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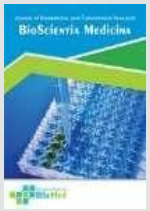

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One-Way Valve as Management of Chest Tube Ambulation in Pneumothorax Cases

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A B S T R A C T

An adequate chest drainage system is the main goal of fluid and air evacuation and restoring negative pressure intrapleural so it can help lung development. The intrapleural is a closed, airtight space filled with a small amount of fluid as a lubricant for lung movement during the breathing process. Accumulation of intrapleural air is known as pneumothorax, and one of the initial management options is the implantation chest tube. Chest tubes, which are connected to a water seal, conventionally show varying results and have shortcomings because they require monitoring and limit patient mobility, so the safety of their use in outpatient settings is questionable. Lungs that are not inflated or have an inflated water seal still show air bubbles even though it has been installed. A chest tube adequate for 48 hours is a condition known as persistent air leak, thus requiring extended usage time from chest tube to the drainage management complex. Use of ambulation management through the use of various tools and equipment devices which can be connected with a chest tube can be an option with the aim of reducing treatment time, lowering funding, increasing comfort and hopefully providing better external results.

1. Introduction

The potential space between the visceral pleura layer that lines the lung parenchyma and the parietal pleura that covers the chest wall, diaphragm, and mediastinum is the intrapleural.[1,2] The intrapleural is an airtight closed chamber where the pressure is sub-atmospheric and varies during the respiratory cycle, increasing during expiration and decreasing during inspiration. The recoil of the lungs and chest wall tends to expand, causing intrapleural pressure to become negative, resulting in the formation of transpulmonary pressure. Abnormal accumulation of air and fluid in the intrapleural can have a pressing effect and interfere with the negative pressure in the intrapleur.[1] Pneumothorax is a condition where the intrapleural is filled with air, which can occur spontaneously or traumatically. Spontaneous pneumothorax, based on etiology, is grouped into primary spontaneous pneumothorax (without underlying lung disease) and secondary spontaneous pneumothorax (accompanied by underlying lung disease).[1,3]

Secondary spontaneous pneumothorax (SSP) is associated with higher morbidity and mortality and more difficult management than primary spontaneous pneumothorax (PSP). Symptoms of SSP can be minimal or absent, in contrast to PSP, which, although small in size, can show dominant symptoms.[4] PSP or SSP patients with symptoms of significant shortness of breath and large pneumothorax size according to guidelines British Thoracic Society (BTS) in 2010, intervention must be carried out based on the text of

the BTS public consultation on pleural disease in 2022, it has proposed a new pathway for pneumothorax management, substantial things have changed in the latest BTS recommendations, extensive pneumothorax is no longer an indication for invasive management and use chest tube more focused on high-risk patients.[4,5]

The main goal of an adequate intrapleural drainage system is to drain fluid and air, prevent air from returning to the intrapleural, and restore negative pleural pressure, thereby facilitating lung expansion. An intrapleural drainage system with a chest tube connected to a conventional WSD requires good management, water levels, and a tip chest tube. The WSD must be maintained to prevent the return of air to the intrapleural.[6,7] Drainage management intrapleural is currently undergoing adjustments along with technological developments and selected with various considerations, including clinical conditions. The use of WSD bottles, limiting the patient's mobility or ambulation due to the weight and size of the bottle, can prolong the length of stay and, in some cases, require the use of a chest tube over a longer period of time, which causes discomfort, and monitoring is difficult for patients and health workers.[1,8] Another disadvantage of the conventional WSD system, apart from impaired mobility, is that the suction pressure is variable and unreliable, and this system cannot detect and calculate the amount of air or liquid leaks objectively and accurately.[2]

Pneumothorax patients with lung development failure after adequate chest tube insertion for more than 48 hours (persistent air leak), a patient who requires extended use of chest tube with more complex drainage management. Management of more complex drainage, such as the use of suction, tube repositioning, pleurodesis, and consultation with the thoracic surgery department. Pleurodesis is one option in invasive therapy, and using an ambulation management chest tube is a non-invasive alternative.[4] The ambulation device generally incorporates a one-way valve (Heimlich valve) that replaces the conventional WSD, either by installation of the chest tube online or as part of an integrated device. The smaller-sized portable device was created to facilitate quicker ambulation management in patients compared to large WSD bottles. Ambulation management chest tubes can provide convenience and comfort to patients so they can mobilize safely, and several tools and equipment devices with and without suction help more quickly resolve pneumothorax. A systematic review of the literature on various studies addresses the management of ambulation chest tubes. Outpatient treatment for both spontaneous and iatrogenic pneumothorax has an overall success rate of approximately 86% with few complications.[4,9]

Chest tube ambulation management

Ambulation management can be done with a mounting chest tube, which is connected to a one-way valve at the external end of the tube, allowing the patient to mobilize independently and be discharged from the hospital. Mobilization can be done without having to carry a bottled water seal. The use of a one-way valve can remove air and fluid from the thoracic cavity during the inspiratory phase and prevent it from entering again during the expiratory phase. A one-way valve that is attached to the chest tube can be used in patients who still need drainage in the thoracic cavity but do not need to be hospitalized. Patients can use the chest tube during outpatient care with appropriate management, mobilize, and perform some activities without interruption by keeping the valve fixed to the chest wall.[2,10]

The use of one-way valves can be performed and followed by other actions or connected with other enhancements, such as followed by needle aspiration, suction, or without additional other actions or devices.[11] The size of the pneumothorax is adequate for intervention, which is clinically dependent, but usually the distance between the collapsed lung and the parietal pleura ≥ 2 cm laterally or apically in the thoracic photograph and of any size as long as it can be safely accessed with radiological assistance computed tomography scan (CT Scan) of the thorax. The selection of ambulation management must be

supported by the availability of a health center with monitoring facilities and the nearest emergency installation. Outpatient monitoring is carried out regularly after installation of the ambulation device every 2-3 days. The hose can be removed during the repair pneumothorax and if stable monitoring is carried out on an outpatient basis for 2 to 4 weeks.[5]

Structure and working mechanism of one-way valve/Heimlich valve

The one-way valve functions to prevent air that has been evacuated from re-entering the chest cavity through a chest tube installed. The valve is made of a plastic housing with a rubber sleeve inside, as in Figure 1.[12]

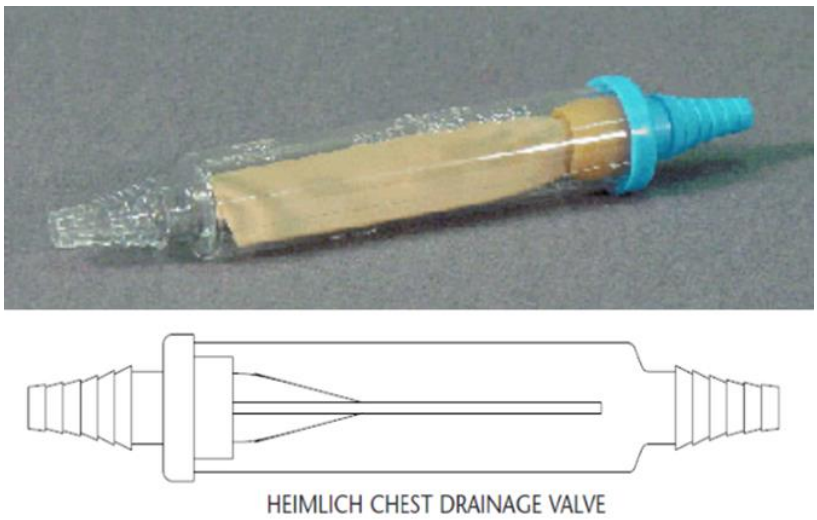

Figure 1. Drawing and schematic of the Heimlich valve.

The Heimlich valve has two nozzle ends; one end is an inlet that allows air to pass through the valve through the attached chest drainage tube, and the other end is an outlet that allows air to flow to the environment or collecting device during expiration. A rubber sleeve is attached to the inlet end in such a way that, during inhalation, the valve closes, thereby preventing air from re-entering through the valve into the intrapleural.[13,14]

The working mechanism of the Heimlich valve looks like Figure 2: the airflow from the end side is attached to the rubber connected to the chest tube, which will create positive pressure in the valve tube, expand the valve, and let the air out, then the pressure will return to negative and close the valve, preventing air from coming back in. The design of the Heimlich valve is a one-way valve, and the direction of airflow is determined by the orientation of the valve installation. Installing a reverse valve will reverse the direction of airflow from outside to inside the intrapleural during the inspiratory phase, which can result in air being trapped in the intrapleural and not being able to escape through the valve, resulting in the pneumothorax getting wider in a short time.[15]

The function of the Heimlich valve will be achieved if installation is carried out in the right direction, the adapter at each end of the valve has an identical shape, and some products are made with a symmetrical design with a tapered end that can adapt to various sizes chest tube. The similarity of the design at the end of the valve results in doubts and errors in installing the valve direction, as in Figure 2.

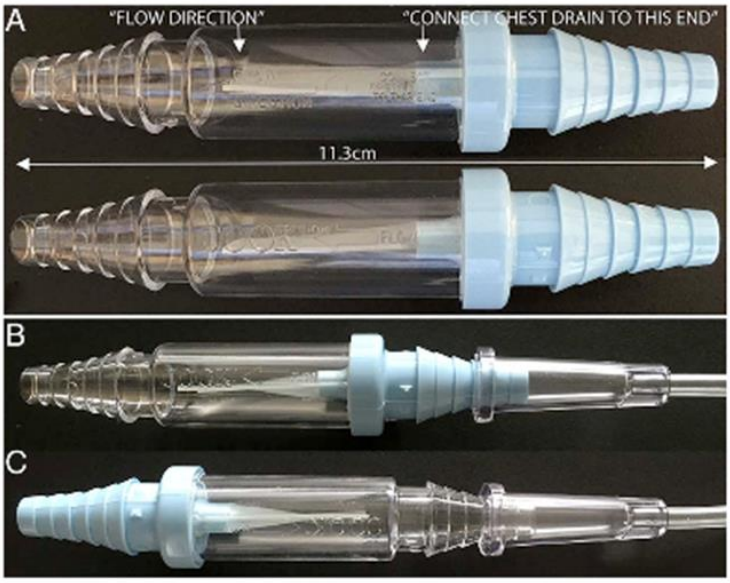

Figure 2. Installation of Heimlich valves. A) Shows the shape of both ends of the valve with a symmetrical and constricted design like a "Christmas tree", B) Proper installation of the Heimlich valve. C) Indicates incorrect installation of valve direction.

Advantages of one-way valves

The installation of the valve can prevent the operation in closing the presence of air leakage, and can reduce the treatment time. Cerfolio and Brims et al. Review serious complications resulting from the installation of a one-way valve, which is a rare occurrence.[15,16] The use of the Heimlich valve has several advantages compared to other drainage devices. The Heimlich valve is small, light, easy to use, and has good portable properties, thus enabling patients to mobilize/ambulate more quickly, safely, simply, and efficiently. The function and working mechanism of this valve is not difficult for health workers or patients to understand. The manufacturing cost is relatively cheap and allows it to be used as a disposable device that does not require re-sterilization. The valve was sterilized before entering the packaging and stored in a sterile place so that it could be used immediately.[16]

Patients who have a Heimlich valve installed can feel more comfortable and mobilize more quickly. The patient can walk around the hospital by storing the valve under clothing. Mobilization can also improve lung function, increase motivation, and avoid associated stigma chest tubes.[7] Chest tube The Heimlich valve that has been installed can be in various positions and is not limited to the position it must be in under only and does not need to be clamped. Patients can go home faster from hospital treatment, thus reducing treatment costs and preventing nosocomial infections.[15]

Indications and contraindications for the use of one-way valves

Patients with pneumothorax or hydropneumothorax require special care in the hospital. Air, fluid, or blood in the intrapartum causes lung collapse and deviation of the mediastinal structures, resulting in shortness of breath and can become a life-threatening condition (tension).[16] The procedure for removing air, water, or blood is carried out by installing a chest tube, which is connected to the WSD system during the hospital stay. The lungs cannot fully expand in some circumstances, requiring longer-term treatment, increasing treatment costs, and causing discomfort to the patient. The use of a one-way valve is an alternative option to the WSD bottle in patients with persistent pneumothorax or cases with hydropneumothorax. Persistent pneumothorax patients with remaining lung tissue

and low lung function are unlikely to undergo surgery, requiring treatment with a chest tube. In the long term, this is another indication for installing a one-way valve to allow air to flow from the intrapleural during outpatient treatment.[14] Indications for the use of the Heimlich valve are intended as outpatient management in cases of first-episode primary spontaneous pneumothorax, early discharge in postoperative patients after lobectomy/segmentectomy for lung cancer, and in cases of persistent pneumothorax.

Failure of lung expansion or persistent pneumothorax risks prolongation of the implant chest tube accompanied by complex drainage management such as the use of suction and repositioning the chest tube until referral to the thoracic surgery department.[4] Causes of persistent pneumothorax, such as related chest tube (kinking or malposition), lung parenchymal disease, bronchopleural fistula, or esophageal-pleural fistula, are shown in Table 1. Specific contraindications for the use of the Heimlich valve do not exist based on the literature, and hydropneumothorax with a massive volume or with thick pleural fluid is a relative contraindication because the pleural fluid is thick can increase the risk of adhesion/blockage.

Table 1. Etiology of persistent pneumothorax/persistent air leak.

Causes	**Example**
Chest tube	Kink Obstruction Malposition Incomplete seal
Bronchopleural fistula (BPF)	Iatrogenic Traumatic Erosive
Alveolar pleural fistula (APF)	Rupture bulla Traumatic Necrotizing pneumonia Ulcerated lung cancer, metastasis osteosarcoma
Other	Esophagopleural fistula (EPF)

One-way valve installation and maintenance

The rubber sleeve on the Heimlich valve is attached to the end of the inlet nozzle. When inhaling, the rubber will close, preventing air from being sucked in through the valve into the intrapleural. Air passes through the inlet nozzle through a rubber sleeve, which then opens and allows air to escape during expiration so that, in this way, the pneumothorax is safely evacuated. The same mechanism in the Heimlich valve can also facilitate fluid evacuation. The inlet at the end of the nozzle is attached to a rubber sleeve connected to the end chest tube, which is outside the chest wall, where the other end is in the chest cavity. The valve connection with the hose can be secured with adhesive installation, and the valve is attached to the end chest tube fixed to the chest wall, keeping the distal end/nozzle outlet open. Connecting the outlet end of the valve nozzle with a collecting device like a bag can be used for fluid evacuation and connection with negative pressure or suction if needed. The chest tube can vary from small to large sizes and can be connected to the Heimlich valve according to the cone-shaped design of the nozzle tip "Christmas tree".[14] Air passes through the valve with an audible "flutter" sound that ensures the device is functioning properly. A missing "flutter" sound followed by no movement of the rubber sleeve during installation indicates no air is passing through the valve, which may indicate the resolution of the pneumothorax or blockage. chest tube, which can be confirmed by chest wall auscultation or chest X-ray examination.[17]

Re-examine the suture at the insertion chest tube It is important to do this before the patient goes home

from the hospital. Re-stitching can be done if the stitching is not strong enough and is loose using non-absorbable thread, as well as bandage. Make sure the plaster is installed properly to prevent its shift or accidental disconnection of the hose.[6] Monitoring Heimlich valve use should also assess for injury at the insertion site chest tube. Every part and side is connected to the drainage system and drainage bag. The wound must be covered with a bandage that is clean and dry and must be changed every day to prevent possible sources of infection. Hydropneumothorax patients with installed Heimlich valves must be connected to the drainage bag to accommodate the escaping fluid. The drainage fluid collection bag must be replaced regularly and emptied periodically, and the amount and color of pleural fluid must be recorded to assess progression. An increase in the amount of fluid or a change in color can be a sign that further examination is needed.

A Heimlich valve that is accidentally disconnected between the connectors must be reconnected immediately, so patients are asked to be careful in their activities. The patient is also asked to cough to expel air that may have entered the chest cavity when the Heimlich valve dislodged. Monitoring the condition of the Heimlich valve and assessing disease progression can be done once a week. The clinician evaluates the presence of valve occlusion, leakage, discoloration of pleural fluid secretions, and complications such as infection and subcutaneous emphysema. Radiological investigations may be performed periodically to assess lung condition. Patients can make unscheduled visits once a week if there are symptoms such as high fever, heaviness and pain in the chest that is increasingly intense, swelling in the neck or hands, pain that increases and does not go away with pain medication, increased fluid levels, changes in color and smell.[16]

Risks and complications of one-way valves

Risks that can occur when installing a Heimlich valve are the valve coming loose or improper installation, leaks, adhesions, or blockage of the valve. Disconnection between drainage system parts and valves can occur accidentally. Improper installation when connecting a loose valve can result in free air entering the intra-pleura due to the pressure in the intra-pleura being lower than the outside air, especially during the inspiratory phase. During the expiratory phase, the valve that is installed backward cannot open; this can cause pneumothorax tension. The risk of unexpected events, such as a valve coming loose, can be prevented by applying additional adhesive to the hose connection with the valve. The risk of incorrect reconnection can be prevented by using different colors on the proximal and distal ends of the valve.[6,8] Serious adverse events were defined as events that required hospital treatment. Serious adverse events often occur not randomly exclusive due to ambulation management, such as additional pneumothorax due to obstruction or kinking on the chest tube, so the patient must be treated for repositioning or reinstallation chest tube.[9]

Poor condition of the Heimlich valve or prolonged use due to leaks can result in the rubber on the valve not functioning optimally, and the function is one-way disturbed. Thick pleural fluid secretions such as blood or empyema can cause blockage and obstruction of airflow and must be connected to a WSD bottle. As part of the complications of pneumothorax in general, subcutaneous emphysema can occur in patients with a Heimlich valve installed and requires hospital treatment. Intrapleural complications include infection, which is characterized by the intra-pleural fluid turning cloudy and smelling, which can occur as a result of the chest tube and the Heimlich valve being installed in a less sterile manner. Poor wound care near the chest tube can also cause local infection, which can be a very high risk of detachment chest tube. Infectious complications can be prevented by carrying out sterile insertion procedures, good wound care, and administering antibiotics.[14]

Multicentre study with a randomized control trial addressing ambulation management chest tube in 117 patients with primary spontaneous pneumothorax, 10 patients experienced serious adverse events and

required hospital re-admission, 4 of them experienced widespread pneumothorax on repeated chest X-ray examination during outpatient treatment, which required installation. chest tube repeated, 2 patients experienced malfunctioning chest tube (kinking or blocked), 1 patient was asymptomatic but showed pulmonary edema on chest X-ray, 1 patient had fluid production, 1 patient had a loose device, and 1 patient was treated for additional suction. Unexpected events that fall into the non-serious category in this study are pain at the insertion site, hematoma or bleeding, subcutaneous emphysema, and drainage device failure. Bias may occur in the outpatient group that uses ambulation chest tubes because the definition of a serious adverse event is an event that also occurs in the standard care group where being hospitalized is normal care.[18-20]

2. Conclusion

Ambulation management can be done by installing a one-way valve on the chest tube and replacing the water supply lock system, which does not allow patients to mobilize and install a chest tube in outpatient care due to doubts about its safety and follow-up care. The principle of a one-way valve/Heimlich valve is that it allows air or fluid to leave the chest cavity and prevents it from returning. The one-way valve, or Heimlich valve, was the first valve discovered and applied. Currently, there are many innovations and modifications in its use. Ambulation management is especially needed in patients who require intra-pleural drainage for a long period of time so that it can reduce costs and length of stay but still provide good success rates.

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