Perioperative Precision Medicine
ISSN: 2957-5443

Zentime

Expert Consensus https://doi.org/10.61189/447393ljoyfh

Main types, application conditions, and standards of thoracic drainage tubes in peacetime and wartime: An expert consensus

Wangzheqi Zhang[1], Chenglong Zhu[1], Xingzhi Liao[2], Feixiang Wu[3], Hui Chen[4], Wenyun Xu[5], Jinlong Qu[6], Miao Zhou[7], Jinfei Shi[8], Liangqing Lin[9], Shengyun Cai[10], Wenchao Gao[11], Hua Tang[12], Ying Huang[13], Zui Zou[1]

[1]School of Anesthesiology, Naval Medical University, Shanghai 200433, China. [2]Department of Anesthesiology, 904th Hospital of The Joint Logistics Support Force of the PLA, Wuxi 214044, Jiangsu, China. [3]Department of Anesthesiology, The First Affiliated Hospital of Wenzhou Medical University, Wenzhou, Zhejiang 325000, China. [4]Department of Anesthesiology and Perioperative medicine, Shanghai Fourth People's Hospital, School of Medicine, Tongji University, Shanghai 200434, China. [5]Department of Anesthesiology, Second Affiliated Hospital of Naval Medical University, Shanghai 200003, China. [6]Department of Emergency and Critical Care Medicine Second Affiliated Hospital of Naval Medical University, Shanghai 200003, China. [7]Department of Anesthesiology, the Affiliated Cancer Hospital of Nanjing Medical University, Jiangsu Cancer Hospital, Jiangsu Institute of Cancer Research, Nanjing Medical University, Nanjing 210009, Jiangsu, China. [8]Department of Anesthesiology, Anhui Provincial Hospital of the Armed Police, Hefei 230001, China. [9]Department of Anesthesiology, The First Hospital of Putian City, Teaching Hospital of Fujian Medical University, Putian 351100, Fujian, China. [10]Department of Obstetrics and Gynecology, First Affiliated Hospital of Naval Medical University, Shanghai 200433, China. [11]Department of Colorectal Surgery, Second Affiliated Hospital of Naval Medical University, Shanghai 200003, China. [12]Department of Thoracic Surgery, The Second Affiliated Hospital of Naval University, Shanghai 200003, China. [13]Department of Intensive Care Unit, the Affiliated Huaian No.1 People's Hospital of Nanjing Medical University, Huaian, Jiangsu 223300, China.

Corresponding authors: Hua Tang, Ying Huang and Zui Zou.

Acknowledgement: This study was funded by the following projects: Shanghai Industrial Collaborative Innovation Project (HCXBCY - 2023 – 041, XTCX - KJ - 2024 - 39, HCXBCY - 2024 – 033), 2024 Basic Medicine Innovation Open Topic (JCKFKT - MS - 002), and the 2024 Annual Pharmaceutical Science and Technology Key Research Project of the China Medicine Education Association (2024KTZ011).

Declaration of conflict of interest: None.

Received January 20, 2025; Accepted February 20, 2025; Published March 31, 2025

Abstract

Thoracic drainage plays a crucial role in both peacetime and wartime clinical medicine, serving as an indispensable method for treating thoracic diseases and managing trauma patients. Whether in routine medical care or in the complex situations of war or military operations, thoracic drainage is essential. This expert consensus aims to clarify the primary uses and appropriate patient populations for different types of thoracic drainage tubes, providing healthcare professionals with a systematic guide for the correct selection and application of drainage tubes in various scenarios, thereby optimizing treatment outcomes. We emphasize the need to establish specific rapid response mechanisms to meet the urgent medical demands of wartime, ensuring timely and effective thoracic drainage even in resource-limited situations. Furthermore, innovation in new technologies and materials is also key to advancing thoracic drainage techniques.

Keywords: Thoracic drainage, drainage tubes, clinical application, wartime medicine, procedural standards

Address correspondence to: Hua Tang, Department of Thoracic Surgery, The Second Affiliated Hospital of Naval University, Shanghai 200003, China. Email: Tangh_mits@163.com. **Ying Huang,** Department of Intensive Care Unit, the Affiliated Huaian No.1 People's Hospital of Nanjing Medical University, Huaian, Jiangsu 223300, China. Email: huangying5249@163.com. **Zui Zou,** School of Anesthesiology, Naval Medical University, 168 Changhai Road, Shanghai 200433, China. Email: zouzui@smmu.edu.cn.

Introduction

Thoracic drainage occupies an essential position in clinical medicine, both in peacetime and wartime, serving as a crucial intervention for treating thoracic diseases and trauma patients [1, 2]. During peacetime, the primary indications for thoracic drainage include pleural effusion [3]; pneumothorax [4]; and empyema [2, 3, 5-9]. Although thoracic drainage has become a well-established technique in clinical practice, the continually evolving spectrum of thoracic diseases necessitates that healthcare professionals continuously update their knowledge and skills to meet new challenges [10]. In routine medical settings, considerable progress has been made in standardizing and regulating the use of thoracic drainage techniques. However, further optimization is still needed, particularly regarding the refinement of indications, enhancement of therapeutic outcomes, and reduction of complications [7]. In the context of war or military operations other than war, thoracic drainage often needs to address severe chest trauma, hemothorax, and pneumothorax under complex environmental and situational constraints. Managing chest trauma in combat soldiers is notably challenging and urgent; failure to provide timely and effective thoracic drainage can lead to severe or even fatal outcomes. Given the limited medical resources available during wartime, performing thoracic drainage efficiently and safely becomes critically important. Additionally, the complexities and unpredictability of wartime situations demand higher levels of procedural skills, emergency response capabilities, and psychological resilience from medical personnel [6, 11]. Therefore, a systematic exploration and summary of the types of thoracic drainage tubes, their conditions of application, and standardized operational guidelines are not only beneficial for enhancing routine clinical treatment outcomes but are also crucial for guiding the emergency management of trauma during wartime.

The objective of this consensus is to clearly define the main uses and target audiences for different types of thoracic drainage tubes, providing systematic guidelines to assist healthcare providers in the correct selection and application of drainage tubes across various scenarios to optimize treatment outcomes [10]. In addition, specific operating procedures have been developed to meet the emergency needs of wartime medical conditions and to make timely and effective thoracic drainage under resource-limited situations. We analyze in detail the design features, applicable scenarios, and respective advantages and disadvantages of traditional drainage tubes, minimally invasive drainage tubes, and novel catheter devices to help clinicians make the best choice under different clinical conditions and resource constraints. We also analyze the conditions and indications of application of thoracic drainage tubes, which are: pleural effusion, pneumothorax, and the peculiar conditions of wartime management, detailing for each type of drainage tube the applicable scenarios.

Types of thoracic drainage tubes

Traditional drainage tubes

The traditional thoracic drainage tubes are basic tools in current practice and are usually made of silicone or polyvinyl chloride (PVC). This type of tube is characterized by sturdy walls and several side holes, allowing the evacuation of major amounts of liquid or gas effectively. They are mainly indicated for treating of open and closed pleural effusions and for extensive accumulations of pleural gas, following diseases like massive trauma-induced hemothorax or pneumothorax [10].

Traditional drainage tubes have many advantages. First, these tubes are made from materials that can maintain their stability in very harsh conditions, which is important during wartime when doctors face limited medical supplies and challenging environment. Besides, the multi-side hole design guarantees effective drainage [12]. However, the traditional drainage tube also presents several limitations. Firstly, their high invasiveness might contribute to postoperative complications, and the operation requires a very high level of technical skill and stringent aseptic conditions. Their rigid structure may cause discomfort for the patient and can even lead to secondary injuries in the process of placement [12].

Minimally invasive drainage tubes

With the advances in minimally invasive techniques, including thoracic drainage tubes, this has become a focus of considerable clinical interest. The soft and flexible materials (e.g. polyurethane) in the manufacture of these tubes minimize tissue damage at the time of placement. Its ergonomic design allows accurate placement through smaller incisions, thus minimizing trauma and reducing the risk of infection [13-18].

Minimally invasive drainage tubes are suitable for a wide range of indications, especially in cases with stable effusions and small gas accu-

mulations, including patients sensitive to trauma, such as elderly patients or patients with hematological disorders. The main advantages include less discomfort for the patient during placement, and shorter postoperative recovery periods, and finally, fewer complications. It is much easier to operate, more flexible, and minimally invasive compared to the conventional drainage tubes and may be used in combat or resource-constrained environment [18-20].

However, one of the major disadvantages of minimally invasive drainage tubes is their possible lower efficiency in draining large volumes of fluid or gas. The technologies are relatively new, and the relevant equipment used is extremely expensive. Their use in resource-poor regions is further limited by the high levels of technical proficiency and experience required from operators [19].

Innovative catheter devices

Recent development in technology has introduced advanced catheter devices, including those that use antimicrobial materials and intelligent monitoring systems. These devices further enhance performance when used alongside traditional drainage tubes, offering better patient adaptability and postoperative management benefits [21-25].

Novel catheter devices are designed with sensors and automatic control functions that can monitor the condition of drainage in real time and transmit data [21-23, 26, 27]. This facilitates remote the monitoring and treatment adjustments by healthcare professionals. Therefore, such devices will be suitable not only for routine effusions and gas accumulations but also for wartime rapid response and remote medical settings.

The principal benefits of novel catheter devices are their high degree of intelligence, easing the work of health professionals and thus improving patients' safety and comfort [22-24, 26-28]. On the other hand, the costs of development and application are high. They need highly technical maintenance and operational expertise, which limits their wider application [27, 24]. There are also technical problems related to real-time data transmission and the protection of privacy.

In summary, different types of thoracic drainage tubes each have their respective advantages and applicable scenarios. Optimal drainage methods should be selected based on the specific circumstances in both peacetime and wartime to ensure effective and safe treatment. In the future, the integrated application and technological advancements of these thoracic drainage devices in emergency medical environments will further enhance the standards and outcomes of thoracic drainage therapy.

Indications and applications

In clinical practice, chest drainage tubes play a crucial role in managing various pathological conditions [3, 5]. They are particularly indispensable in cases of pleural effusion, pneumothorax, and emergency medical situations during wartime [3, 4, 28, 29]. However, the specific application and indications can vary significantly depending on the context. Making an informed choice and using chest drainage tubes correctly is essential for ensuring patient safety and therapeutic efficacy [12].

Pleural effusion is one of the most common conditions requiring the use of chest drainage tubes. The clinical indications often include heart failure, infectious diseases such as bacterial pleuritis, and malignant tumors such as lung cancer or metastatic breast cancer [30-32]. For these patients, chest drainage can promptly relieve dyspnea and improve lung function. However, there are different contraindications, including severe coagulopathies and localized infections. For such patients, risks and benefits have to be weighed, while considering alternative treatment options where indicated. A chest drainage tube essential in the treatment of pneumothorax is equally [33-36]. When performing thoracentesis, it is imperative to pay close attention to the patient's coagulation function. For patients with abnormal coagulation profiles, specifically those with platelet counts less than 50 × 10^9/L or an INR (International Normalized Ratio) greater than 1.5, the procedure should be cautiously executed under ultrasound guidance to mitigate the risk of bleeding and ensure the safety of the intervention. However, the anticoagulation considerations for thoracentesis suggest that traditionally perceived contraindications such as coagulopathy, thrombocytopenia, and the use of anticoagulant or antiplatelet medications, may not require the treatment of bleeding risk, indicating that patients can safely undergo the procedure without modification of their anticoagulation status. In summary, it is crucial for clinicians to be aware of the risk factors and to employ strategies that enhance procedural safety, recognizing that major complications from thoracentesis are rare [37, 38].

Typically, spontaneous pneumothorax affects young persons who are usually tall and slender

[4]. Although traumatic pneumothorax may not directly relate to rib fractures, it often coincides with the fracture of ribs or lacerations of lung tissues [39-41]. Thus, patients with pneumothorax generally present with sudden chest pain and dyspnea which, in severe cases, may lead to respiratory failure and shock. Observation or needle aspiration may be forms of clinical treatment for a stable simple pneumothorax. The primary treatment options include the insertion of a chest drainage tube for tension pneumothorax and large pneumothorax. At the time of the placement of the tube, strict attention to sterile technique is critical to avoid injury to the lung and infection [39-41].

Chest drainage tubes also play a critical role in wartime scenarios, such as traumatic hemothorax or battlefield emergency care. Combat-related injuries often involve explosions or gunshot wounds that result in either hemothorax or traumatic pneumothorax [42]. Early chest drainage can greatly improve survival. In these environments, providers should be familiar with methods for battlefield emergencies and should know how to carry out a temporary chest drainage procedure [43-45]. Innovations such as high-sealing and minimally invasive drainage tubes possess a great deal of value within the field by offering flexibility where there would normally be restraints from bulky equipment. In addition, during emergency situations such as combat trauma, the placement of chest tubes may be performed under complex environmental conditions that can compromise the maintenance of strict aseptic technique. In such scenarios, whenever feasible, it is imperative to adhere to the principles of asepsis as closely as possible. Should conditions preclude the guarantee of effective asepsis, in accordance with the clinical management guidelines for intravascular catheters, it is recommended that chest tubes be replaced as soon as possible, ideally within 48 hours of insertion, provided the patient's condition permits. This approach is intended to mitigate the risk of infection. This further underscores the critical importance of sterile technique in the process of chest tube insertion [42-44].

In sum, chest drainage tubes are crucial for the treatment of pleural effusion, pneumothorax, and some special wartime conditions. The indications for selection should be appropriate, flexibly adapted to development in clinical practice, follow strict sterility principles, and employ modern equipment-all these are the keys to guarantee successful drainage without complications. While chest drainage technology continues to evolve and research into a variety of special application conditions deepens, the clinical outcomes will be further improved and bring more hope for patient recovery.

Procedural techniques and standards

The standardization of thoracic drainage procedures during both peacetime and wartime is crucial to ensure efficient and safe operations under varying circumstances, since the procedural specifics and skill level directly affect patient outcomes.

Preoperative preparation

Preoperative preparation is pivotal in ensuring the success of thoracic drainage. Initially, a comprehensive evaluation of the patient is essential, encompassing medical history, physical examination, and necessary imaging studies to ascertain the nature and location of the thoracic pathology. A systematic patient assessment significantly increases the success rate but decreases unnecessary trauma to the patients. Besides, adequate psychological support and detailed explanation will alleviate anxiety in patients for better tolerance of the procedure [46-49].

Equipment selection and preparation must be performed strictly in accordance with the standards. Depending on their design features and indications, traditional drainage tubes, minimally invasive tubes, and new catheter devices must be chosen based on the specific case. All instruments should undergo thorough sterilization before use to ensure aseptic conditions and prevent postoperative infections and other complications [9].

Placement technique

The placement of thoracic drainage tubes is a technically demanding procedure requiring a profound understanding of anatomy and extensive clinical experience. The standard procedural steps are as follows:

1. Utilize imaging and surface landmarks to identify the appropriate puncture site, avoiding critical neurovascular structures [9].

2. Apply local anesthesia and make a small incision on the skin with a surgical knife [7, 12, 50, 51].

3. Insert the drainage tube through the incision into the thoracic cavity promptly, ensuring stable and efficient drainage [7, 50].

4. Secure the drainage tube and connect it to a negative pressure device. If feasible, the use of a closed drainage system is recommended to prevent air from entering the thoracic cavity, which could cause pneumothorax or other complications [7, 12, 50, 52].

It is worth noticing that strict following of aseptic techniques is obligatory during the whole treatment to reduce the level of infection risk. Extra attention is given to the angle and depth of placing the tube to avoid unintentional injury of internal organs or further damage [9].

Postoperative management

Management after surgery is crucial to ensure proper working of the drainage tube and to avoid complications [52]. There is a need for regular monitoring of the volume and characteristic of the fluid drained to correctly assess the efficacy of the treatment in a timely manner. Furthermore, close monitoring of the puncture site is necessary to promptly detect signs of infection, subcutaneous emphysema, or other complications, alongside standard care of the drainage tube according to institutional protocol, including dressing changes, at least daily, maintenance of tube patency, and regular inspection of the negative pressure device [53]. Special attention should be given to securing the drainage tube and limiting patient activity to minimize the risk of accidental dislodgement, especially in patients requiring prolonged drainage [52, 53]. In postoperative management, the secure fixation of the thoracic drainage tube is of paramount importance. Appropriate fixation should be tailored to the patient's position; for instance, when the patient is lying supine, the thoracic drainage tube should be fastened securely at the bedside, maintaining a degree of slack to prevent traction or displacement due to movements such as rolling over, thereby enhancing patient comfort. Concurrently, with respect to drainage, it is imperative to closely monitor the color, volume, and nature of the drainage fluid, ensuring that the drainage tube remains unobstructed. Should any drainage impairment be detected, prompt action should be taken to identify the cause and implement the necessary interventions. This may include inspecting for obstructions or kinks in the tube and managing them in accordance with medical protocols.

In summary, standardization of techniques for thoracic drainage and postoperative management enhances the therapeutic results and significantly reduces complications. Standardized peacetime procedures and adaptable wartime responses are essential for ensuring patient safety and the success of treatments. Future efforts should focus on advancing research and training in this area, promoting the adoption of new technologies and materials to continually improve the proficiency of thoracic drainage procedures.

Discussion

In resource-limited settings, particularly under wartime medical conditions, the implementation of thoracic drainage faces numerous challenges. Firstly, it is crucial to establish a rapid response mechanism to ensure effective intervention in the shortest possible time. This includes not only the swift coordination of medical equipment and supplies but also the quick assembly and deployment of specialized medical teams. Flexibility and adaptability are paramount in this process. Medical personnel must possess the ability to perform thoracic drainage under variable and extreme conditions, which raises the bar for both their technical prowess and psychological resilience. Given the urgent need for rapid response, a systematic and ongoing training mechanism for personnel is essential. The constraints on the number of surgeons and technical staff in wartime environments can be mitigated through simulated drills and remote education. Specifically, with the aid of virtual reality technology and tele-mentoring systems, healthcare workers in remote areas can receive timely and effective training, ensuring they have the confidence and capability for actual operations.

The advancement of thoracic drainage technology will greatly depend on the application of new technologies and materials. For instance, progress in nanotechnology could lead to the development of more efficient and less complication-prone new drainage tube materials [54]. Concurrently, the evolution of minimally invasive surgical equipment will make thoracic drainage safer and more convenient, thereby accelerating patient recovery. Additionally, advancements in AI technology can facilitate the intelligent use of drainage tubes, reducing the burden on medical personnel and allowing for more accurate patient data recording, ultimately enhancing the quality and comfort of medical care. While technological progress is significant, continuous clinical trials and evidence accumulation are crucial for the promotion of new technologies. Only by demonstrating the safety and efficacy of new technologies through large-scale clinical trials can they be widely adopted in clinical practice. Hence, emphasis should be placed on foundational and applied research in

the relevant fields, establishing a comprehensive research and medical integration mechanism.

Thoracic drainage, as a vital medical procedure, relies on multidisciplinary collaboration. The close cooperation of various disciplines is especially critical in both peacetime and wartime medical care. For example, surgeons, internists, and emergency physicians need to communicate thoroughly and discuss the patient's condition to devise the most optimal treatment plan. Furthermore, the meticulous management of postoperative care by nursing staff and the assurance of drug supply by pharmacists are key elements in ensuring the success of drainage. In wartime and other special conditions, multidisciplinary collaboration can significantly enhance the overall efficiency of emergency medical response. By establishing interdisciplinary emergency response teams and coordinated workflow processes, resources can be quickly mobilized, enabling the rapid treatment of the injured. The cross-disciplinary cooperation also promotes the integration of medical technologies, such as imaging techniques for the precise placement of drainage tubes, thereby improving the success rate and safety of the procedure [55].

In conclusion, the application of thoracic drainage in both peacetime and wartime necessitates the reinforcement and optimization of techniques and drainage devices. This approach is vital for effectively elevating the application level of thoracic drainage technology and ensuring the provision of the highest quality medical services to patients under various extreme conditions.

Author Contributions: Wangzheqi Zhang and Chenglong Zhu: Conceptualization and initial draft preparation. Xingzhi Liao, Feixiang Wu, Hui Chen, Wenyun Xu, Jinlong Qu, and Miao Zhou: Contributed to clinical data collection and analysis for the manuscript. Jinfei Shi, Liangqing Lin, Shengyun Cai: Participated in reviewing and refining the content on drainage tube applications. Wenchao Gao, Hua Tang, Ying Huang, Zui Zou: Supervised the study, provided crucial guidance, and finalized the manuscript. All authors jointly ensured the quality and accuracy of this expert consensus.

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