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Experience with the Operation of Thoracic Drainage Devices

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Abstract: In daily clinical work, the placement of thoracic drainage device is a common operation in thoracic surgery and respiratory department for the diagnosis and treatment of various respiratory diseases, including thoracocentesis and closed thoracic drainage. The application of this technology is of great significance for the rapid relief of patients with dyspnea and other clinical symptoms. It is also an important part of the standardized training of medical students, practicing physicians and resident physicians. During the standardized training of residents (September 2021-March 2024), under the guidance of thoracic surgery specialists, the author summarized the experience and experience of the operation through personal operation and observation of more than 70 catheterization cases, careful thinking and combined with relevant references.

1. Introduction

Chest drainage device is the most commonly used device in thoracic surgery and respiratory medicine for the diagnosis and treatment of various kinds of pneumothorax, various causes of pleural effusion [1], trauma patients, etc. [2], which can be used to discharge abnormal accumulation of gas or liquid in the pleural cavity [2]. This holds significant importance for rapidly alleviating patients 'dyspnea. Currently, the most commonly used and effective clinical treatments for pleural effusion are thoracentesis and chest tube drainage [3]. The thoracic drainage devices mentioned in this article refer to closed thoracic drainage and chest tube drainage, which are respectively applied to various pneumothorax and pleural effusion cases. The core operational steps of both methods are largely similar, differing mainly in the positioning of the puncture site on the chest wall and the drainage device connected. This article will provide detailed explanations. During my residency training period (September 2021-March 2024), under the guidance of a thoracic surgeon, I first observed senior physicians' operations to master basic technical standards, then independently performed over 70 catheter insertions through observation and hands-on practice. This experience has enabled me to summarize relevant operational techniques and insights, aiming to continuously improve clinical skills, standardize procedures, and better serve patients. Based on literature review and personal

practical experience, I summarize the following key points. (Note: These experiences are based on operations using the Aibel puncture kit and may not apply to all types of puncture kits)

2. Preparations for operation

2.1 Grasping the indications for catheter placement and identification of relevant medical data

First, physicians should thoroughly understand the patient's medical history and assess the necessity of the puncture after confirming indications and excluding contraindications. They should observe the patient's general condition, measure vital signs, verify laboratory tests (including complete blood count, coagulation function, infectious diseases), and avoid unnecessary risks associated with invasive procedures during the puncture. Second, imaging studies such as chest CT scans and chest X-rays should be reviewed to evaluate the degree of lung compression in pneumothorax and the volume of pleural effusion [4]. During image interpretation, physicians must exercise meticulous attention to detail, carefully differentiate between pneumothorax and pleural effusion, determine whether pleural effusion contains air, identify encapsulated fluid (requiring ultrasound-guided puncture and drainage if present), and distinguish pleural effusion from atelectasis (which requires treatment of the underlying disease rather than catheterization). These critical distinctions are essential for selecting appropriate puncture sites and equipment. Additionally, using imaging software tools to measure thoracic wall thickness at the puncture site (defined as the vertical distance from skin surface to thoracic cavity) on chest CT scans [5] provides guidance for local anesthesia administration and needle insertion depth during the procedure.

2.2 Informed consent for invasive procedures was signed

Physicians must clearly inform patients and their families about the purpose of the procedure, its workflow, potential risks during the operation, and post-procedural complications. They should also explain the risks of local anesthesia and the possibility of additional pain relief during or after the procedure [6]. After addressing any questions from patients and their families, the informed consent form should be signed with their agreement.

2.3 Communication and preparation with the patient before operation

Before performing any procedure, the physician should first ease the patient's anxiety and clearly explain all precautions. Patients must be instructed to immediately signal discomfort during the procedure for prompt medical attention, ensuring effective communication and cooperation. Additionally, patients are required to empty their bladder beforehand, remain calm, and wait patiently throughout the process.

2.4 Selection of puncture point

The puncture point of pneumothorax is generally located at the second intercostal space along the midclavicular line [7], and the location of pleural effusion can be selected as the fifth intercostal space along the axillary front line, the sixth intercostal space along the axillary midline, the seventh intercostal space along the axillary posterior line, and the seventh and eighth intercostal spaces along the scapular angle [8]. Based on the author's practical experience and that of relevant specialist physicians, puncture site localization should integrate chest examination methods such as percussion and auscultation to establish an approximate area through clinical judgment. For precise placement, imaging modalities like Chest computed tomography (CT) or Chest X-ray are still required. When

dealing with small-volume encapsulated effusions, ultrasound-guided localization can be employed for puncture site selection or under ultrasound guidance [9]. After positioning, choose appropriate intercostal spaces, positioning the puncture site at the upper edge of the adjacent rib to avoid damaging critical blood vessels and nerves. The puncture site should be marked with a marker after confirmation.

2.5 Selection of puncture pack

The puncture kit used by the author and relevant specialist physicians during the puncture process is the Albert puncture kit, and the core item in the package is the puncture catheter commonly known as the pig tail tube [10]. This type of catheter can be reliably used for the treatment of pneumothorax, pleural effusion, etc. [11]. Meta analysis studies have shown that compared with ordinary chest tube, the use of pig tail catheter for pneumothorax can effectively reduce the time of postoperative catheter placement [12]. In clinical practice, compared to other types of drainage tubes, this device causes significantly less friction and pressure on the pleura, resulting in marked pain reduction [13]. For adult patients, 12Fr or 10Fr catheters are typically selected based on body dimensions. Pediatric cases require smaller puncture kits, while central venous access kits can be used when unavailable.

2.6 Position selection and exposure of puncture site

Before initiating procedures, physicians should clearly communicate the required patient positioning and exposed areas. For anterior chest wall operations, clinicians are advised to recommend a seated position suitable for the patient. When performing posterior chest wall procedures, physicians may suggest a chair-riding position where the patient faces the chair back with forearms resting on it and forehead pressed forward. Critical care patients are exempt from mandatory positioning requirements. For specific cases requiring simulated chest CT positioning, patients should be instructed to lie flat to better align with imaging findings. Patients are recommended to wear open-front hospital gowns or sleepwear. Where room temperature permits, chest wall exposure should be maximized (with particular attention to maintaining patient privacy for female patients).

2.7 Selection of operating sites

Physicians may perform procedures in the dressing room or at the bedside when patients are critically ill and unable to get out of bed (patients requiring oxygen therapy and ECG monitoring). During these procedures, they should pull the bed curtains to protect patient privacy and ensure warmth. When performing punctures on female patients, male physicians must be accompanied by female medical staff. To maintain a relatively clean environment during operations, in addition to implementing disinfection protocols and ensuring operators 'hand hygiene, it's essential to minimize the number of people in the same ward as much as possible.

2.8 Preparations for the operator

The operator must thoroughly understand the patient's condition and clinical data, memorize all procedural steps, and prepare necessary items: Abel puncture kit, 2% lidocaine, iodine tincture, adhesive tape, drainage bottle/bag, 500ml normal saline (if required), and medical tape. After completing item preparation, preoperative personal preparation should be performed by donning a protective mask and performing hand hygiene with antiseptic gel.

3. Operations

3.1 Check the puncture pack

After completing hand hygiene and disinfection, the physician places the puncture kit on the dressing cart. The outer layer of the kit is opened first, followed by surgical gloves before opening the second layer. Upon completing the unpacking process, the operator should: 1) verify that all components are present and check the patency of the puncture and anesthesia needles; 2) remove the J-shaped guidewire catheter from its snap-fit packaging and place the blade and skin dilator in an easily accessible position within the puncture box. After removing the protective covers from the guidewire, catheter, and blade, arrange them neatly for quick access. Finally, ensure the treatment cart is positioned conveniently for the procedure.

3.2 Disinfection and draping

The physician instructed the assistant to dispense an appropriate amount of iodine tincture into the grid of the puncture kit. After soaking a sterile brush, the area was disinfected three times with a circular motion, covering a disinfection zone approximately 15cm in diameter (the disinfection range may be expanded as needed based on operational protocols). The disinfection process must be thorough and complete without leaving any blank areas, with subsequent disinfection zones being smaller than the previous ones. When draping the drape, the assistant should position their hands at the corners using the drape's perforations to prevent contamination. The operator should align the perforations in the drape with the intended puncture site before securing it. Since undried iodine tincture adheres to the drape, if the drape fails to securely contact the patient's skin, the assistant should apply medical adhesive tape to maintain proper fixation.

3.3 Local anesthesia

The physician and assistant jointly verify the 2% lidocaine injection. After aspirating the anesthetic using a 5ml syringe and expelling air, the physician holds the needle with right hand while positioning the index and middle fingers on the puncture site with a diagonal approach (approximately 30 °angle to skin). Subcutaneous injection is administered to form a small skin dome. The physician assesses the patient's condition and pain level. If pain is minimal, the needle is inserted vertically with continuous aspiration. If no blood flows out, the medication is injected. In case of accidental vascular penetration, retract the needle and select a new puncture site. Anesthesia is layered down to the subpleural space, followed by gradual needle insertion until a breakthrough sensation occurs. When gas or fluid is aspirated, stop advancing and slowly withdraw the needle. Throughout this process, maintain pleural anesthesia to prevent pleural reactions. The physician monitors the syringe's penetration length from the skin surface to the pleural cavity, calibrating subsequent needle insertion depth. For thick chest skin preventing needle access, stabilize the syringe with right hand while applying rib space compression with left hand to assist insertion. If still inaccessible, use a puncture needle cautiously—be vigilant against pleural reactions and avoid deep puncture risks to vital blood vessels, nerves, or organs.

3.4 Insertion of the puncture needle

Before performing the puncture, the physician uses their thumb and index finger to determine the required depth for accessing the thoracic cavity on the needle, while gripping the syringe portion with the remaining three fingers. The left index and middle fingers then secure the skin along the intended

path. After advancing the needle to the marked depth, the physician aspirates the syringe to apply negative pressure and slowly advances the needle. When gas or fluid begins to flow out, this confirms proper placement into the thoracic cavity, at which point further advancement becomes unnecessary.

3.5 Inserting the guidewire

After removing the protective sheath from the J-shaped guidewire's tip, the physician inserts the guidewire into the puncture needle's tail and rapidly advances it into the thoracic cavity [14]. Throughout the procedure, the physician should monitor the patient's response and assess their comfort level. If the patient experiences coughing, the guidewire insertion should be paused until they rest briefly and symptoms subside before resuming. Should the patient suddenly develop chest tightness, shortness of breath, dizziness, nausea, or a sense of impending doom (indicating possible pleural reaction), the procedure must be immediately halted. The patient should be placed in a supine position with oxygen therapy administered, and appropriate medications provided based on symptoms and physical signs. If no adverse reactions occur, the physician may advance the J-shaped guidewire to a position 10cm from the puncture needle's tail, avoiding excessive exposure of the guidewire's tip to the chest wall to prevent movement and potential contamination. The physician then firmly grasps the puncture needle's tail with the left hand while removing the needle tip with the right hand. After the puncture needle withdraws through the skin, the guidewire at the needle's tail is held by the right hand, while the left thumb and index finger pinch the guidewire entering the puncture site. Finally, the puncture needle is completely withdrawn through the guidewire using the right hand.

3.6 Expanding the skin

The physician removes the protective sleeve from the trocar. Using the thumb and index finger of the right hand, they mark the required depth (typically 3-5mm, depending on the catheter model) for the blade insertion. The blade's back edge is then positioned against the guidewire, parallel to the intercostal space [15]. The operator must avoid using the blade's edge to guide the wire, as it can damage the wire or surrounding tissue upon entry into the thoracic cavity. During this process, the left thumb and index finger maintain firm grip on the exposed guidewire near the chest wall to prevent dislodgement. The procedure begins with a small trocar: inserted through the guidewire, the guidewire's tail end is pinched between the left thumb and index finger while the right thumb rotates the trocar into the thoracic cavity. Once adequate expansion is achieved, the small trocar is withdrawn and replaced with a larger one using the same technique. If the patient develops pleural reaction symptoms during this process, the physician must initiate emergency management according to standard protocol guidelines.

3.7 Catheter placement

After confirming satisfactory skin expansion, the physician inserts the puncture catheter through the guidewire into the thoracic cavity. During thoracentesis procedures, significant fluid leakage from the catheter may occur during insertion. In such cases, the catheter should be promptly positioned at an appropriate depth of approximately 12-15cm [16] (the insertion depth should be determined based on age, gender, height, and weight). The closure mechanism on the catheter is then activated. The physician stabilizes the catheter with the left hand while removing the guidewire with the right hand, which can be safely retracted into its protective sheath to prevent contamination and facilitate potential reinsertion for drainage if needed. Following guidewire retraction, the physician connects a syringe to the catheter's tail end, activates the closure mechanism, and performs aspiration to detect air or fluid. Successful aspiration confirms successful catheter placement.

3.8 Fixation

The physician removes a self-prepared straight needle with a wire from the puncture kit. After inserting the needle above the puncture site and tying a surgical knot, they wrap the fine wire multiple times around the exposed portion of the puncture catheter to enhance friction. Once satisfied, the two ends of the wire are inserted into the small circular holes on the catheter's built-in fixation device, secured with a knot, and excess wire is trimmed. This method requires only one skin puncture, minimizing patient discomfort while ensuring effective stabilization.

3.9 Connection of drainage device

The physician should securely connect the fixed puncture catheter to the drainage tube and collection bottle or bag. When assembling the tubing, apply iodine tincture to the connection points for easier assembly. After completing all connections, simultaneously activate the clamping mechanism on the puncture catheter and the control valve on the drainage tube. This will allow visible air bubbles to escape or liquid to flow out. When setting up the drainage system, adjust the entire tubing length appropriately to prevent excessive length that could compromise drainage effectiveness or cause patient discomfort.

3.10 Fixing of the device

The physician removes the drape from the puncture site and suture fixation area after disinfection. A small gauze pad or cotton ball is then wrapped around the puncture site, followed by covering it with a medium or large-sized dressing patch to prevent direct contact between the adhesive surface of the fixation device and the puncture site or suture fixation area. The control valve of the puncture catheter is secured with sterile gauze, and the drainage tube is attached to the lateral abdominal wall using medical adhesive tape (positioning may vary according to the physician's operational preference) to avoid excessive length that restricts patient mobility. The insertion time is marked on the drainage tube for reference.

4. Related matters after operation

4.1 Inform patients of relevant precautions

After the physician completes the procedure, the assistant assists the patient in tidying up their clothes. The operator explains relevant precautions to the patient and encourages pneumothorax patients to cough up phlegm (though excessive coughing should be avoided). For patients with pleural effusion, the initial drainage volume on the first day is generally not exceeding 700ml. When opening the drainage tube, it's crucial to appropriately control both the drainage rate and volume to minimize adverse reactions such as pneumothorax and re-expansion pulmonary edema [17] [18]. If the patient experiences discomfort after the procedure, immediate medical attention should be provided.

4.2 Waste classification and treatment

The assistant needs to put all the sharps in the operation process, including syringe needle, suture needle, knife, J-shaped guidewire and safety bottle into the sharp bucket. All medical waste should be placed in the yellow contaminated garbage can, and all the outer packaging of the items should be placed in the black household garbage can.

4.3 Nursing-related requirements

The physician should instruct the nurse on the daily drainage volume and key nursing care points. The nurse must regularly replace dressings at the thoracentesis site, monitor for fluid leakage at the catheter placement site, and check the drainage tube's gauge. Careful attention should be paid to prevent compression, folding, twisting, or dislodgement of the drainage tube during patient repositioning [19]. The clinician must ensure that the drainage bag remains below the puncture site throughout drainage to avoid the risk of backflow[20]. Daily records must document the volume, color, and characteristics of drainage fluid, with regular replacement of drainage devices. During education, patients should be advised to get out of bed early when medically permissible to restore daily living adaptability and normal limb function, while avoiding forceful coughing, heavy lifting, and strenuous exercise [21].

4.4 Operation is complete

After completing the procedure, the physician documents the puncture course and summarizes the experience by reviewing the puncture operation. The next day, chest computed tomography (CT) or chest X-ray should be performed as needed to assess the drainage tube's position and initial drainage effectiveness [22]. If no fluid discharge is observed from the drainage tube, follow-up examinations may be conducted. Once pneumothorax or pleural effusion is confirmed absent, the physician may remove the drainage tube after the patient holds their breath during deep inhalation. The wound should then be closed with sterile gauze and secured with a pressure dressing [23].

5. Summary and experience

Through active mentorship from attending physicians and hands-on practice under the author's guidance, a total of 72 procedures were completed in clinical practice. Among these, 70 patients achieved successful thoracic tube placement with a success rate of 97.22%. Analysis of unsuccessful cases: 1 case involved neonatal pneumothorax. After using an empty needle for air aspiration, monitoring showed increased oxygen saturation and normalized respiration. Subsequent bedside chest X-ray revealed no significant air accumulation, leading to non-tube placement. Another case involved a middle-aged woman with post-traumatic old fluid retention in the thoracic cavity. Localization puncture failed to drain the fluid, likely due to prolonged hematoma organization and encapsulation. Subsequent ultrasound-guided drainage was performed after unsuccessful needle aspiration. In successful cases, 3 complications occurred: pleural reaction in 1 patient, re-expansion pulmonary edema in 1 patient, and subcutaneous air accumulation in 1 patient, with a complication rate of 4.29%. Analysis revealed: 1 pleural reaction case resulted from incomplete subpleural anesthesia during diaphragmatic expansion using a retractor. 1 re-expansion pulmonary edema case occurred due to rapid fluid drainage without proper valve adjustment after initial puncture. 1 subcutaneous air accumulation case developed the next day, attributed to prolonged pneumothorax duration and preoperative subcutaneous gas buildup causing a "snow grip" sensation. Prolonged puncture duration exacerbated the subcutaneous gas accumulation. The above adverse reactions were properly handled in accordance with the relevant principles of complications management, and the patients did not have obvious discomfort after treatment. All patients who underwent puncture and catheter placement were followed up and discharged after subsequent symptomatic treatment.

The placement of thoracic drainage devices is a common procedure in thoracic surgery and respiratory medicine, playing a crucial role both in disease diagnosis and in rapidly alleviating patients with pneumothorax or pleural effusion. This drainage method is simple to perform, ensures high treatment compliance, and minimizes patient discomfort. For some pleural effusion cases,

drainage tubes can deliver targeted medications into the thoracic cavity to enhance therapeutic outcomes. Fresh samples can be collected for testing at any time, while drainage volume can be precisely controlled to ensure thorough clearance [24]. Surgeons must thoroughly assess patients' baseline conditions, strictly evaluate indications and contraindications (such as severe pleural adhesions leading to pleural cavity collapse, critical coagulation disorders, patient non-compliance, or anesthetic drug allergies), and select appropriate treatment plans accordingly. Additionally, surgeons should master every procedural step, accumulate experience, optimize workflows, and develop preemptive measures for potential complications and emergencies to prevent serious medical incidents.

During the procedure, physicians should prioritize patient communication. The clinician must explain the procedure's necessity to build trust and reduce patient anxiety, and provide clear instructions to secure cooperation before beginning the operation. Throughout the procedure, physicians should regularly check on patients 'comfort levels, promptly identify and address any discomfort to ensure their overall well-being. Post-procedure care requires not only explaining postoperative care instructions but also conducting follow-up observations and rehabilitation monitoring to support patients' recovery journey.

The placement of thoracic drainage devices is a crucial component in standardized training assessments for medical students, licensed physicians, and resident physicians [25]. This procedure and other invasive techniques form the foundation of clinical skills that accompany our medical education journey, serving as the cornerstone for future advancements in medical expertise. The development of fundamental clinical competencies represents an essential pathway for every medical professional's growth. During theoretical learning, it's vital to establish solid foundational knowledge, while clinical skill training requires persistent practice and hands-on application. Only through such preparation can one confidently handle real-world clinical scenarios and effectively resolve critical issues when needed. For novice practitioners, each clinical procedure demands thoughtful reflection and continuous refinement during both learning and execution. By improving operational techniques and refining workflows, professionals can achieve sustained progress in their careers. Any potential shortcomings in the thoracic drainage placement methodology described herein are humbly submitted to colleagues for constructive criticism and guidance, for which we are deeply grateful.

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