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Emergency Department Thoracotomy

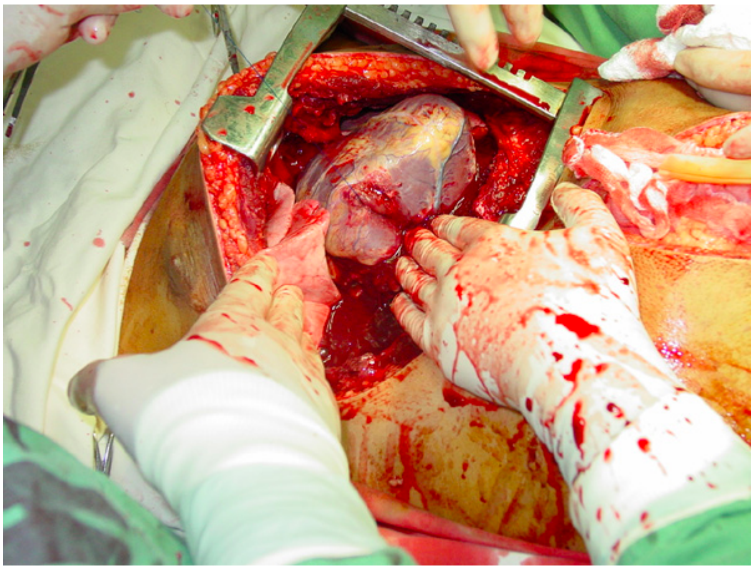
Indications and technique of resuscitative thoracotomy

Karim Brohi, London, UK, September 30, 2006

"The surgeon who should attempt to suture a wound of the heart would lose the respect of his surgical colleagues" - Theodore Billroth, 1882

Introduction

Many surgeons still share the pessimism of Bilroth when discussing emergency thoracotomy. Nevertheless, current studies have shown survival rates approaching 60% in selected groups of patients. Shortly after Bilroth dismissed surgery for cardiac injury, the first report of successful management of traumatic cardiac injury was published by Rehn in 1900. The first successful 'prehospital' thoracotomy and cardiac repair was carried out by Hill on a kitchen table in Montgomery, Alabama in 1902.



Emergency department thoracotomy is a life-saving procedure in a select group of patients. Exactly who these patients are is a matter of some controversy in the trauma literature. There is a significant amount of published data on the indications for and outcomes of resuscitative thoracotomy. However the results of interventions varies widely, as does each unit's experience, puclished data ranging for 11 patients in 10 years to 950 patients in 23 years.

Most studies give little indication as to what has gone before (apart from physiological data). Prehospital data such as time of injury, paramedic on-scene time and time in the emergency department prior to thoracotomy are rarely given. The use of prehospital manoeuvers that may worsen outcome, such as external chest compressions and large volume fluid resuscitation, are also not routinely published. Similarly, the indications for performing surgery are not uniform and inconsistently applied, or not recorded at all. There are only 3 prospective studies in the literature.

Indications

While the technique of emergency thoracotomy is fairly standard, the indications for performing surgery remain a source of controversy. The following are a suggested set of guidelines for general use. In practice these will vary with local resources and skill availability.

Accepted Indications

Penetrating thoracic injury

- Traumatic arrest with previously witnessed cardiac activity (pre-hospital or in-hospital)
- Unresponsive hypotension (BP < 70mmHg)

Blunt thoracic injury

- Unresponsive hypotension (BP < 70mmHg)
- Rapid exsanguination from chest tube (>1500ml)

Relative Indications

Penetrating thoracic injury

- Traumatic arrest without previously witnessed cardiac activity

Penetrating non-thoracic injury

- Traumatic arrest with previously witnessed cardiac activity (pre-hospital or in-hospital)

Blunt thoracic injuries

- Traumatic arrest with previously witnessed cardiac activity (pre-hospital or in-hospital)

Contraindications

Blunt injuries

- Blunt thoracic injuries with no witnessed cardiac activity
- Multiple blunt trauma
- Severe head injury

Rationale

Overall survival of patients undergoing emergency thoracotomy is between 4 and 33% depending on the protocols used in individual departments. The main determinants for survivability of an emergency thoracotomy are the mechanism of injury (stab, gunshot or blunt), location of injury and the presence or absence of vital signs.

Mechanism of Injury

For penetrating thoracic injury the survival rate is fairly uniform at 18-33%, with stab wounds having a far greater chance of survival than gunshot wounds. Isolated thoracic stab wounds causing cardiac tamponade probably have the highest survival rate, approaching 70%. In contrast, gunshot wounds injuring more than one cardiac chamber and causing exsanguination have a much higher mortaility.

Blunt trauma survival rates vary between 0 and 2.5% and some authorities suggest that thoracotomy for blunt trauma should be abandoned altogether. However, this is an oversimplification of the literature. There is a distinct survival rate for patients with isolated blunt thoracic trauma who undergo emergency thoracotomy. This is highest for patients who are severely hypotensive in the emergency room and are exsanguinating from a chest injury. Blunt thoracic trauma causing traumatic arrest in the emergency department should also undergo thoracotomy. Whether this should be extended to those patients arresting in the presence of prehospital emergency services is debatable.

Location of Injury

Almost all survivors of emergency thoracotomy suffer isolated injuries to the thoracic cavity. Cardiac injuries have the highest survival rates, with improved outcome for single chamber versus multiple chamber injuries. Injuries to the great vessels and pulmonary hila carry a much higher mortality. Injuries to the chest wall rarely require emergency thoracotomy but tend to have a good outcome.

The rationale for performing thoracotomy for injury to other parts of the body, such as the abdomen or pelvis, is to cross-clamp the descending aorta and so control exsanguination and redistribute blood flow to the vital organs. Penetrating injury to the abdomen may benefit from this manoeuver but thoracotomy for multiple blunt trauma has an almost universally poor outcome.

Presence of vital signs

The presence of cardiac activity, or the amount of time since loss of cardiac activity is consistently related to the outcome following emergency thoracotomy. In one study of 152 patients (Tyburski) survival rates were 0% for those patients arresting at scene, 4% when arrest occurred in the ambulance, 19% for emergency department arrest and 27% for those who deteriorated but did not arrest in the emergency department.

Survival for blunt trauma patients who never exhibited any signs of life is almost uniformly zero. Survival for penetrating trauma patients without signs of life is between 0 and 5%.

Resuscitation

What does and does not happen before and during the emergency thoracotomy is as important as the operative procedure itself. Many patients die because of inappropriate interventions in the prehospital or early in-hospital phase, because of delay in performing thoracotomy and due to poor peri-operative management.

ALS/ACLS algorithms DO NOT APPLY to traumatic arrest.

The primary causes of traumatic arrest are hypoxia, hypovolaemia due to haemorrhage, tension pneumothorax, and cardiac tamponade. Hypoxic arrests respond rapidly to intubation and ventilation. Hypovolaemia, tension pneumothorax and cardiac tamponade are all characterised by loss of venous return to the heart. External chest compressions can provide a maximum of 30% of cardiac output in the medical arrest situations and are dependent on venous return to the heart. Chest compressions in the trauma patient are wholly ineffective, may increase cardiac trauma by causing blunt myocardial injury and obstruct access for performing definitive manoeuvers.

The administration of inotropes and vasopressors such as adrenaline to the hypovolaemic patient (who is already maximally vasoconstricted) causes profound myocardial hypoxia and dysfunction.

Management of Traumatic Arrest

Immediate treatment of traumatic arrest is directed at treating the cause of the traumatic arrest.

Hypoxic arrest

Tracheal intubation is mandatory and should be secured immediately. Ventilation with 100% oxygen should rapidly reverse hypoxic traumatic arrest without the need for further interventions. This is especially true of paediatric head injuries.

Tension pneumothorax

Relief of tension pneumothorax should be accomplised rapidly either by needle chest decompression or preferably bilateral thoracostomies (as per chest tube insertion). Bilateral tension pneumothoraces may exist and the classic signs of a tension (tracheal deviation, unilateral hyperresonance) may not be present. Tension pneumothoraces should therefore be presumed and bilateral decompression undertaken in all cases of traumatic arrest.

Massive haemorrhage

Performing bilateral thoracostomies has the advantage of identifying major haemorrhage and which side of the chest the major injury is on. This will determine the initial incision for the thoracotomy.

The treatment of massive thoracic haemorrhage is control of haemorrhage, not intravenous fluid therapy. Fluid therapy prior to haemorrhage control worsens outcome in penetrating thoracic trauma (and perhaps all penetrating trauma patients). If there is no response to a small (500ml) fluid challenge, fluid administration should be halted until haemorrhage control is achieved.

Cardiac tamponade

The classic signs of distended neck veins and muffled heart sounds are almost universally absent in traumatic cardiac tamponade. Needle pericardiocentesis may also fail as a diagnostic measure due to blood in the pericardial sac being clotted. FAST ultrasound scan, if available, will indicate the presence of pericaridal fluid. The pericardium may be felt through the left thoracostomy to assess for the presence of tamponade.

Anaesthesia

Patients in traumatic arrest will not require induction of anaesthesia prior to intubation and thoracotomy. Patients who are hypotensive but awake will require a modified rapid sequence intubation. Induction of anaesthesia may lead to a dramatic loss of blood pressure and care should be taken with the choice of induction agent. Ketamine and/or an opiate (such as fentanyl or alfentanil) may be preferable to the standard intravenous induction agents. Even etomidate may cause a large fall in cardiac output in the hypovolaemic patient. Anaesthesia may be maintained with an infusion or bolus doses of intravenous anaesthetic. Muscle relaxation is maintained throughout.

Fluid Therapy

Large-volume fluid therapy should be avoided prior to haemorrhage control. Once haemorrhage is controlled patients will need rapid correction of hypovolaemia to refill the heart and restore perfusion to non-vital organ systems. Patients will be cold and profoundly coagulopathic. Blood and component therapy should be warmed and administered rapidly AFTER haemorrhage is controlled. See 'Transfusion for Massive Blood Loss'. Administration of colloid solutions is not indicated.

Inotropic / Vasopressor administration

As mentioned above, the use of adrenaline (or other inotropes/pressors) is contra-indicated in the presence of hypovolaemia. Inotropes may be required after control of haemorrhage and cardiac repair. Direct myocardial injury, ischaemic myocardial injury, acute cardiac dilatation, pulmonary hypertension and mediator release due to global tissue ischaemia can all lead to cardiogenic shock which may require inotropic support.

Operative Technique

The primary aims of emergency thoractomy are:

- Release of cardiac tamponade
- Control of haemorrhage
- Allow access for internal cardiac massage

Secondary manoeuvers include cross-clamping of the descending thoracic aorta.

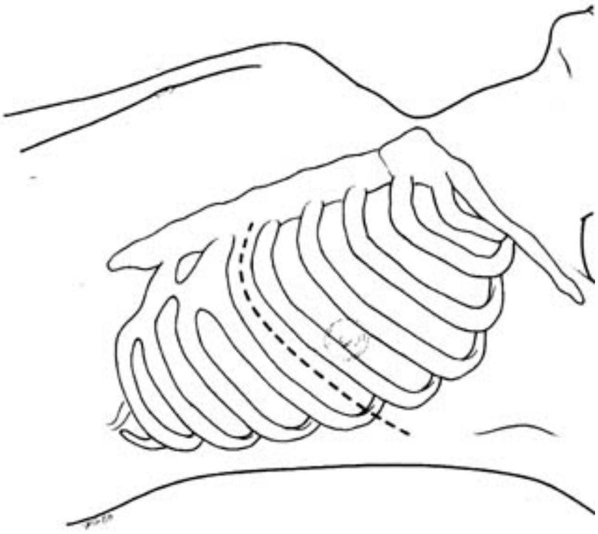
Once control is achieved and cardiac activity restored, the patient is transferred rapidly to the operating room for defintive management.

Equipment

Approach:	
Scalpel with 10 blade	
Curved Mayo scissors	
Rib spreader	
Gigli saw or large 'trauma' shears	
Haemorrhage control:	
McIndoe / Metzenbaum scissors	3/0 non-absorbable suture (nylon, polypropene) on round-bodied needles - multiple
DeBakey vascular forceps (long)	2/0 absorbable ties (vicryl, pds etc) - multiple
DeBakey aortic clamp	Laparotomy packs
Satinsky vascular clamp (large & small)	Teflon pledgets - small. (10)
Mosquito / Dunhill artery clips (10)	
Long & short needle holders	
High volume, high-displacement suction	

Approach

A supine anterolateral thoracotomy is the accepted approach for emergency department thoracotomy. A left sided approach is used in all patients in traumatic arrest and with injuries to the left chest. Patients who are not arrested but with profound hypotension and right sided injuries have their right chest opened first.



In both cases it may become necessary to extend the incision across the sternum to aid access and vision. With a right sided thoracotomy, the left chest will have to be opened if internal cardiac massage becomes necessary.

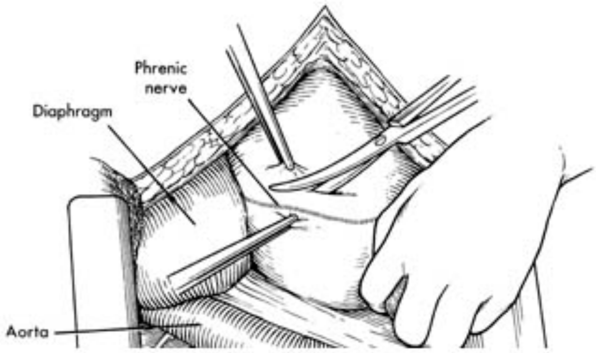
Gaining access to the thoracic cavity should take no more than 1-2 minutes. After rapid skin preparation with large antiseptic-soaked swabs, a skin incision is made in the 5th intercostal space from the border of the sternum to the mid-axillary line. This is continued down through subcutaneous tissues to reach the intercostal musculature. Enter the chest bluntly with a finger through the intercostal muscles (as with a chest tube insertion). The opening is extended with a combination of heavy scissors and blunt dissection. Take care not to lacerate the lung at this stage. Insert the rib spreaders between the ribs and open.

If the thoracotomy has to be extended to the other side of the chest, repeat the thoracotomy on the other side. To divide the sternum, a large pair of trauma shears (as used to cut the clothes off patients) will easily go through the sternum. Otherwise the Gigli saw is used to divide the sternum. The first time you see a Gigli saw should not be the first time you perform a thoracotomy. Examine one to see how it is put together and practice the action needed to saw through bone. Once through the sternum the rib spreader is moved to the midline to open the chest at the sternum.

Division of the sternum results in transection of the internal mammary arteries. These will start to bleed once blood pressure is restored and will need clipping and ligation subsequently.

Relief of tamponade

The pericardium is opened longitudinally to avoid damage to the phrenic nerve, which runs along its lateral border. It is difficult to visualise the phrenic nerve in the emergency thoracotomy. Make a small incision inthe pericardium with a scalpel and then tear the pericardium longitunidally with your fingers - this will avoid lacerating the phrenic nerve. Extend the incision with scissors up to the root of the aorta. If necessary more access can be gained by extending the base of the incision as an inverted 'T'. Evacuate any blood and clot from the pericardial cavity.

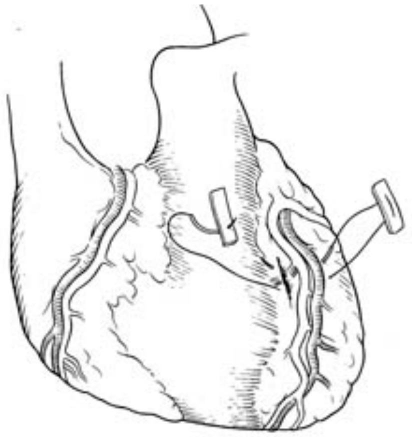


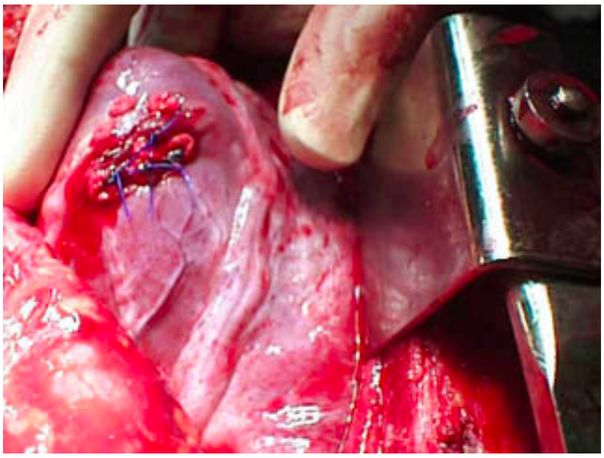
Control of haemorrhage

Cardiac wounds

Cardiac wounds should be controlled initially with direct finger pressure. Large wounds may be controlled temporarily by the insertion of a foley catheter with inflation of the balloon. The balloon may obstruct inflow or outflow tracts however and it may also lead to extension of the laceration if excessive traction is placed on it. Satinsky clamps can be placed across wounds of the atria to control haemorrhage. With extensive cardiac damage it may be necessary to temporarily obstruct venous inflow to allow repair. Take care also not to miss posterior cardiac wounds. Examination of the posterior surface of the heart requires displacing it anteriorly, which may obstruct venous inflow.

Cardiac wounds can be directly sutured using non-absorbable 3/0 sutures such as nylon or polypropene. Bypass is unnecessary, even in the beating heart. Teflon pledgets are unnecessary in the left ventricle but, if available, may be used in the right ventricle. With wounds in the region of the coronary vessels, mattress sutures are used to avoid obstructing coronary flow. Atrial wounds are sutured using a continuous technique.





Pulmonary & Hilar injuries

Massive haemorrhage from the lung or pulmonary hilum can be temporarily controlled with finger pressure at the pulmonary hilum. This may be augmented by placement of a Satinsky clamp across the hilum. This can however cause laceration of the pulmonary veins when used emergently by the inexperienced surgeon. An alternative is to tie off the pulmonary hilum using tracheal tube tie or tape from a laparotomy pack.

Acute occlusion of the pulmonary hilum often leads to immediate acute right heart failure, especially in the young fit adult. This needs to be recognised early and managed with only partial or intermittent occlusion of the pulmonary hilum.

Lesser haemorrhage from the lung parenchymas can be controlled with a temporary clamp.

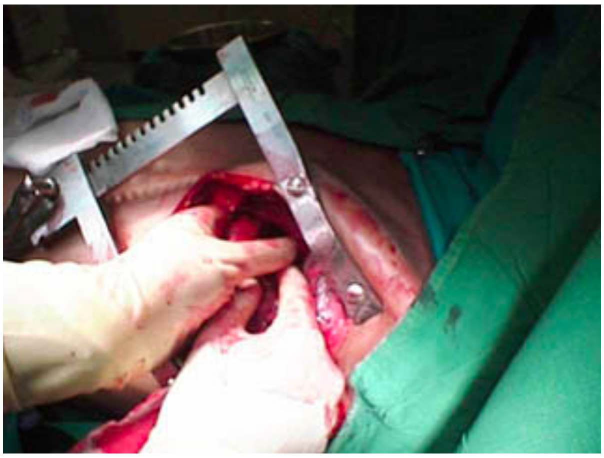
Great vessel injuries

Small aortic injuries can be sutured directly using the 3/0 non-absorbable suture. Larger injuries, especially to the arch may require temporary digital occlusion and insitution of cardiac bypass.

Access to the vascular structures of the superior mediastinum is difficult with an anterolateral thoracotomy. The sternum may have to be split in the midline and/or a supraclavicular incision used to control haemorrhage from subclavian and innominate vessels. Again, control is achieved temporarily with digital pressure or proximal & distal clamp application prior to defintive repair.

Internal cardiac massage

In traumatic arrest, internal cardiac massage should be started as soon as possible following relief of tamponade and control of cardiac haemorrhage. A two-handed technique produces a better cardiac output and avoids the low risk of cardiac perforation with the one-handed manoeuver.



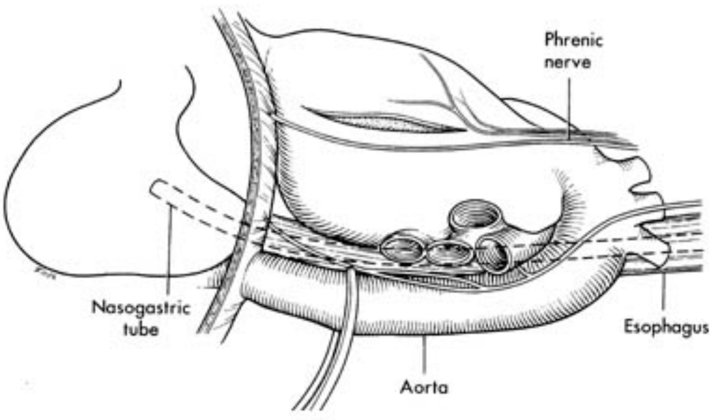
Aortic cross-clamping

Cross-clamping of the descending thoracic aorta is used routinely in some centres and not at all in others during emergency thoracotomy. The rationale for clamping the aorta is to redistribute blood flow to the coronary vessels, lungs and brain, to reduce exsanguination from injuries in the lower torso.

The efficacy of the aortic cross clamp in improving perfusion of the coronary arteries and brain is unclear however. Over-zealous fluid replacement with the aortic clamp in place may lead to a significant rise in afterload and precipitate cardiac failure.Organs distal to the clamp will become ischaemic and this includes the spinal cord when the clamp is placed higher, at the aortic isthmus. Clamp time should ideally be 30 minutes or less. On removal of the clamp there is reperfusion of the ischaemic lower torso, and products of anaerobic metabolism and activated inflammatory mediators are released back into the system. This may lead to myocardial depression and subsequent systemic inflammatory response syndrome.

Cross-clamping of the descending thoracic aorta should possibly be reserved for patients with potential exsanguinating injuries to the distal torso.

Cross-clamping is done ideally at the level of the diaphragm, to maximise spinal cord perfusion. Otherwise just below the left pulmonary hilum. The lung is retracted anteriorly and the mediastinal pleura incised. Blunt disection is used to separate the aorta from the oesophagus and prevertebral fascia. This dissection should be enough to place a clamp across the aorta but not complete, to avoid avulsing aortic branches supplying the cord and thorax.



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