying injury; it should never be withdrawn in the prehospital setting or the ED [7,8]. Removal should take place in the operating room, under direct vision, only once the approach chosen has exposed the structures along the track. In our patient, before the blade was withdrawn along its track, the pericardium had been opened to expose the heart and proximal great vessels and the left pleural space had been opened to allow inspection of the full length of the blade and its relationship to the hilum, with cardiopulmonary bypass available through the same incision. Thoracoscopy followed, rather than preceded, extraction because the handle in situ compromised positioning and port placement and because the sternotomy already provided the vascular control that thoracoscopy could not.

This reasoning applies to a hemodynamically stable patient and the following criteria: CT of quality sufficient to define the track and its relation to the hilum and mediastinum, an impaled object whose position and positioning constraints are compatible with the chosen approach, and access to both

open and thoracoscopic expertise so that the strategy can be tailored and, if needed, converted; where these conditions are not met, immediate operative exploration by the most familiar route should take precedence.

This report has further limitations. It describes a single patient, so the approach described is intended as a decision aid for reasoning in similar stable presentations rather than a validated protocol, and the optimal approach remains institution-dependent. The mechanism of the epicardial lesions is inferred from their position beneath the tented pericardium and from the preoperative troponin elevation and cannot be proven. Manipulation during pericardial opening or cardiac inspection cannot be excluded as a contributor. Intraoperative imaging of the pericardium before pericardiotomy was limited, and clearer documentation of its surface would have strengthened the description.

Conclusions

This case illustrates that marked anatomic risk within the cardiac box can coexist with initial hemodynamic stability, which makes trajectory-based planning and controlled extraction especially important. In selected stable patients, physiology-based triage and contrast-enhanced CT-defined trajectory assessment can inform a tailored, staged surgical approach, and an impaled blade should be removed in the operating room, under direct vision, only after the structures along its track have been exposed for vascular control. Operative sequencing should be individualized according to physiology, trajectory, the positioning constraints imposed by the object, and the exposure required

for vascular control, rather than following a fixed pathway. In our patient, this meant performing sternotomy first and thoracoscopy second. This staged approach applies to cases in which imaging is adequate to define the injury trajectory and in which both open and thoracoscopic surgical capability are available.

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Department and Institution Where Work Was Done

Chang Gung Memorial Hospital, Linkou Medical Center, Taoyuan, Taiwan.

Patient Consent and Ethics Approval

This study was approved by the Institutional Review Board of Chang Gung Memorial Hospital (IRB number 202402277B0). Written informed consent for publication, including images, was obtained from the patient. Patient information was anonymized.

Declaration of Figures' Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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