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Chest drains – An overview

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Abstract

Chest drains are used in a number of circumstances for the treatment of specific conditions and also for symptomatic relief, and hence insertion of a chest drain can be a life-saving intervention. Therefore, it is imperative that every hospital doctor is familiar with the indications and the principles of safe chest drain insertion. The knowledge of chest drain management following insertion is equally essential. Appropriate chest drain insertion and management underpins the management of chest trauma. Appropriate chest drain management will allow for resolution and management of the underlying clinical condition. This review article outlines the indications, contraindications, and principles of chest drain insertion. Furthermore, it provides an overview of chest drain management and associated complications. Although this review refers to a surgically placed chest drain, the same principles can be applied to a chest drain that is inserted percutaneously.

Keywords

Chest drain, suction, surgery, thoracic, trauma

Introduction

The insertion of a chest drain in appropriate circumstances can be life saving as well as offering symptomatic relief and the correct treatment for a number of conditions. This applies equally to civilian and military trauma patients and to in-hospital patients in other speciality settings. A quarter of trauma-related deaths in the United Kingdom can be attributed to thoracic injuries[1,2] ranging from rib fractures through to penetrating cardiac injuries and disruption of major vessels. Early identification of the requirement for a chest drain and correct placement with appropriate post-insertion management are essential.

Thoracic trauma includes both blunt and penetrating injuries. Blunt vehicle-related trauma is more common in the civilian population and usually results from rapid deceleration or crush injuries following a road traffic collision. Penetrating trauma is traditionally more common in military patients and results from gunshot or fragmentation injuries. However, some more recent military injuries have been a combination of blast, blunt, and penetrating injuries. Blast and blunt injuries have the potential to cause significant pulmonary contusions and may require chest drain placement to manage the resulting pulmonary complications.

In a more urban environment, there is now an increasing number of penetrating injuries amongst civilians. The majority of these injuries can be managed without radical surgical intervention and with appropriate chest drain management. In-hospital patients requiring chest drain placement and management can range from post-operative general surgical or cardiac patients to those with general medical or respiratory conditions.

Therefore, every hospital doctor should be trained in, and capable of, inserting and managing a chest drain safely. The *Advanced Trauma Life Support (ATLS)* course and *Trauma Care Manual* provide guidelines for the insertion of chest drains in the emergency setting.[3,4] The British Thoracic Society (BTS) provides guidelines for the insertion of drains by physicians in a controlled environment.[5] We present a review of the indications, contraindications, and technique of

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insertion and removal, maintenance, and complications of chest drainage for civilian and military patients.

Indications for chest drain insertion

The role of a chest drain is to drain the pleural space and restore the negative intra-thoracic pressure necessary for lung expansion. Usually, the contents requiring draining are air or blood but they may include chyle, empyema, and gastric or oesophageal contents.

In the trauma patient, the primary aim of a chest drain is to avoid mortality secondary to hypoxia, hypovolaemia, and cardiac or pulmonary injuries. In the post-thoracotomy patient, chest drains are placed to avoid development of a pleural collection and to aid lung expansion. In the post-cardiac surgery patient, drains are placed to avoid pleural and mediastinal collections, allow assessment of ongoing bleeding and to avoid tamponade in the presence of such bleeding. The indications for chest drain insertion are outlined below:[5]

- Pneumothorax
  - Tension pneumothorax
  - Open pneumothorax/traumatic pneumothorax
  - Simple pneumothorax
  - Recurrent pneumothorax
- Pleural effusion or haemothorax
- Haemopneumothorax (usually in the trauma patient)
- Post-operative, i.e. thoracotomy, cardiac surgery, and oesophagectomy

In a stable patient, it may be useful to wait for a chest radiograph to confirm an indication for chest tube insertion, if this can be done without delay. However in the trauma setting where there are unilateral chest signs or evidence of penetrating trauma, a chest drain should be placed as an emergency without waiting for radiological confirmation. Bilateral chest drain insertion may be a requirement in the unstable polytrauma patient. Chest drain insertion is indicated in any patient who has developed a pneumothorax and requires positive pressure ventilation, general anaesthesia, and intubation or transport.

Pre-hospital

Pre-hospital chest drain placement may be indicated for life-threatening conditions such as open pneumothorax, tension pneumothorax, flail chest, and massive haemothorax. Chest drains may be placed by appropriately trained paramedics or medical personnel at the scene of injury.

A prospective study looking at pre-hospital chest tube insertion showed a <1% rate of missed pneumothoraces and 2.4% non-therapeutic chest tube insertions rate. Of 76 chest tubes placed, 4 required re-positioning due to malfunction or mal-positioning and there were no intra-parenchymal tube placements.[6] Pre-hospital chest tube placement has been associated with similar infection rates to emergency room tube placements.[7] These studies have shown that pre-hospital chest drains can be placed safely and effectively by trained individuals.

It is worth considering that a review of casualties from the Vietnam War showed that 3%–4% of casualties died secondary to a tension pneumothorax and these soldiers may have been helped by a battlefield chest drain insertion.[8]

Contra-indications for chest drain insertion

Differentiation between a pneumothorax and bullous disease should be made before chest drain insertion. This may require careful and thorough radiological investigations. Furthermore, drainage under radiological guidance in patients with large bullae may be the preferred option.

In cases of complete unilateral 'white out' on chest radiography, differentiation should be made between consolidation and pleural effusion or haemothorax before chest drain insertion. In these cases, an ultrasonographic assessment may be useful.

Prior to chest drain insertion, the clotting status, including platelet function or coagulopathy should be checked and corrected, thus avoiding the risk of haemorrhage. Correction of clotting is only prudent in the stable, non-trauma patient where there is no clinical urgency for chest drainage.

Lung densely adherent to the chest wall throughout the hemithorax is an absolute contraindication to chest drain insertion.[5]

Intercostal chest drain insertion

Equipment

All equipment for the insertion of a chest drain should be available and prepared before commencing the procedure. The equipment necessary will depend on the type of chest drain being inserted. The equipment needed for insertion of a large bore drain is as follows:

- Sterile gloves, gown, and drapes
- Skin prep (Chloprep, Iodine, and Chlorhexidine)
- Local anaesthetic, i.e. lidocaine (1%/2%)
- 10-ml syringe and green needle
- Cut down set (inc blunt clip for blunt dissection)
- Gauze swabs
- Large bore chest tube

- Scalpel and blade
- Suture (1/0 silk)
- Drainage bottle with sterile water for underwater seal
- Connecting tubing
- Appropriate dressing

Applied anatomy for insertion

The ideal and safest position for insertion of an intercostal chest drain is in the fifth intercostal space in the mid-axillary line, within the '*triangle of safety*'.[5,9–13] The anterior border of the triangle of safety is formed by the lateral border of Pectoralis Major, the posterior border is formed by the anterior border of Latissimus Dorsi and the triangle's inferior border is formed by an imaginary line running horizontally just inferior to the level of the nipple. The triangle has an apex within the axilla.

Knowledge of surface anatomy, underlying structures, and viscera is important to avoid neurovascular damage to the chest wall and injury to intra-thoracic or intra-abdominal viscera. Positioning a chest tube within the triangle of safety avoids damage to muscle and breast tissue (Figure 1).

The fifth intercostal space is located by counting the ribs down from the manubrio-sternal angle (angle of Louis). The angle of Louis is located by initially identifying the supra-sternal notch and palpating down the manubrium. The second intercostal space corresponds to the manubrio-sternal joint as the second costal cartilage is located here. From here, the fifth intercostal space is identified by counting down the intercostal spaces.

The neurovascular bundle is found within each intercostal space, protected in the subcostal grove of the rib. It runs between the second and third layer of the intercostal muscles. Hence, it is important to place the chest tube within the intercostal space above and over the rib. The risk of diaphragmatic and intra-abdominal injury is higher if the drain is placed below the fifth intercostal space as the apex of the dome of the diaphragm reaches the fifth intercostal space. This is higher on the right than the left due to upward pressure by the liver. Perforation of the diaphragm can lead to injury to the liver, stomach, or spleen.

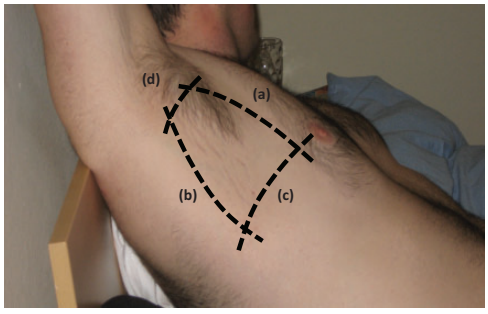

Figure 1. Triangle of safety, (a) The anterior border – lateral border of Pectoralis Major, (b) the posterior border – anterior border of Latissimus Dorsi, (c) the inferior border – an imaginary line running horizontally just inferior to the level of the nipple and (d) the triangle has an apex within the a-xilla (Image produced by the lead author).

Analgesia

Chest drain insertion is a painful procedure. One study has shown that 50% of patients experience pain levels of 9–10 out of 10. It is thought pre-medication would be beneficial to limit the potential pain; however, there is limited evidence to suggest a true benefit. Pre-medication could be an anxiolytic such as midazolam titrated to achieve adequate sedation immediately before or an opioid 1 h before the procedure. Care must be taken with those at risk of respiratory depression when administering both these drugs as pre-medication. In the trauma setting, adequate pain relief with pre-medication is difficult to achieve and local anaesthetic may be the only pain relief that can be provided.

Local anaesthetic, usually 1% or 2% lidocaine, should be infiltrated into the skin and underlying subcutaneous tissue before making the incision and performing blunt dissection. Local anaesthetic should be infiltrated through the layers of the chest wall down to the rib below the intercostal space. Here, local is injected around the periosteum of the rib. This should be administrated using a small gauge needle to raise a dermal bleb and then a larger gauge needle for infiltration of deeper tissue down to and including the intercostal muscles and pleural surface. Up to 3 mg/kg of lidocaine can be safely used to avoid neurotoxic effects.

Patient position, asepsis, and antibiotic prophylaxis

An ideal position is with the patient on a bed, sitting up at an angle of 45°, with the arm of the affected side placed over or behind the head to expose the axillary region.[11,14]

An aseptic technique should be used for chest drain insertion, even in the trauma setting. A chest drain may be in place for a number of days and every effort should be taken to maintain asepsis thereby reducing the risk of wound site infection or secondary empyema. In trauma, the incidence of empyema post-chest drain insertion is reported to be approximately 2.4%.[15]

A meta-analysis of studies using antibiotic prophylaxis for chest tube insertion has suggested that the absolute risk of empyema is reduced by 5.5%–7.1% and all infectious complications by 12.1%–13.4% in the presence of any chest trauma. Although the

prophylactic use of antibiotics is indicated in trauma, it is less clear in elective insertion of chest drains for other indications.[16]

Insertion technique

Once a safe site has been identified and the local anaesthetic has taken effect, an incision above and parallel to the rib, is made through the skin and subcutaneous fat. The incision length should be a little larger than the diameter of the chest tube to be inserted and must allow enough room for the operator's finger and for blunt dissection. About 2 cm is usually appropriate. From this point, a blunt dissection technique is recommended using a Spencer–Wells forceps or similar, to separate the underlying facia and the intercostal muscle. This dissection should be carried out over the upper border of the sixth rib. The use of a trocar to insert large bore chest drains is unnecessary, dangerous and has resulted in several reported cases of damage to intra-thoracic structures.[1–3,6,9,17] In comparison, one study showed only 4 of the 447 cases using blunt dissection technique had a technical complication.[15]

Once the parietal pleura is reached, the tip of a blunt instrument such as artery forceps can be used to break into the intra-thoracic cavity. Once the pleura is opened, a 'finger sweep' must be performed before insertion of the chest tube. A gloved finger is passed into the pleural cavity and swept round to explore the pleural cavity, clear any adhesions of the lung and visceral pleura and assesses the integrity of the adjacent diaphragm. If fractured ribs may be present, extreme care should be taken to ensure that the operator does not suffer finger lacerations from contact with fractured rib ends.

The insertion of the chest tube should be performed without any substantial force. The chest tube is inserted by mounting it on a blunt clamp and guiding this along the track already created, into the intra-thoracic cavity. The size of the chest tube is dictated by the indication for insertion.

Extra care should be taken in inserting a chest drain in a ventilated patient, particularly those with positive end expiratory pressure. It may be helpful to disconnect the patient from the ventilator depending on the clinical condition of the patient, just prior to chest tube insertion to avoid any parenchymal damage to the lung[17] although with the blunt dissection technique this risk is reduced.

Once the drain has been satisfactorily placed it needs to be secured and the distal end connected to a drain bottle with an underwater seal. An appropriate suture is placed around the incision to approximate the skin on drain removal and the drain is sutured in place using a separate suture from that closing the wound.

Stepwise outline for an ICD insertion

1. Appropriate analgesia is given;
2. The area is prepped and draped appropriately to maintain an aseptic technique throughout;
3. The site of drain insertion is confirmed;
4. Local anaesthetic is administered at the site of drain insertion and surrounding tissue;
5. An incision is made through the skin and subcutaneous fat to accommodate the operator's finger;
6. The track is developed, by blunt dissection only, using a closed clamp;
7. The dissection is further developed over the rib until the pleura is breached;
8. A finger is inserted into the pleural cavity and a finger sweep is carried out;
9. An appropriately sized chest tube is mounted onto the clamp and passed through the track into the pleural cavity;
10. The end of the tube is connected to an underwater seal;
11. The drain is secured in place;
12. An appropriate suture is placed around the incision to approximate the tissue on drain removal and the drain is sutured in place;
13. Clinical signs are checked to confirm effect; and
14. A chest radiograph is obtained to confirm drain position and effect.

Alternative drain positions

Persistent apical pneumothoraces can be drained by an anterior ICD placed in the second intercostal space in the mid-clavicular line. Loculated apical pneumothoraces can be drained by a posteriorly sited suprascapular drain.[18] Such measures are very rarely needed.

Drain size

The size of the drain is dictated by the indication for drain insertion. Smaller drains are more comfortable for the patient[19,20] and larger drains are used more frequently for a haemothorax to drain blood and small clots. There have not been any randomised controlled trials comparing large bore to small bore drain tubes, hence there remains controversy regarding the optimum size of drain.[20,21] In the trauma setting, insertion of a large bore drain is recommended.

Large bore drains are preferred to avoid the incidence of drain blockage from thick, malignant or infected fluid.[10,14,22] However, more recently smaller catheters (10–14 F) have been used and shown to be as effective as large bore tubes.[23]

However, the general consensus is that smaller bore tubes should be used for drainage of pneumothoraces whilst large bore tubes (28–30 F) are reserved for haemothoraces.[24] Although pneumothoraces may be drained with chest tubes as small as 9 F, a larger bore tube is required if the air leak exceeds the flow capacity of a smaller diameter tube.[24]

Insertion of small-bore pigtail drains under ultrasound guidance has allowed for the outpatient management of persistent malignant pleural effusions.[25] Empyemas have also been successfully drained using this method.[26]

Position of the drain tip

The ideal position of the drain tip is again dictated by the indication. With a pneumothorax, the drain tip is aimed at the apex of the thoracic cavity, whereas with fluid it should be aimed basally. The drain tip position should be confirmed radiologically although if the drain tip is not ideally placed on radiological confirmation and the chest drain is functioning effectively there is no need to reposition it.

Guiding the chest drain, by mounting it on a clamp and directing the drain tip will help to achieve an appropriate position.[12] A trocar can be helpful only for positioning a large bore tube once the only tip of the tube is within the thoracic cavity. This is achieved by placing the trocar a few centimetres behind the tip of the tube and directing the tube to its position. This technique should be avoided if other means are available due to the risk and potential for intra-thoracic organ damage.

Securing the drain

1/0 silk is ideally used for securing the drain. Once inserted, the drain should be secured immediately using a stay suture to secure the drain and avoid it becoming malpositioned or slipping out. Various techniques have been described;[27] however, the aim is for security of the tube.

A second suture, preferably a series of mattress sutures, should be placed to allow the wound to be closed on drain removal. A 'purse string' suture should be avoided as this may leave an unsightly scar and is likely to be more painful.

Management of chest drains

Closed system drainage

A closed drainage system employs the use of an underwater seal bottle or flutter valve. The chest drain should be connected to a single-flow drainage system allowing one direction of flow. With the underwater seal system, the drainage tube is connected to a bottle that drains under a water seal of approximately 3 cm depth. The drain bottle has a side vent, which allows air to escape or can be used to connect to a suction system.[28]

In the case of a pneumothorax, the operator is able to see air bubbles 'bubbling' as the lung expands. The presence of continuous bubbling following prolonged drainage, might indicate a visceral air leak due a breach in the lung paranchyma or airways. Alternatively if one of the air inlets in the drainage tube is outside the thoracic cavity and the drain bottle is placed on suction, there may also be evidence of continuous bubbling. Ideally, there will be a respiratory swing of fluid within the drain tube, and this confirms tube patency and position within the thoracic cavity. The underwater seal system will also allow accurate assessment and rate of drainage from a pleural effusion or haemothorax. Care should be taken to maintain the underwater seal bottle upright and below the level of the chest. This positioning may hinder patients' mobilisation and require in-patient management.

Heimlich flutter valves can be used in patients with pneumothoraces. This allows patients' to mobilise and patients with persistent pneumothoraces may even be managed as an out-patient with good success rates.[29] However, there have been case reports where wrong direction of flow through these valves due to error in their use has resulted in tension pneumothorax.[30] Care must therefore be taken when using these valves. Furthermore, use of these valves in the drainage of fluid is limited as they tend to become blocked by clotted blood or other solid matter.

Nursing and ward instructions

Patients with a chest drain should be managed on specialist wards by appropriately trained staff. The chest drain bottle must be kept upright, below the level of the chest at all times and an adequate underwater seal maintained to cover the end of the tube.[31] The presence of 'bubbling', the amount drained, and a 'respiratory swing' should be recorded hourly on a dedicated chest drain or intensive care unit chart. The drain tubes and connections should be checked regularly to avoid disconnection and to ensure the integrity of the seals.

Chest drains should not be clamped under any circumstances. Clamping can cause a tension pneumothorax in the presence of an existing air leak. Transfer of patients does not require clamping of drains.

Patients should also be educated about their chest drain. They should be taught to keep the underwater seal upright and below the level of their chest and to inform staff if there is tugging or pulling at the drain insertion site.

Chest radiograph

A chest radiograph should be taken as early as possible post-drain insertion, based on the patient's clinical condition. This is to confirm drain position and to assess resolution of a pneumothorax, haemothororax, or pleural effusion. A chest radiograph will also allow exclusion of any complications on chest drain insertion such as iatrogenic pneumothorax.

Suction

A high-volume low-pressure suctioning system should be used. Suction is performed by using an underwater seal system at a pressure of 10–30 cm H_2O or 2–5 kPa. A high-volume pump is required to cope with a large air leak. Use of a low-volume pump should be avoided to prevent a possible tension pneumothorax developing when the pump is unable to cope with the rate of air leak.

Suction is used routinely in patients post cardiac and thoracic surgery. In these cases, wall suction is used with a regulator, but care must be taken to avoid the high negative pressures available. Non-resolving pneumothoraces may require suction management. When suction is required, patients must be nursed by appropriately trained staff. If suction is turned off, it is essential to disconnect the tube from the suction point.

Brief disconnection from suction may not be detrimental as long as the underwater seal bottle is kept below the level of the chest, and the patient does not become symptomatic with increasing dyspnoea, tachypnoea, or desaturation.

Removal of chest drains

The timing of chest drain removal is dependent on the clinical need for insertion and clinical progress. Therefore, this is purely a clinical decision and should take into account patient progress and radiographic correlation. In general, chest drains may be removed once they are no longer draining any fluid and any air leak has resolved. With a pneumothorax, drains should not be removed until the operator is satisfied that there is no longer any 'bubbling' or an air leak and the pneumothorax has resolved, confirmed by chest radiograph. With a haemothorax or pleural effusions, drains should not be removed if there is evidence of continued drainage or evidence of residual blood or effusion on chest radiograph. In patients post cardiac surgery, drains are left in place until there is evidence of no further bleeding or collections. With persistent effusions or pneumothoraces further radiographic investigations may be required before removal of chest drains.

Clamping of the chest drain at the time of removal is unnecessary. The chest drain should be removed whilst the patient performs a Valsalva manoeuvre or during end expiration. The tube should be removed with two people present. One person should remove the tube in a brisk and firm movement, whilst the other ties down the previously placed closure suture to prevent air being sucked in.[12,14,28]

A chest radiograph after removal is advisable to confirm there is no recurrence of pneumothorax or recollection of pleural fluid. Studies have shown that approximately 3% of patients required re-insertion of a chest drain for recurrent pneumothorax following chest drain removal.[32,33]

Complications

Complications related to chest drains can be classified as early or late.

Early

- Haemothorax due to laceration of intercostal vessels;
- Lung laceration due to inadequate clearance of pleural adhesions;
- Diaphragmatic or abdominal cavity penetration by low drain placement;
- Stomach or colon injury due to failure to recognise a diaphragmatic hernia;
- Subcutaneous placement of the drain;
- The distal drain inlet lying outside the thoracic cavity;
- The drain placed too far into the thoracic cavity causing pain; and
- The chest drain falling out due to it not being secured effectively.

Late

- Chest drain blockage;
- Failure of drainage of pleural effusion or haemothorax due to sub-optimal drain placement or change in drain position;
- Wound infection;
- Empyema; and
- Post-removal pneumothorax due to removing the drain too early, poor technique or ongoing air leak.

In May 2008, the UK's National Patient Safety Agency (NPSA) issued a *rapid response report* highlighting significant complications directly related to intercostal chest drain insertion. A search on the *National Reporting and Learning System* database for chest drain associated patient safety incidents revealed

12 deaths and 15 cases of severe harm out of 2152 incidents reported, between January 2005 and March 2008.[34] Eleven of the 12 deaths in the NRLS database related to the Seldiger technique and involved insertion of the drain into the heart, liver, or other viscera. Forty-two percent of these incidents occurred in medical specialities with 19% occurring in surgical specialties. Of the 2152 cases reported to the NRLS, only 64% were judged to have caused no harm.

Based on these findings, the NPSA rapid response report has made the following recommendations:

- Chest drains are to be inserted by staff with relevant competencies and adequate supervision;
- Ultrasound guidance is strongly advised when inserting a chest drain for fluid;
- Clinical guidelines must be followed and staff made aware of the risks;
- A lead for training of all staff involved in chest drain insertion must be identified;
- Written evidence of consent must be obtained from the patient before the procedure wherever possible; and
- Local incident data must be reviewed and incident reporting encouraged.

The rates of empyema post chest drain insertion, range between 2% and 4%.[15,35] A study looking at the efficacy and complications of small bore (12–20 F) chest drains showed a 2% empyema rate. A multicentre trial looking at the effects of antibiotics for chest drains for traumatic haemo-pneumothorax showed a low rate of empyema with no added advantage with the use of prophylactic antibiotics.[36]

Conclusion

Insertion of a chest drain in a safe manner can be a life-saving intervention. Intercostal chest drain insertion is a common procedure and every hospital doctor should be aware of the indications, safe insertion techniques, and subsequent management of chest drains. Specialist support and advice should be sought early in dealing with the complicated patient with thoracic injuries.

There still remains wide variability regarding the technique of insertion, type of drain used, and level of expertise when inserting chest drains. Standardisation of equipment and standardised insertion and management techniques should reduce complications associated with chest drains.

Based on the recommendations of the NPSA, local guidelines for chest drain insertion should be implemented and local practice routinely audited to promote patient safety with chest drain insertion.

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