VIDEOS IN CLINICAL MEDICINE

Chest-Tube Insertion

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INDICATIONS

Insertion of a chest tube is indicated in either emergency or nonemergency situations. Specific indications are listed in Table 1.[1-3]

CONTRAINDICATIONS

Published guidelines state that there are no absolute contraindications for drainage by means of a chest tube[1] except when a lung is completely adherent to the chest wall throughout the hemithorax.[2] Relative contraindications include a risk of bleeding in patients taking anticoagulant medication or in patients with a predisposition to bleeding or abnormal clotting profiles. Whenever possible, coagulopathies and platelet defects should be corrected with the infusion of blood products, such as fresh frozen plasma and platelets.

EQUIPMENT

Most hospitals have presterilized, packaged chest-tube–insertion trays. The key components of the tray are a scalpel with size 11 blade; several dissecting instruments, such as curved Kelly clamps or artery forceps; a 10-ml syringe and a 20-ml syringe; one small-gauge needle (size 25) and one larger-gauge needle for deeper anesthetic infiltration (size 18–21); a needle driver; scissors; one packet of strong, nonabsorbable, curved sutures of size 1.0 or larger, made from silk or nylon[4]; and a chest tube of appropriate size (see below). A commercially available pleural drainage system, such as the Pleur-evac (Teleflex Medical), should also be ready for connection after the chest tube is inserted.

Table 1. Indications for Chest-Tube Insertion.

Emergency
Pneumothorax
In all patients on mechanical ventilation
When pneumothorax is large
In a clinically unstable patient
For tension pneumothorax after needle decompression
When pneumothorax is recurrent or persistent
When pneumothorax is secondary to chest trauma
When pneumothorax is iatrogenic, if large and clinically significant
Hemopneumothorax
Esophageal rupture with gastric leak into pleural space
Nonemergency
Malignant pleural effusion
Treatment with sclerosing agents or pleurodesis
Recurrent pleural effusion
Parapneumonic effusion or empyema
Chylothorax
Postoperative care (e.g., after coronary bypass, thoracotomy, or lobectomy)

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Grasp the proximal free end of the chest tube with a clamp or forceps. Using another clamp or forceps, grasp the distal tip of the tube to prepare it for insertion.[4]

CHEST-TUBE SIZE

The size of the chest tube that is needed depends on the indication for the insertion of a chest tube. Table 2 provides a summary of size recommendations based on indication.[5-11]

PREPARATION

If time permits, explain the procedure to the patient or next of kin and obtain written consent; this may not be possible when the need for chest-tube insertion is urgent.

Position the patient in either a supine or a semirecumbent position. Maximally abduct the ipsilateral arm or place it behind the patient's head. The area for insertion is approximated by the fourth to fifth intercostal space in the anterior axillary line at the horizontal level of the nipple. This area corresponds to the anterior border of the latissimus dorsi, the lateral border of the pectoralis major muscle, the apex just below the axilla, and a line above the horizontal level of the nipple—often referred to as the "triangle of safety."[2] You can isolate this area by palpating the ipsilateral clavicle, then working downward along the ribcage, counting down the rib spaces. Once the fourth to fifth intercostal space is felt, move your hand laterally toward the anterior axillary line (Fig. 1). This is the area for incision; the actual insertion site should be one intercostal space above the chest-tube incision site. Mark the spot for incision on the skin with a pen or the back of a needle.

Figure 1. Locating Landmarks.

Use full barrier precautions (wash your hands and wear a sterile gown and gloves, protective eyewear, and a face mask). Create a large, sterile field on the patient's skin, using sterile gauze and 2% chlorhexidine solution. Drape the patient, exposing only the marked area. Using a 1% or 2% lidocaine solution and a 25-gauge needle, create a wheal of anesthetic in the cutaneous tissue at the marked spot. Draw up more lidocaine solution in a 20-ml syringe. Using a 21-gauge needle, anesthetize the deeper subcutaneous tissues and intercostal muscles. Locate the rib lying below the intercostal space where the tube will be inserted, and continue to anesthetize the periosteal surface. Ten to 20 ml of lidocaine solution may be used to ensure optimal analgesia.[1] While anesthetizing the rib, find the superior aspect of the rib and use this to bevel or "march" the needle on top of it. Using continued negative suction as the needle advances, with the needle beveled on top of the rib, confirm entry into the pleural space when a flash of pleural fluid enters the cham-

Table 2. Sizing of Chest Tubes on the Basis of Indication.

Indication for Chest Tube	Recommended Size of Chest Tube
Pneumothorax	
Large pneumothorax in patient in stable condition	16-French to 22-French 14-French or smaller (insert by Seldinger method)*
Large pneumothorax in patient in unstable condition Patient receiving mechanical ventilation Secondary pneumothorax	24-French to 28-French
Pleural collections	
Malignant pleural effusion Transudative effusion	Consider smaller-bore, 8-French to 16-French first* If ineffective, try larger-bore (22-French or larger)
Parapneumonic effusion Empyema	No firm recommendations 20-French or larger may be tried

* The Seldinger method of chest-tube insertion is performed with the use of 14-French or smaller chest drains usually under ultrasound guidance either at the bedside or in a radiology suite. This method is not covered in this review.

ber of the syringe. If a pneumothorax is being evacuated, the syringe may only fill with air. Stop advancing the needle and inject any remaining lidocaine to fully anesthetize the parietal pleura. Withdraw the needle and syringe completely.

INCISION AND DISSECTION

An incision 1.5 to 2.0 cm in length should be made parallel to the rib. Use the Kelly clamp or artery forceps to cut through the subcutaneous layers and intercostal muscles (Fig. 2). The path should traverse diagonally up toward the next superior intercostal space. Once you have dissected through the subcutaneous tissues, find the surface of the rib lying below this space with the dissecting instrument. Then slide the instrument straight up, until you find the top edge of the rib. Use this to bevel or balance the dissecting instrument as you dissect the intercostal muscles (Fig. 3). Once you reach the parietal pleura, gently push the dissecting instrument through it. You may also digitally penetrate the pleura to avoid puncturing adjacent lung tissue,[3,4] using your index finger to explore the tract. Once your finger enters the pleura, withdraw the Kelly clamp. Use your finger to palpate within the pleural layer and ensure that the lung falls away from the pleura.[1] If it does not, this may indicate the presence of an adhesion, so tube insertion may be difficult. (Trocar insertion, considered dangerous, is no longer advised.[4])

Figure 2. Dissection.

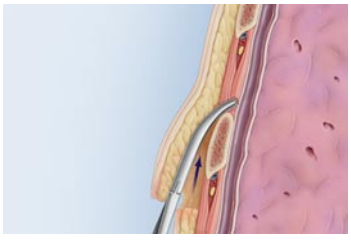

Figure 3. Positioning the Dissection Instrument.

TUBE INSERTION

Once the distal tip of the tube has passed through the incision, unclamp the Kelly clamps or forceps and advance the tube manually. Aim the tube apically for evacuation of a pneumothorax and basally for evacuation of any fluid.[1-3]

SECURING THE TUBE

Mattress or interrupted sutures should be used on both sides of the incision to close the ends. Use the loose ends of the sutures to wrap around the tube and tie them off, anchoring the tube to the chest wall.[1] Tape the tube to the side of the patient and wrap a petroleum-based gauze dressing around the tube. Cover this gauze with several pieces of regular sterile gauze, and secure the site with multiple pressure dressings.

Purse-string sutures are not recommended owing to poor cosmetic results and increased risk of skin necrosis; the seal they provide does not prevent air leaks.[3]

Connect the distal end of the chest tube to a sterile pleural drainage system, such as the commercially available Pleur-evac. Once the tube is connected, unclamp the distal end; if there is a pneumothorax, bubbling may be seen. If there is a large pleural effusion, it will begin collecting. Do not reclamp the chest tube, once released, unless the pleural drainage system is being changed. Reclamping the tube may lead to the redevelopment of a pneumothorax and may create a tension pneumothorax.

CHEST RADIOGRAPH CONFIRMATION

Once you have secured the chest tube, obtain an anterior-posterior chest radiograph to confirm placement, which can be done by identifying the radio-opaque line along the tube. If the proximal drainage hole is outside the pleural space, drainage may be ineffective and an air leak may result. In this circumstance, the tube should be removed and a new chest tube inserted.

COMPLICATIONS

The most important complications associated with chest-tube insertion[1-3,9] include bleeding and hemothorax due to intercostal artery perforation, perforation of visceral organs (lung, heart, diaphragm, or intraabdominal organs), perforation of ma-

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jor vascular structures such as the aorta or subclavian vessels, intercostal neuralgia due to trauma of neurovascular bundles, subcutaneous emphysema, reexpansion pulmonary edema, infection of the drainage site, pneumonia, and empyema. There may be technical problems such as intermittent tube blockage from clotted blood, pus, or debris, or incorrect positioning of the tube, which causes ineffective drainage.

TIMING OF CHEST-TUBE REMOVAL

The timing of chest-tube removal depends on the indication for insertion of the chest tube.

For a pneumothorax, bubbling must have ceased and the lung must be fully expanded on chest radiograph before the tube can be removed. If suction is being used to evacuate a pneumothorax, most physicians will use a trial of underwater seal to ensure that the lung stays expanded without suction. Practice differs greatly among physicians with regard to duration of observation after air leak cessation and before removal of the tube and whether or not to clamp the tube before removal to rule out a persistent air leak.[11] On the basis of available data, most physicians would obtain a chest radiograph 12 to 24 hours after the last observed evidence of an air leak to ensure that the lung stays fully expanded before tube removal. Because opinion and practice are clearly divided on the need for clamping the drain before tube removal, no strong recommendation can be made here.

If placement was for any pleural fluid drainage, once the drainage volume is less than 200 ml in a 24-hour period,[3,5] the fluid is serous, the lung has re-expanded on the chest film, and the patient's clinical status has improved, the chest tube may be removed.

If the patient's condition fails to improve after chest-tube insertion, a respirologist or a thoracic surgeon should be consulted for more definitive management, such as fibrinolytic therapy or surgical decortication.[8,9]

TECHNIQUE OF TUBE REMOVAL

The major concern with removal of a chest tube is the risk of pneumothorax during removal. Again, physician practice differs with respect to the point in the respiratory cycle at which the tube is removed: during end-inspiration or end-expiration. Neither has been shown to be superior in the prevention of pneumothorax.[5] When preparing to remove the tube, two people may need to participate so that one can instruct the spontaneously breathing patient and pull the tube while the other can quickly occlude the insertion site. Cut the skin sutures, using sterile technique. Have additional strong nylon or silk sutures ready in case additional sutures are required to seal the hole. Sterile petroleum-based and regular gauze should also be ready.

Instruct the spontaneously breathing patient to perform a forced Valsalva maneuver or to inhale to total lung capacity after a full exhalation. If the patient is being fully mechanically ventilated, removal should be timed to end-expiration. One operator can pull the tube out while the other quickly occludes the site with gauze, adds additional sutures to close the opening, and secures the site with a pressure dressing. A chest radiograph 12 to 24 hours after removal is recommended[1,3]; this should be done sooner if there is clinical suspicion of a residual air leak or a new pneumothorax.

Caution must be exercised when removing a chest tube from any patient receiving mechanical ventilation. This is of particular importance for patients with high oxygen or positive end-expiratory pressure requirements, chronic lung disease, or any additional reasons for persistent air leaks or recurrent pneumothoraces. In these cases, highly experienced physicians should supervise the decision to remove a chest tube.

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A procedural check list for pleural decompression and intercostal catheter insertion for adult major trauma

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ABSTRACT

Background: Intercostal catheter (ICC) insertion is the standard pleural decompression and drainage technique for blunt and penetrating traumatic injury. Potentially high complication rates are associated with the procedure, with the literature quoting over 20% in some cases (1–4). Empyema in particular is a serious complication. Risk adverse industries such as the airline industry and military services regularly employ checklists to standardise performance and decrease human errors. The use of checklists in medical practice is exemplified by introduction of the WHO Surgical Safety checklist.

Methods: The Alfred Hospital in Melbourne, Australia is an Adult Level 1 Trauma Centre. In August 2009 The Alfred Trauma Service introduced an evidence-based checklist system for the insertion of ICCs, combined with standardised formal training for resident medical staff, in an attempt to minimise the incidence of ICC related empyema.

Results: Between January 2003 and July 2009 the incidence of empyema was 1.44% (29 in 2009 insertions). This decreased to 0.57% between August 2009 and December 2011 (6 in 1060 insertions) when the measures described above were introduced [$p = 0.038$ Fisher's exact test, 2-tailed].

Conclusion: Quality control checklists – such as the ICC checklist described – are a sensible and functional means to standardise practice, to decrease procedural error and to reduce complication rates during trauma resuscitation.

Background

Intercostal catheter (ICC) insertion, or tube thoracostomy, is the standard pleural decompression and drainage technique for blunt and penetrating traumatic chest injury. Potentially high complication rates are associated with the procedure, with the literature quoting between 20 and 30% in some cases [1–4]. Complications include insertion related injuries to the viscera or neurovascular bundle, mal-positioning including extra-thoracic placement, ineffective positioning requiring re-insertion and infections of the wound tract as well as empyema [5].

Certain factors have been shown to increase the risk of ICC related morbidity, including polytrauma, hypotension, mechanical ventilation and pre-hospital placement [5]. Inadequate resident medical staff training has also been cited as a potential cause for complications [6]. In a retrospective study of complications of ICC insertion by resident medical staff at a level 1 Trauma Centre, Ball et al. quoted a complication rate of 28% of patients. Although the majority (72%) of resident medical staff had completed an Advanced Trauma Life Support (ATLS) course, the high complication rate suggested that increased training alone may be inadequate to decrease complication rates – and that systems-based interventions may also be needed.

The importance of a systems based approach has been emphasised in a recent Injury editorial, which called for the implementation of a checklist to be used as an 'aide-memoire' during insertion of ICCs due to the ongoing 'steady stream of articles indicating poor decision-making, poor site selection and poor insertion technique'... 'no matter how much education is provided to those involved in care of the trauma patient' [7]. Other risk adverse industries such as the airline industry and military services regularly employ checklists to standardise performance and decrease human errors [8]. The use of checklists in medical

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practice is exemplified by introduction of the WHO Surgical Safety checklist, which involves 'both changes in systems and changes in behaviour of individual surgical teams' to reduce rates of errors [9].

The aim of this study was to evaluate whether a standardised structured programme including a checklist would decrease tube thoracostomy complication rates and specifically empyema.

Methods

This was a retrospective observational study using prospectively collected registry data from the Alfred Hospital in Melbourne, Australia, which is an Adult Level 1 Trauma Centre. In 2011 there were 3849 Trauma Service admissions, of which 90% were secondary to blunt trauma. 954 of these patients had an injury severity score (ISS) greater than 15, with 324 having a chest maximum abbreviated injury score of $\geq$3.

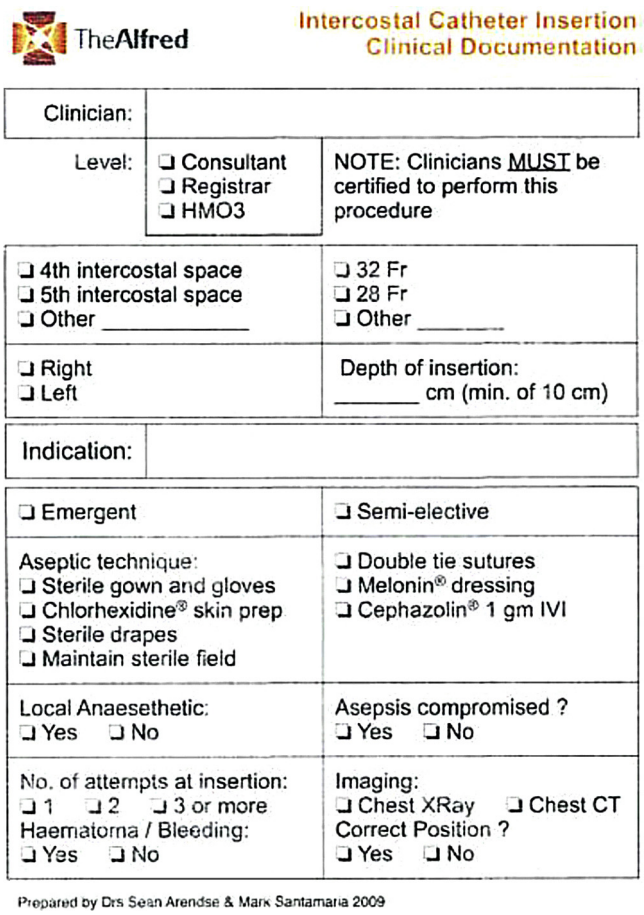
In August 2009 The Alfred Trauma Service introduced an evidence-based checklist system for the insertion of ICCs, combined with standardised formal training for resident medical staff, in an attempt to minimise the incidence of empyema as an ICC complication. This broad approach employed:

1. Standardised guidelines;
2. a formal trauma orientation programme including specific procedural ICC insertion training using pig torsos, and
3. a self-adhesive ICC insertion checklist for use in the Emergency & Trauma Centre and on the wards.

The standardised guidelines were introduced in 2009 to standardise practice related to insertion, management and removal of chest tubes and chest drainage systems. They were based on available evidence, and specifically concentrating on measures such as aseptic technique, use of prophylactic IV antibiotics on insertion and frequent monitoring and review on the ward. The introduction of a follow up programme including a Trauma Outpatient review within 3 weeks of discharge aimed to ensure adequate and timely identification of potential complications.

The day long Trauma Orientation Programme is run twice a year for all resident medical staff working with the Trauma Service during the following six months. This includes Surgical, Emergency Medicine and Intensive Care trainees. There is a dedicated presentation on the pathophysiology of chest trauma, indications for pleural decompression and intercostal catheter insertion technique. This is followed by a surgical skills station which includes a DVD demonstration of ICC insertion detailing techniques taught in the EMST/ATLS programme. Ex vivo porcine thoraces (sternotomy and viscera removed) are then used for didactic procedural and motor skills training, with a senior trauma specialist first demonstrating the technique for insertion of a 32 French ICC followed by each participant performing the procedure under supervision in turn. The trauma specialist emphasises aseptic technique, digital pleural decompression as a first step and ICC placement as a second step [10]. A standardised technique with two vertical mattress sutures placed either side of the ICC, securing with figure of eight ties, closure of the remaining wound with skin staples, application of a 2.5 cm^2 Melonin™ key hole dressing and then application of a Tegaderm™ mesentery dressing is taught.

The ICC checklist uses evidence-based guidelines for ICC insertion. It provides an aide-memoire for the procedure and includes essential practices such as sterile technique, use of antibiotics, the technique for stabilising the tube and post insertion imaging (see Fig. 1). The ICC checklist stickers are stored in the Trauma Centre and in the trauma ward, and are inserted into the patient's medical file by the doctor performing the procedure. Resident medical staff are familiarised with the ICC checklist during the orientation programme.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Intercostal Catheter Insertion
Clinical Documentation

Clinician:	
Level: ❑ Consultant ❑ Registrar ❑ HMO3	NOTE: Clinicians MUST be certified to perform this procedure
❑ 4th intercostal space ❑ 5th intercostal space ❑ Other _____	❑ 32 Fr ❑ 28 Fr ❑ Other _____
❑ Right ❑ Left	Depth of insertion: _____ cm (min. of 10 cm)
Indication:	
❑ Emergent	❑ Semi-elective
Aseptic technique: ❑ Sterile gown and gloves ❑ Chlorhexidine® skin prep ❑ Sterile drapes ❑ Maintain sterile field	❑ Double tie sutures ❑ Melonin® dressing ❑ Cephazolin® 1 gm IVI
Local Anaesethetic: ❑ Yes ❑ No	Asepsis compromised ? ❑ Yes ❑ No
No. of attempts at insertion: ❑ 1 ❑ 2 ❑ 3 or more Haematoma / Bleeding: ❑ Yes ❑ No	Imaging: ❑ Chest XRay ❑ Chest CT Correct Position ? ❑ Yes ❑ No

Prepared by Drs Sean Arendse & Mark Santamaria 2009

Fig. 1. Intercostal catheter (ICC) insertion checklist.

The Alfred Trauma Registry records data on all patients admitted into the Trauma Service. Registry injury coding uses both the abbreviated injury scale (AIS) 1998 and the 2008 update. For this study we report AIS 98 coded data. Registry data of all trauma patients undergoing ICC insertion following admission to the Alfred from January 1st 2003 (introduction of the registry) until December 31st 2011 was extracted. The primary outcome measured was proportion of cases to develop empyema post insertion, and was determined for the period before and after the introduction of the measures described above. The difference in proportion of cases was examined using Fisher's exact test; a p-value of <0.05 was considered statistically significant. Empyema was defined as identified via VATS (video-assisted thoracopic surgery) and confirmed microbiologically.

Results

From January 2003 through until December 2011, there were 3069 ICCs inserted (approximately 341 per year). The overall incidence of empyema for ICCs inserted at The Alfred was 35 cases (1.14%).

Between January 2003 and July 2009 the incidence of empyema was 1.44% (29 in 2009 insertions), which decreased to 0.57% between August 2009 and December 2011 (6 in 1060 insertions) when the measures described above were introduced [$p = 0.038$ using Fisher's exact].

Discussion

Pleural decompression and ICC insertion is an essential trauma care skill. However, there are continuing reports of high complication rates associated with the procedure. In a recent Injury editorial Mr. Ian Civil advocated a checklist for chest tubes in an attempt to decrease complication rates [7].

Our report demonstrates that the introduction of additional formal teaching and a standardised ICC checklist has seen a reduction in empyema incidence at a high volume Adult Level 1 Trauma Centre with an already initial low rate of empyema. In the first six months of 2009, we had noted that our empyema rate post ICC insertion had increased to 3.5% from just over 1% from the same period the year previous, the reason for which was not clear. Although it was similarly unclear which of the empyema rates best represented the longstanding trend it was determined that the checklist should be introduced, and that the empyema rate over a longer period should be examined. In an effort to reduce all possible complications of ICC insertion, and improve the skill set of resident medical staff rotating through the trauma unit, we introduced a formal didactic teaching programme along with a new checklist system. We then observed a decrease in empyema rate.

There are limitations to this observational study. Our study is only a brief report of an intervention at a single institution. The routine administration of antibiotics on insertion, improved senior medical staff supervision and improvements in the overall management of trauma patients may have potentially influenced these results. In addition, these combined measures were introduced simultaneously and we are unable to determine if a checklist alone would decrease empyema rates. We did not analyse compliance rates of use of the checklist. We have not addressed nor analysed rates of other complications associated with ICC insertion, purely focusing on empyema rates. This has the potential for further study and development of a more comprehensive checklist. Finally, the empyema rate of 3.5% in the 6-month period prior to the intervention, retrospectively identified as a relatively isolated spike, may have increased the chance of seeing the post-intervention effect. This potential bias may have led to an overestimate of the effect size.

Conclusion

An aide memoir such as the ICC checklist described is a sensible and practical means to standardise practice and to decrease error and complications rates associated with ICC insertion, and provide an easy instrument for appropriate documentation of the procedure in the patient's medical record.

Conflicts of interest statement

There are no conflicts of interest identified by any of the authors.

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