Review Article

Chest drain and thoracotomy for chest trauma

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Abstract: Traumas are the leading cause of death in the first four decades of life. Nevertheless, thoracic traumas only seldom require invasive procedures. In particular, chest drain placement is required in case of pleural disruption causing haemothorax, pneumothorax or haemopneumothorax. Although large-bore chest drains have been traditionally used in case of haemothorax, recent evidences seem to question this routine, showing good performances of small-bore and pig tail drains. Although it is a common procedures, experience and training is needed to avoid complications which might be even lethal. Surgical exploration after thoracic trauma is rare, accounting for less than 3% of traumas. Penetrating traumas more likely require surgical exploration compared to blunt trauma. Anterolateral thoracotomy is usually performed in this setting, but also clamshell or hemi-clamshell approach can be used. In selected patients, minimally invasive techniques can be performed. Large randomized trials are still needed to assess and standardized the role of new tools and procedures in the thoracic trauma setting.

Keywords: Chest trauma; chest drain; thoracotomy; hemothorax; pneumothorax

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Introduction

Traumas are the leading cause of death in the first four decades of life and are mostly caused by traffic accidents (1). Nevertheless, they might be related with other types of causalities, like falling or firearm injuries.

Thoracic traumas might lead to severe consequences, even though less than 50% of them required a surgical revision (2). Thoracic traumas can be divided in blunt or penetrating, according to the presence of open wound in the chest.

Blunt traumas are the most frequent type of trauma in Europe and USA and they are responsible of more than 150,000 deaths in the Europe every year (3). In blunt traumas, rib fractures are common and they might be associated with haemothorax, pneumothorax or haemopneumothorax that are the most typical lesions that need to be faced by thoracic surgeons; moreover, lung injuries such as contusion or laceration can also be found.

On the other hand, penetrating trauma are mostly related to stubbing and gunshot and they usually present with lung or other thoracic organs lesions. Mortality related to penetrating chest traumas is significantly higher than blunt traumas, and more than 90% is not able to reach the hospital alive; nevertheless, mortality for patients with no cardiac involvement is less than 1% (4).

Chest trauma management

Chest trauma can be approached on two levels: pre-hospital and in-hospital. Pre-hospital level is usually the place where the trauma happened, with limited diagnostic

facilities and possible difficulties that might make operative procedure more challenging; in-hospital level can be either in emergency room or operating theatre (4). However, a prompt and adequate recognition and diagnosis of chest injuries is necessary and strongly influences outcomes (5). In a large single centre study analysing different type of chest trauma, Kulshrestha and colleagues found one or more rib fractures in almost half of patients (6). Concurrently, in only less than 20% an invasive approach was necessary. In particular, around 18% of patients required a chest drain, and in 2.6% a thoracotomy was needed. Moreover, also in case of penetrating chest trauma, intercostal drain positioning can be adequate in up to 95% of cases without requiring any further surgical exploration (4,7,8).

Chest drain

Positioning of a pleural drain often represent the first step of the management of a chest trauma. The indication for the insertion of a chest drain have been clearly stated by international trauma management guidelines (9). In particular, chest tube positioning is considered necessary in case of a pleural disruption with pneumothorax; intrapleural bleeding causing haemothorax; or in case of pneumo-haemothorax.

Although chest drain insertion is a quite common procedure, a correct training is required before being able to do it properly and safely (10). As a matter of fact, complication rates are strictly related to the experience of the operator (4).

When to insert a chest drain

According to clinical features of the patient, chest drain can be placed on the trauma location, and therefore outside hospital, or in the trauma bay or even in the first 24 hours after hospitalization of the patient. The best timing to insert a chest drain in case of thoracic trauma depends on clinical signs and symptoms (for example: shortness of breath, reduced motion of one hemithorax). Pre-hospital, on field chest drain insertion mostly rely on clinical examination that should reveal open or tension pneumothorax or massive haemothorax. In this context, physical examination, and in particular auscultation, have a high sensitivity and specificity (90% and 98% respectively) (10). Nevertheless, a repeated examination is important to avoid missing a possible progression of an unrecognized pneumothorax (11).

In case of an in-hospital evaluation, imagining techniques should be used to assess the extent of trauma and the possible presence of haemothorax or pneumothorax. In details, sonography (Extended Focus Assessment Sonography in Trauma, e-FAST) and chest radiography can be performed rapidly. A meta-analysis showed that, in case of pneumothorax, chest X-ray lacks sensitivity in the emergency room in half of patient, while e-FAST reaches 90.9% sensitivity (12). CT might also be useful, but it is generally reserved in case of severe trauma or in case of clinical or radiological suspect of deep injuries (13).

Establish a correct diagnosis remains the most important issue to decide to insert a chest drain. Moreover, in case of a patient with chest trauma with no cardiac output a bilateral drainage to exclude tension pneumothorax should be performed (4).

Where to insert a chest drain

There are two main site of insertion that are commonly used for the positioning of chest drains: the ventral approach, on the second intercostal space on the mid-clavicular line (Monaldi approach); and the lateral approach at 4^{th}–6^{th} intercostal space on the anterior or mid axillary line (Bülau approach) (14,15). Although British guidelines suggest a preference for the Bülau approach, the use of these techniques for a trauma mainly relies on trauma scenario, operator experience and contents of the pleura. More in detail, the Monaldi approach might be preferred in case of isolated apical pneumothorax, while the lateral approach is used in case of pleural effusions or large pneumothoraxes. Huber-Wagner and his colleagues (16) prospectively analysed outcomes in terms of complications and chest tubes malposition according to the different approach in 101 trauma patients over a 4-year period: the authors did not find any statistically significant difference between the two groups in terms of overall malposition, but they found an significant higher rate of intra-parenchymal placement using the ventral approach (P=0.045) and a higher rate of intrafissural placement using the lateral approach (P=0.013). Concurrently, they did not observe other complications such as empyema or organ damage in none of the groups. Finally, no differences for both malposition and complications were found when they considered only drains inserted on the trauma scene. Authors conclude that, although the Bülau approach was usually preferred by operators, both techniques might be equally considered safe and effective in a trauma scenario.

Size, type and material of chest drain

Several types and measure of chest drain are available: silicon, polyvinyl chloride (PVC) or pig tails are the most commonly used. External diameter of drains is reported in French or Charrière (Fr and Ch respectively, equivalent to 0.333 mm); nevertheless, real inner diameter is dependent to the thickness of the chest tube itself (17).

There is a general lack of high-grade evidences regarding type and size of tube to be placed in case of trauma. Recommendation of Advanced Trauma Life Support (ATLS) (9) and the British Thoracic Society guidelines (15) suggest the use of a large bore chest drain (more than 28–30 Fr) in case of acute haemothorax, which could allow to better assess real blood loss. These recommendations are actually supported by physics laws: according to both Poiseuille's law and Fanning equation for the flow of fluids and gas inside a tube, a small increase in tube diameter results in a consequent exponential increase in flow. Consequently, larger bore tubes are used as they are supposed to avoid clotting of the tube, but no randomized trials support these conclusions, which mainly rely on surgeons' habits (18,19).

On the other hand, a preclinical study did not find significant drainage capacities comparing 19- and 28-Fr chest tubes (20). Conversely, an *in vitro* study (21) report the importance of different fluids' viscosity as a main factor in the choice of drain size.

Interestingly, results of clinical cohorts seem to be consistent with the possibility of use small bore chest drain also in case of haemothorax; Inaba *et al.* (22) prospectively compared outcomes in patients treated with (relatively) small bore (28–32 Fr) chest tube versus a large bore (36–40 Fr) for trauma; authors did not find differences in terms of chest tube output and related complication. Moreover, they did not find a significant higher rate of retained haemothorax in smaller bore drain group (11.8% and 10.7% in small and large bore group respectively, P=0.981).

Another American study report a monocentric experience comparing the use of 14-Fr pigtails drains and conventional large bore drains in case of haemothorax in trauma patients (23,24). In details, the authors prospectively analysed failure and effectiveness of pig tails in patients with traumatic haemothorax with or without pneumothorax. Although pig tails were more likely to be inserted in a non-emergent situation, authors found a significant higher output in the pig tail group with no differences in failure rate. On the other hand, they appreciate a higher complication rate in the pig tail group compared to traditional chest tubes. Acknowledging limitations of a single centre non-randomized study, the authors recommend a routinely use of small-bore pig tail drainages in case of traumatic haemo-(pneumo-)thorax.

As far as traumatic pneumothorax is concerned, pig tail or smaller bore chest drain are generally accepted by the largest part of thoracic surgeons. A recent randomized controlled trial (25) compared the use of 14-Fr pig tail and a 28-Fr silicon chest tube in the management of uncomplicated traumatic pneumothorax among 40 patients. Outcomes in terms of duration, complications and failures were similar between the two group, with a significant lower pain in patients who were treated with a pig tail. Nevertheless, data regarding pain assessment comparing small and large bore chest drains are inconsistent and several studies did not show any significant difference (22,26-28).

Management

A recent meta-analysis (29) compared outcomes of three randomized trial on chest tube management after traumatic haemothorax and pneumothorax focusing on the use of water seal or suction. Despite a relatively small cohort of patients and several bias influencing the resulting quality of evidences, results of meta-analysis were in favour of gently suction. More in details, when suction was used, patients experienced a significant reduction of both chest tube duration and length of stay in the hospital; moreover, a "moderate" evidence supported suction in case of air leak, while advantage was not likewise clear in case of clotted haemothorax.

Complications

Although chest drain insertion is a common practice in hospital, several even lethal complications can plague this procedure. Complication rate may vary from 6% to 37% (30-33), that reflects the high variability of the emergency setting and a no-standardized definition of complication.

The Mayo clinic group elaborated a Tube Thoracostomy Complication Classification System to better define complications (34). The authors divided complications in: insertional; positional; removal; infective-immunologic and Institutional/education/equipment. Positioning complication are indeed the most frequent among all kind

of complications (33,35) and they are more likely to happen during emergency due to the usual complexity of this setting.

When chest drain is inserted inside the pleural space, malposition might be related to an intrafissural or intraparenchymal position (36). A retrospective single centre study evaluated clinical consequences of intrapleural chest drain malposition (either intrafissural or intraparenchymal drains) in trauma patients focusing on replacement rate (37). The authors did not find significant differences in the number of drains that need to be replaced among the groups (correctly positioned, intrafissural or intraparenchymal). Conversely, out-of-hospital insertion and non-targeted chest tubes (which did not reach the target area) showed to be the main factors influencing the replacement rate.

On the other hand, Huber-Wagner and colleagues (16) differentiate a radiological malposition and a malposition with a clinical relevance, pointing out that replacement should be reserved only for chest tube with a clinical malposition. Lastly, an Indian prospective study (38) on 154 trauma patients evaluating the relationship between radiological features of drain position and a particular clinical outcome (retained haemothorax) failed to find significant correlations.

Other complications include bleeding, subcutaneous placement, dislodgement, infection and laceration or perforation of other organs (4). Bleeding is the most common complication and it is usually related to intercostal vein or artery injury (reported to be up to 75% of serious complications). Other intrathoracic vessels can be injured as well, with lower incidence but with a significantly higher morbidity and mortality. (4). According to a survey conducted in UK among several trusts, serious hemorrhage was almost 25% of all adverse clinical events (39). Concurrently, heart can also be damaged with a high mortality rate. As mentioned before, lung can be relatively easily perforated during chest drain insertion; Harris and colleagues described intrapulmonary placement as the most common adverse clinical events accounting for 38% complication. Beside lung, also diaphragm can be lacerated, and possible abdominal organ injury might result (liver, spleen, stomach and colon). In case of severe organ injury, surgical exploration should be required.

Thoracotomy

In case of chest trauma which cannot be treated with a chest drain alone or when the chest drain reveals a more severe injury, surgical exploration is mandatory.

In general, penetrating traumas are more likely to require a thoracotomy compared to blunt traumas. Indeed, patients with no signs of life after blunt trauma have a worst prognosis and are generally not indicated for emergency thoracotomy.

In a monocentric series of more than 1,000 patients, Kulshrestha and colleagues report that thoracotomy was needed in 2.6% of chest trauma (6). Conversely, a more recent Turkish paper (40) on a larger cohort of patients from I level trauma centre, report a thoracotomy rate as high as 6%. This difference is the result of epidemiology of trauma which is deeply influenced by several economic and social issues.

ATLS guidelines (9) recommend immediate thoracic surgical intervention in case of blood loss more than 1,500 mL at first or more than 200 mL/hour during the first 2–4 hours from chest tube placement; in case of endobronchial blood loss or tracheobronchial injury; and in case of heart or great vessel injuries. Moreover, a review of the literature by the Easter Association for the Surgery of Trauma (41), suggest thoracotomy in case of penetrating trauma with or without vital signs and the do not recommend thoracotomy in case of blunt traumas without vital signs. As a matter of fact, outcomes after emergency thoracotomy are strictly dependent on a correct patients' selection (42).

Which thoracotomy?

In emergency cases, anterolateral thoracotomy at 4^{th}–6^{th} intercostal space is usually performed. This approach usually guarantees a safe and large enough access for all emergent procedures, even great vessel clamping which might allow to save time to reach the operating theatre when the emergency thoracotomy is performed in the emergency room (6). Nevertheless, in up to 20% of case anterolateral thoracotomy might not be enough to guarantee a correct view of possible lesions; in these cases, clamshell or hemi-clamshell approaches can be performed (42).

The role of video-assisted thoracic surgery (VATS)

Recently, VATS has been used more and more often in the treatment of elective lung resection and showed to be beneficial compared to thoracotomy in terms of

postoperative chest pain (43). Similarly, VATS has been proposed to be used also in selected patients with stable hemodynamic conditions for persistent non-massive haemothorax, persistent air leak, diaphragmatic rupture; moreover, also trauma sequelae such us empyema can be treated with a minimally invasive technique (5).

Conclusions

Chest traumas is one of the leading causes of morbidity and mortality worldwide with different epidemiology due to economic and social factors; they require a careful management by emergency doctors or thoracic surgeons. Following the stream of recent innovations, also thoracic trauma surgery is moving towards a minimally invasive approach. Thinner chest tubes are gathering more and more evidence to be as efficient as large bore drain; and VATS is carving out a role in case of post-traumatic surgical exploration. Nevertheless, high grade evidences to support all these innovations are currently lacking. Large clinical trials are therefore needed to correctly assess the role of new minimally invasive tools in the management of chest trauma (44).

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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