LITERATURE REVIEW

Journals BAHIANA
SCHOOL OF MEDICINE AND PUBLIC HEALTH

# PRACTICAL ASPECTS ABOUT CLOSED CHEST DRAINAGE CARE: A LITERATURE REVIEW

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**ABSTRACT | Context:** The drained pleural contents may vary, as well as their drainage, however closed drainage system is the most frequent one and reaches flaws along those who are in charge of their management. **Objetive:** Provide a comprehensive review about close chest drainage. **Methods:** A systematic search of the PubMed and Medline databases was conducted on closed drainage system using the following keyword combination: chest tubes AND drainage. **Results:** From eight hundred eight-three articles retrieved after our preliminary search, 17 articles were chosen for final analysis. Representative schemes were drawn to better understanding of the three types of chest drainage systems for pleura effusion: (i) the closed drainage system; (ii) the open drainage system; and (iii) the suction drainage system. Representative pictures were also developed in order to facilitate additional care in the field. **Conclusions:** Bringing information together about chest tube management in closed drainage system may imply in a better approach to the patients, minimize institutional cost, minimize material waste and promote efficient communication among the multidisciplinary staff. Understanding details about tubular tube, pig tail tube, one-way bag, one-way valve and collectors is the only way to perform a better approach to the patient who needs closed drainage system.

**Key-words:** chest tube, drainage, empyema, pneumothorax.

Submitted 2017/02/14, accepted for publication 2017/05/06 and published 2017/05/29
DOI: 10.17267/2238-2704rpf.v7i2.1280

## INTRODUCTION

Drained pleural contents may vary from air (pneumothorax), transudative, exudative, hematic (sanguinous), sero-hematic (serosanguinous), to chylous (lymph fluid) or pus. Ideally, a closed system decreases infection risk and restore the negative pressure of the pleural space[2,3,4].

Although there are few reports about notification and errors, some papers present staff flaws around pleural drainage5,6.

Properly managing the drainage system minimizes procedure-related complications[7,8]. Therefore, strategic educational initiatives are in place to ensure knowledge deficits are focus on a chest drain management.8, A greater awareness of the areas of knowledge weakness regarding chest drain management will facilitate targeted educational initiatives in the future, ensuring improved chest drain management[9].

This paper aims to bring knowledge in order to fulfill lacks in literature, all in one, in a exposure manner to help staff directly to patients at bedside.

## METHOD

### Literature search strategy

A systematic search of the PubMed and Medline databases was conducted on closed drainage system.

The search was performed using the following keyword combination: chest tubes AND drainage.

### Inclusion criteria

Studies were eligible for inclusion if they (1) were related to pleural drainage; (2) were human studies; (3) were published in English and Portuguese; (4) were free full text publishing access.

The initial selection was based on the title, second on the abstracts. Those deemed relevant were retained for further analysis, which included selection based on an analysis of the full text of the articles. The authors performed a double-check review of the list of possible studies (ACT and ISTN), and in the case of disagreement between the two on whether or not a study was included, the opinion of a third reviewer (PHXNA) was consulted.

Manuscripts were cited and presented alphabetically (based on their first authors) to better clarify data presentation.

### Exclusion criteria

Studies were not included if they only presented (i) combined therapy, (ii) cardiac drainage, (iii) digital drainage system or other electronic devices, (iv) management of pleural aspiration / suction or indication of surgical procedures; (v) animal results; (vi) epidemiological data; (vii) suture innovation; (viii) complications, vital capacity and six-minute walk or other related investigation (only had pleural drained itself as a sample' characteristic) (ix) development of curved chest tube (unusual material); were also not deemed as relevant, and were not included in final analysis

### Data extraction

The following data were collected for final analysis from each study: physiology; physiopathology of pleural effusion; difference of bottles in closed drainage system; scheme of one-bottle water-seal chest drainage chest drainage system; scheme of two-bottle water-seal chest drainage chest drainage system; scheme one-way valve chest drainage chest drainage system; different drainage recipients (bottles x bags); drainage recipient placement; nursing care; changing or emptying the drainage container; pleural-space disruptions management; caring for the chest tube and drainage system during transport; controlling fluid evacuation.

Based on these collected information, an aggregation of all data and schemes were performed for better exposure and explanation among the issue.

## RESULTS AND DISCUSSION

Eight hundred eight-three articles were retrieved after our preliminary search, and 666 were considered potentially relevant based on the title. From these, 62 articles were considered eligible due to their abstract contents. After a careful selection, 36 were selected for full-text assessment and 20 were excluded for several reasons. Finally, 16 articles were chosen for final analysis. (Figure 1)

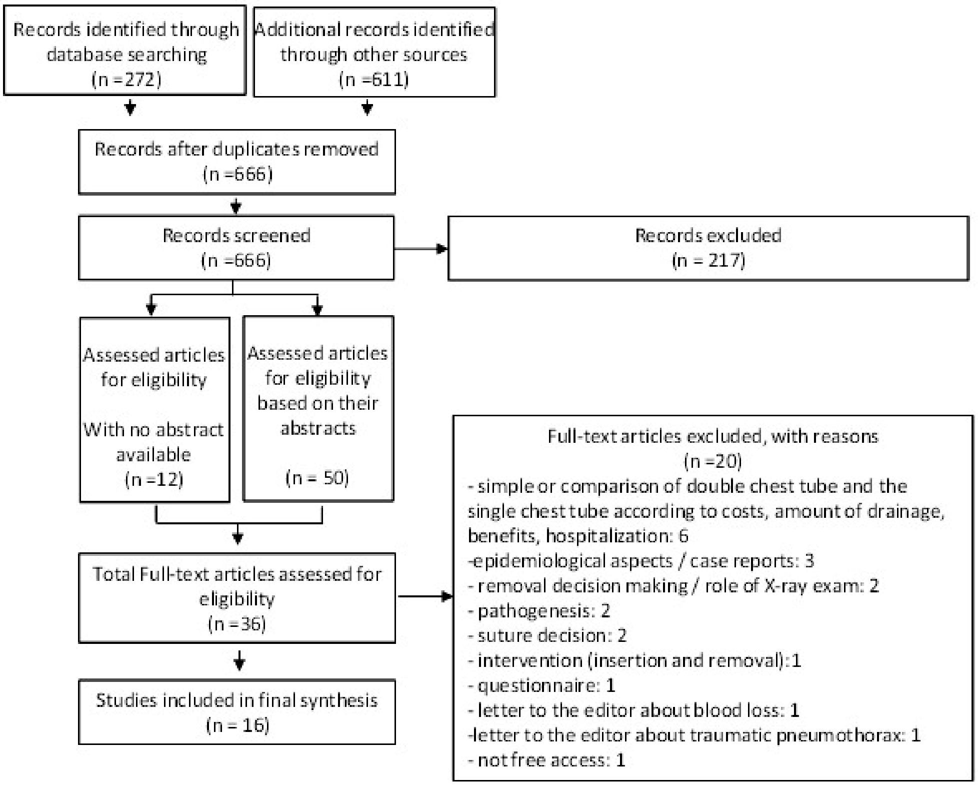


**Figure 1.** Flow chart of paper selection and final inclusion.
Source: developed by the authors

Selected studies dated from 1963 to 2015.8-22 All fifteen selected studies inform lacking data from chest tube management. Table I shows general description of the included studies and provides information regarding the original cited data (table I).

**Table 1.** General description of the included studies. N:no; Y: yes.

| Author | Physiology | Physiopathology of pleural effusion | Difference of bottles | Scheme One-bottle water-seal | Scheme Two-bottle water-seal | Scheme One-way valve | Diferrent drainage recipients (bottles x bags) | Drainage recipient placement | Nursing care | Changing or Emptying the Drainage Container | Pleural-space disruptions management | Caring for the Chest Tube and Drainage System During Transport | Controlling Fluid Evacuation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Charnock[10] | N | N | N | N | N | N | N | N | N | N | Y | Y | Y |
| Durai[11] | N | N | N | N | N | N | N | N | Y | Y | N | Y | Y |
| Buaman[12] | Y | Y | N | N | N | N | N | N | Y | N | Y | N | N |
| Haggie[13] | N | N | N | N | N | N | N | N | N | Y (clamping) | N | N | N |
| Kwiatt [14] | N | N | N | N | N | N | N | N | Y | N | Y | N | N |
| Laws[15] | N | N | N | Y (only mention) | N | Y (only mention) | Y (only mention) | N | Y | N | N | N | Y |
| Magner [9] | N | Y | N | N | N | N | N | Y | Y | N | Y | N | Y |
| Mohammed[16] | Y | Y | N | N | N | N | N | N | Y | N | Y | Y | Y |
| Morais [7] | N | Y | N | N | N | N | N | N | Y | N | N | N | N |
| Muzzy[17] | N | N | N | N | N | N | N | N | Y | Y | N | Y | N |
| Nishida [8] | N | N | N | N | N | N | N | Y | Y (dressing) | Y (clamping) | N | N | N |
| Saur[18] | Y | Only trauma | N | Y | Y | N | N | Y | Y | N | N | N | N |
| SECHER[19] | N | N | N | Y | N | N | N | Y | Y | Y | N | N | N |
| Tang [20] | Y | Y | N | N | N | N | N | Y | Y | Y | Y | Y | N |
| Yoshimura [21] | N | N | N | N | N | N | N | N | Y (dressing) | N | N | N | N |
| Zisis[22] | N | N | N | Y | Y | Y | N | N | Y | N | Y | N | N |

Nonetheless, the purpose of the system is to allow for drainage from the pleural cavity to the outside and at the same time prevent the entry of atmospheric air into the pleural cavity. The chest drainage also aims to maintain or restore the negative pressure of the pleural space[2-4,12,16,18,20].

For each case, there are 3 types of chest drainage systems for pleura effusion: (i) the closed drainage system; (ii) the open drainage system; and (iii) the suction drainage system[7-18,20-22].

In the early 196Oth, a group of authors proposed a disposable bag for thoracic drainage. However its reasonability is also related to a one-bottle water seal the bag itself did not become much common in literature, which has not been cited elsewhere[19].

Chests tubes can be tubular and pigtail (Figures 1A 1B). Chest tubes are multifenestrated, e.g. have several openings at one end of the tube section (which resides inside the patient wall) and have a rounded end[3,12]. Nontheless, chest tubes are placed on a superior position for air removal (tube placed high) and placed on an inferior position, primarily for fluid removal (tube placed low)[1,2,4,12].

The tubular chest tube is a standard chest drain. It has different sizes (from infants to adult, small for air, larger for fluid), different configurations (curved or straight). Tubular chest tube can be made of polyvinyl chloride (PVC) or silicone. It has a radiopaque filament entire length. (Figure 1A)[8].

The pigtail is a flexible spiralled PVC or silicon drain. It is tightly curled at one end which resides inside the patient wall) (Figure 1B)[8].

Chest tubes may be connected to a variety of closed drainage systems: one-way valve or sealed flutter valve (e.g. pneumostat or Heimlich valve) (Figure 1C) and collector (Figures 1D and 1E). Therefore it management will depend on these factors[15,18,22].

Collectors may vary: with or without water-seal; with one, two bottles; with or without suction control[4,12,15,18,19,22]. If suction is required, either a third bottle is added or some specific thoracic pressure regulator vacuum. Each single collector plays a different role in the drainage system.

Adjustment between the drain and the tube from the collectors connected to the bottle under water seal by using a large-diameter intermediate connector[7].

### Basic physiology of pleura pressure

During inspiration, the inspiratory muscle contraction exerts traction centrifugally throughout the thoracic wall. The parietal pleural portion follows the chest wall traction and intrapleural pressure becomes more negative. This negative pressure moves the drained collected effusion through the drainage tube in some millimetres (at this moment the oscillation or swinging of the debit can be observed). This oscillation can be also presented in the water-seal drainage system[9,12,16,18,20].

During exhalation, the diaphragm and intercostal muscles relax; there is lung elastic recoil, which creates a positive intrapleural pressure. At this time, this positive intrapleural pressure makes air moves out of the lungs by flowing down its pressure gradient, while the pleural effusion is forced to move throughout the drainage-tube to the collector[9,12,16,18,20].

The sequence of the working systems differ from a water-seal drainage system and a single bottle, a water-seal drainage system and two bottles, water-seal drainage system functioning with a one-way drainage bag-collector, and a drainage system functioning with Heimlich valve (one-way valve).

### Functioning of closed drainage system, with a tubular or pig tail tube, during exhalation.

With water-seal drainage system and a single bottle (Figures 2A and 3A), pleura effusion stays in the collector. If fluid is draining, it will add to the fluid in the water seal, and increase the depth. As the depth inside the collector increases, so does the hydrostatic pressure, therefore, it becomes harder for the air to push through a higher level of water. In other words, the level of water in the water seal chamber represents the amount of negative pressure being generated (Figure 3A)[9,11,13,17,19,20].

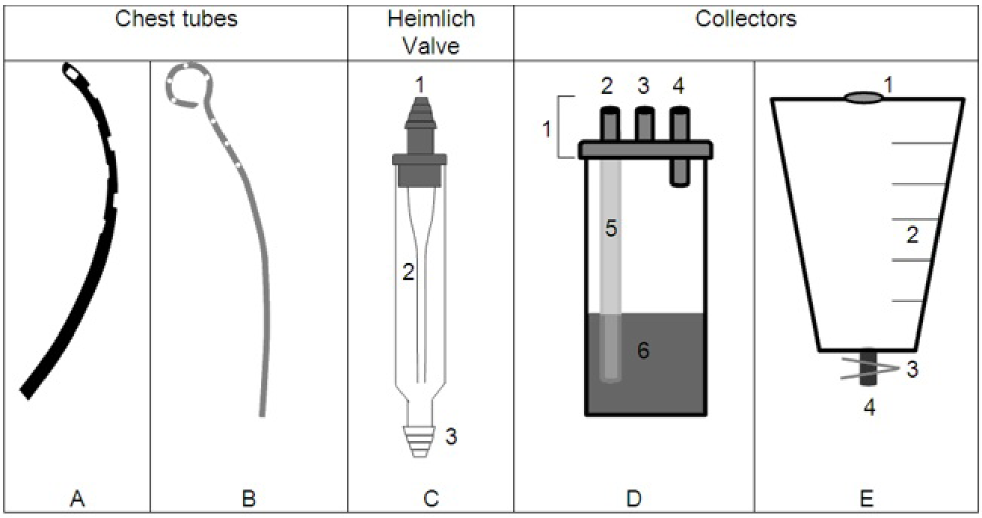


**Figure 2.** Details about chest drainage.
A: tubular chest tube (standard chest drain); B: pigtail chest tube; C: Heimlich Valve. C1: Inlet nozzle; C2: rubber sleeve; C3: Outlet nozzle. D: water-seal drainage bottle. D1: cover collector; D2: drain tube; D3: blind output; D4: output vent gases; D5: drainage-tube; D6: water seal; E: one-way drainage bag-collector; E1: one-way valve; E2: bag-collector (with graduated measurement); E3: clamp; E4: output.

Source: developed by the authors

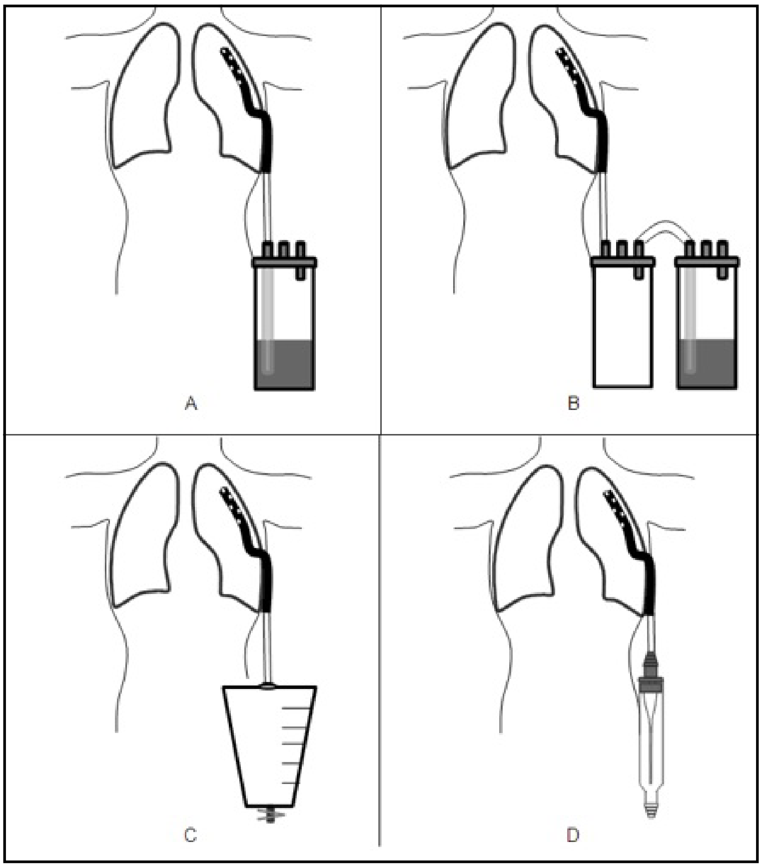


**Figure 3.** Closed drainage system with a tubular chest tube.
A: Tubular chest tube with a water-seal drainage system and a single bottle; B: Tubular chest tube with a water-seal drainage system and two bottles; C: Tubular chest tube with a water-seal drainage system with a one-way drainage bag-collector; D: Tubular chest tube with a Heimlich valve (one-way valve).

Source: developed by the authors

In this type of drainage, the bottles and collection apparatus of the system must be kept 30-40 cm below the level of the chest to prevent backflow and to promote gravity drainage[8,11,18-20]. However some reports only mention that The drainage bottle must be kept below the patient's chest level to prevent fluid re-entering the pleural space[9].

With water-seal drainage system and two bottles (a drainage collector and a water-seal bottle), pleura effusion stays in the collector (first bottle) (Figures 2B and 3B on the left). Therefore, the first bottle only collects the drainage. The positive pressure in the system moves from the first bottle to the second one. The second bottle has the water seal (with it, the water seal must be set at 2cm of water). (Figures2B and 3B right) In this kind of drainage, the bottles and collection apparatus of the system must be kept 30-40 cm below the level of the chest to prevent backflow[11,20].

With a water-seal drainage system with a one-way drainage bag-collector (Figures 3C and 3C), pleural effusion is forced to move throughout the drainage-tube to the one-way drainage bag-collector. The one-way valve of the bag prevents air or fluid from returning to the chest, through the chest drain. The clamp prevents the fluid to go through the output, thus being collected in the bag-collector. (Figure 3C) The one-way valve prevents air or fluid from returning to the chest. Consequently, this kind of drainage works independently on the gravidity[15,22].

With a Heimlich valve (one-way valve) in the drainage system (Figures 2D; 3D and 4), pleural effusion is forced to move throughout the drainage-tube to the Heimlich valve. Then, the more positive pressure makes the sleeve opens, allowing their contain to escape. (Figure 3D left) During inspiration, the parietal pleural portion follows the chest wall traction and intrapleural pressure becomes more negative, making sleeve closes, which prevents backflow of air (Figure 3D right)[3,4,15,22]. This kind of drainage works independently on the gravidity.

A Heimlich valve is quite use for pneumothorax drainage, however fluids can also be drained with this device. In case of fluid drainage, a bag can be kept no its end only for collection reasons (Figures 4B and 4C).

## Additional knowledge

Attention should be given to the inserted sutures that anchors the drain in place and perform a fixed dressing in the tube site[7,8,11,20,21] and use dry gauze pads around and over drains and tubes to protect them from damage or external contamination. The chest drain site should be assessed at least daily for signs of systemic or local infection[10,11,20]. A dressing must be placed in order to assist tube stabilization and helps preventing the tube from becoming disconnected. (Figure 5 A-B)[11,20].

The fluid level in the underwater seal collector must be checked regularly, as well as its colour, consistency of the drainage contain[14,18] and air leak presence (bubbling)[9,20]. Medical staff needs to be notified if there is a sudden increase in amount of drainage greater than 5mls/kg in 1 hour or greater than 3mls/kg consistently for 3 hours[9-11,16,20].

For collection removal, nurse staff must squeeze the pinch clamp on the drainage tube completely[20]. While the clamp maintain the tube closed, the seal-water contain is discharged. (Figure 5 C-D)[11,20] However clamping a chest drain tube can increase the risk of a tension pneumothorax. Therefore, clamping the tube must be avoid[7,9,20] regarding the same aspects, the description of techniques used to maintain drain patency (e.g. ‘milking’ as fanfolding the drainage tubing into segments and squeezing and ‘stripping’ as manual compression of the chest drain tubing from the chest wall towards the collection chamber often using a roller device) is not consensuous, thus not recommended[7,9,14-16].

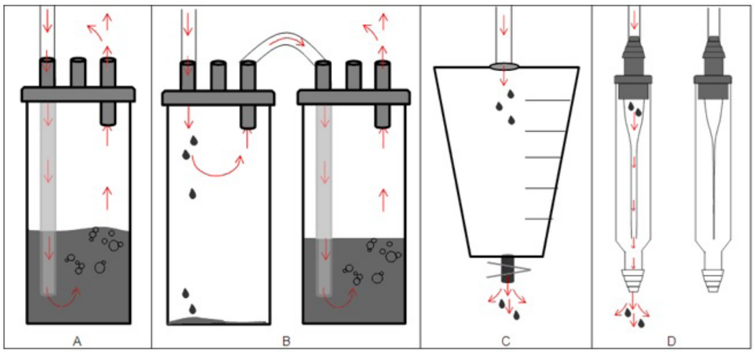


**Figure 4.** Chest drainage with a scheme of pleura contains flow during expiration.
A: with a water-seal drainage system and a single bottle; C: a water-seal drainage system with a one-way drainage bag-collector. Note: the bag contain is removed through the output only when the clamp is open. D: a Heimlich valve (one-way valve) during expiration (left). Note that the rubber collapse during inspiration, preventing the air back flow (right); Arrows and bubbles represent air; Drops represent the fluid contain.

Source: developed by the authors

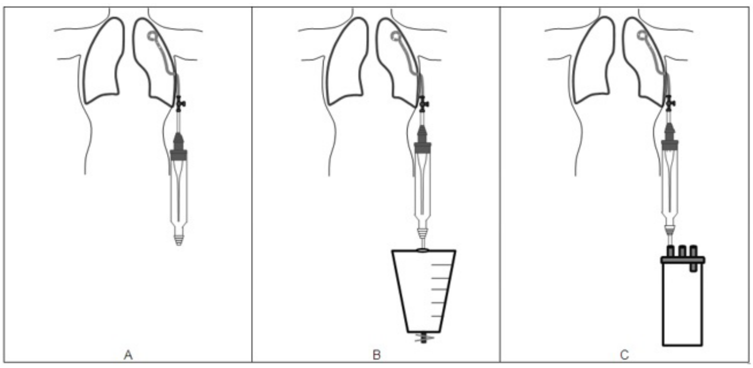


**Figure 5.** Closed drainage system with a pigtail chest tube.
A: Pigtail chest tube with a Heimlich valve (one-way valve). B: Pigtail chest tube with a Heimlich valve (one-way valve) and a one-way drainage bag-collector; C: Pigtail chest tube with a Heimlich valve (one-way valve) and a collector.

Source: developed by the authors

Chest X-ray images after a chest drain insertion helps verifying its correct placement and evaluating the degree of the lung re-expansion and the residual pleural fluid and/or pneumothorax[7,11,20].

The presence of air leak (bubbling contain) can be easily noted in the collector (Figures 2A; 2B; 3A and 3B) or the collect fluid in the bag (Figure 4C). A bubbling contain (water or drained pleura fluids) indicates the presence of a bronchopleural fistula, a communication between bronchial tree and the pleural space. The bubbling can be continuous (throughout the respiratory cycle), during inspiration (called as inspiratory air leak), during expiration (called as expiratory air leak), or there is air leak only when patient performs forced expiration or coughs and also called as forced expiratory air leak. This forced expiratory air leak represents the smallest type of fistula and is classified as benign, with a more possibility of spontaneous reversibility.

A bubbling can be evaluated in chest tube connected to a one-way-valve by placing the system into a glass with water while patient perform a cough or expiration. (Figure 5E)[7,9,11,12,16,20].

The entire drainage system should be noticed: The insertion sutures that anchor the drain in place and the dressing on an attempting of not moving or removing the tube[11,14,20].

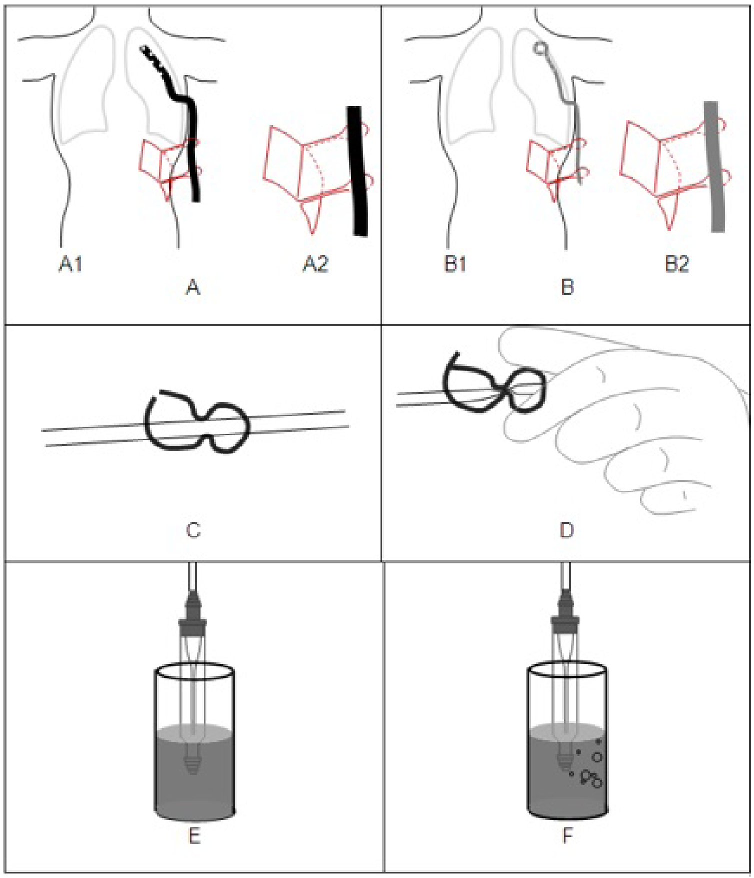


**Figure 6.** Additional orientation and security suggestions to the staff.
A-B: Additional dressing around the chest tube. A1: Dressing around the tubular chest tube on the chest wall; A2; zoon from the dressing; B1: dressing around the pigtail chest tube on the chest wall; B2: zoom from the dressing. C-D: Clamping the drain tube. C: Drain tube portion with an opened clamp (note the drain tube with the pended clamp allows pleural contain flow); D: Drain tube portion with a closed clamp by the hand of the operator (note the drain tube with the closed clamp interrupts pleural contain flow). E-F: Test of bubbling in patients with a chest tube (tubular or pigtail) and a Heimlich Valve. E: Imerge the valve into the glass of water; F: Ask patient to performe a cough or an expiration.

Source: developed by the authors

## CONCLUSION

Bringing information together about chest tube management in closed drainage system may imply in a better approach to the patients, minimize institutional cost, minimize material waste and promote efficient communication among the multidisciplinary staff. Understanding details about tubular tube, pig tail tube, one-way bag, one-way valve and collectors is the only way to perform a better approach to the patient who needs closed drainage system.

### AUTHOR CONTRIBUTIONS

Tavares AC was responsible for the study conception and design, the literature review, the writing of the manuscript and the critical review. Araújo PN was responsible for the literature review and the critical review of the manuscritpt.

### COMPETING INTERESTS

No financial, legal or political competing interests with third parties (government, commercial, private foundation, etc.) were disclosed for any aspect of the submitted work (including but not limited to grants, data monitoring board, study design, manuscript preparation, statistical analysis, etc.).

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