REVIEW

Journal of Indonesian Thoracic Cardiac and Vascular Surgery *(JINATCVS)* 2025,
Volume 2, Number 1: 21-25

Principles of diagnosis and management of tension pneumothorax: A literature review

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Published By :
The Indonesian Association of Thoracic and Vascular Surgeons

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Received: 2025-01-15
Accepted: 2025-02-22
Published:2025-04-02

ABSTRACT

Tension pneumothorax is the most severe form of pneumothorax and constitutes a medical emergency that can be life-threatening if not promptly recognized and managed. This condition is characterized by the progressive accumulation of air in the pleural cavity due to a one-way valve mechanism, leading to increased intrathoracic pressure, mediastinal shift, decreased venous return, obstructive shock, and ultimately cardiac arrest. This literature review aims to provide a comprehensive understanding of the principles of diagnosis and management of tension pneumothorax. A literature search was conducted using PubMed, Cochrane Library, ScienceDirect, and ProQuest with keyword combinations of diagnosis, management, and tension pneumothorax. Diagnosis should be made clinically without waiting for radiological confirmation, especially when patients present with symptoms such as shortness of breath, chest pain, tachypnea, hypotension, decreased unilateral breath sounds, hyperresonance on percussion, tracheal deviation, and distended neck veins. Initial management includes the administration of high-concentration oxygen and immediate needle decompression, followed by chest tube insertion as definitive therapy. The accuracy and speed of diagnosis and emergency intervention are crucial in reducing the mortality associated with tension pneumothorax.

Keywords: Chest tube, diagnosis, management, needle decompression, tension pneumothorax.
Cite This Article: Willim, H.A. 2025. Principles of diagnosis and management of tension pneumothorax: A literature review. *Journal of Indonesian Thoracic Cardiac and Vascular Surgery* 2(1): 21-25

INTRODUCTION

Pneumothorax is a condition characterized by the accumulation of air or gas in the potential space between the visceral and parietal pleura. The presence of air in the pleural cavity leads to the loss of negative pressure, which usually keeps the pleura adhered to the chest wall and lungs. As a result, the lungs' natural ability to expand during inspiration is impaired, leading to lung collapse. In healthy individuals, the pressure within the pleural cavity remains negative to keep the lungs expanded. Pneumothorax can occur spontaneously or as a result of trauma. Spontaneous pneumothorax is classified into primary, which occurs without pre-existing lung disease, and secondary, which is associated with underlying pulmonary conditions. Meanwhile, traumatic pneumothorax can result from blunt trauma, penetrating injuries, or iatrogenic causes. Another form, known as catamenial pneumothorax, is related to the menstrual cycle.[1]

Pneumothorax can be classified into three types: simple pneumothorax, open pneumothorax, and tension pneumothorax. Tension pneumothorax is a medical emergency characterized by the progressive accumulation of air in the pleural space with each breath. This occurs due to a one-way valve mechanism that allows air to enter during inspiration but prevents it from escaping during expiration. As a result, intrathoracic pressure increases, leading to a significant shift of mediastinal structures toward the contralateral side, compressing the vena cava and obstructing venous return to the heart. Additionally, the contralateral lung becomes compressed, causing severe respiratory distress and obstructive shock.[2]

The exact incidence of tension pneumothorax in Indonesia has not been clearly reported. Studies have shown that approximately 5% of deaths from chest trauma in military personnel were found to involve tension pneumothorax at the time of death. In London, the incidence of tension pneumothorax was reported to be 5.4% of all major trauma patients presenting to the emergency department. Prompt and accurate diagnosis and initial management in the emergency department are essential to prevent mortality in this critical condition.[3] This literature review aims to provide a comprehensive understanding of the principles of diagnosis and management of tension pneumothorax. This knowledge is crucial for all clinicians, particularly those working in emergency departments.

METHODS

This literature review was conducted using four major electronic databases: PubMed, Cochrane Library, ScienceDirect, and ProQuest. The search employed a combination of keywords, including diagnosis, management, and tension pneumothorax. Both original research articles and review articles related to the diagnosis and management of tension pneumothorax were considered for inclusion. Studies were excluded if they involved animal subjects, were conference abstracts, or were not available in full-text format. No language restrictions were applied during the selection process. The selected literature was analyzed to synthesize current strategies for the

diagnosis and management of tension pneumothorax.

DEFINITION

Tension pneumothorax is a type of pneumothorax accompanied by progressively increasing intrathoracic pressure. In this condition, a one-way valve mechanism is present, allowing air to enter the pleural space easily but preventing it from escaping. Positive pressure ventilation can exacerbate the effects of this one-way valve. The progressive rise in pleural pressure pushes the mediastinum toward the opposite hemithorax, obstructs venous return to the heart, and compresses the lung on the contralateral side. This results in circulatory instability and may lead to cardiac arrest.[4]

ETIOLOGY

Both traumatic and non-traumatic processes can cause tension pneumothorax. The etiologies include a variety of clinical situations. Blunt or penetrating trauma is one of the most common causes, involving disruption of either the visceral or parietal pleura, and may or may not be accompanied by rib fractures. Iatrogenic causes are also significant, particularly complications arising from the placement of central venous catheters, most commonly into the subclavian or internal jugular veins. Mechanical ventilation, especially with positive pressure, can also lead to the development of a tension pneumothorax. In some cases, spontaneous pneumothorax without a clearly identifiable cause may progress into a tension pneumothorax. Additionally, improper management of an open pneumothorax, where a wound dressing inadvertently functions as a one-way valve, can lead to the transformation of an open pneumothorax into a simple or even a tension pneumothorax.[2]

PATHOPHYSIOLOGY

Tension pneumothorax occurs due to disruption of the visceral pleura, parietal pleura, or tracheobronchial branches. This disruption allows the formation of a one-way valve mechanism that permits air to enter the pleural space but prevents it from escaping. As a result, the volume of intrapleural air increases with each inspiration, leading to a progressive rise in pressure within the affected hemithorax. The ipsilateral lung collapses, causing further hypoxia. The increased pressure shifts the mediastinum toward the contralateral side. During expiration, the air is not effectively expelled due to impaired alveolar elastic recoil. Compression of the superior and inferior vena cava occurs as the mediastinum deviates and intrathoracic pressure continues to rise, leading to reduced cardiac output. Hypoxia subsequently increases pulmonary vascular resistance through vasoconstriction. These changes may result in pre-shock or shock due to vena cava compression. If not promptly managed, this condition can progress to hypoxemia, metabolic acidosis, reduced cardiac output, cardiac arrest, and ultimately death.[2]

Table 1. Clinical presentation of tension pneumothorax[5]

Assessment	Key Features
History taking	- Progressive dyspnea and/or chest pain - History of chest trauma (penetrating or blunt) - Underlying pulmonary disease - Smoking history
Physical examination	- Tachypnea, tachycardia, anxious appearance - Hypotension, hypoxemia, cyanosis - Widened intercostal spaces - Reduced chest wall movement - Tracheal deviation - Distended neck veins - Decreased or absent tactile fremitus - Hyperresonance on percussion - Decreased or absent breath sounds on the affected side

DIAGNOSIS

Tension pneumothorax is an emergency. Diagnosis should be based on clinical presentation, and immediate treatment is essential without awaiting radiologic confirmation (Table 1).[5]

History taking

Patients with tension pneumothorax typically present with complaints of progressive dyspnea and/or chest pain. History-taking should be brief and focused, prioritizing emergency needle decompression. Essential points to inquire about include the patient's age, a history of penetrating or blunt chest trauma, any underlying pulmonary conditions such as COPD or tuberculosis, and smoking history.[5]

Physical examination

The clinical manifestations of tension pneumothorax may include tachypnea, tachycardia, anxious appearance, hyperresonance on percussion, decreased or absent vesicular breath sounds, hypotension, hypoxemia, cyanosis, enlargement of the affected hemithorax compared to the contralateral side, widened intercostal spaces, reduced chest wall movement on the affected side, decreased or absent tactile fremitus, deviation of the trachea and apex beat toward the contralateral side and distended neck veins.[5]

Clinicians need to be aware of the differences in the clinical presentation of tension pneumothorax between conscious patients and those on mechanical ventilation. In mechanically ventilated patients, the onset is typically rapid, with a swift and progressive drop in both arterial and venous oxygen saturation. There is an immediate decrease in cardiac output and/or blood pressure, elevated ventilatory pressures, and on the affected hemithorax, signs of hyperexpansion, decreased mobility, and diminished air entry. Subcutaneous emphysema and jugular vein distension are rarely observed. The mediastinal deviation is inconsistently found, and even when present, the trachea may remain centrally located. Ipsilateral thoracic hyperexpansion, though seldom seen in conscious patients, is more frequent in ventilated patients due to maximal inspiratory effort in response to rising intrapleural pressure. Ipsilateral

Figure 1. Chest X-ray of tension pneumothorax.[6]

Figure 2. Needle decompression.[6]

Figure 3. Triangle of safety.[6]

hypomobility may result from pleuritic pain or rib fractures. Additional breath sounds, such as wheezing or crackles, may also be detected on the affected side.[5]

Chest radiography

Tension pneumothorax is a medical emergency, and its diagnosis should be made clinically. Reliance on chest radiography for diagnosis has been associated with increased mortality, often due to delayed recognition or misinterpretation of the imaging. However, in hemodynamically stable patients with ambiguous clinical signs, a chest X-ray may be used to confirm the diagnosis. Radiographic findings of tension pneumothorax may include hyperlucency without bronchovascular markings, a collapsed lung appearing as a globular mass near the hilum, and signs of ipsilateral hyperexpansion such as diaphragmatic depression, widened intercostal spaces, and increased hemithoracic volume (Figure 1). The mediastinal shift may be evident, including flattening of the ipsilateral cardiac border and deviation of mediastinal structures toward the contralateral side.[6]

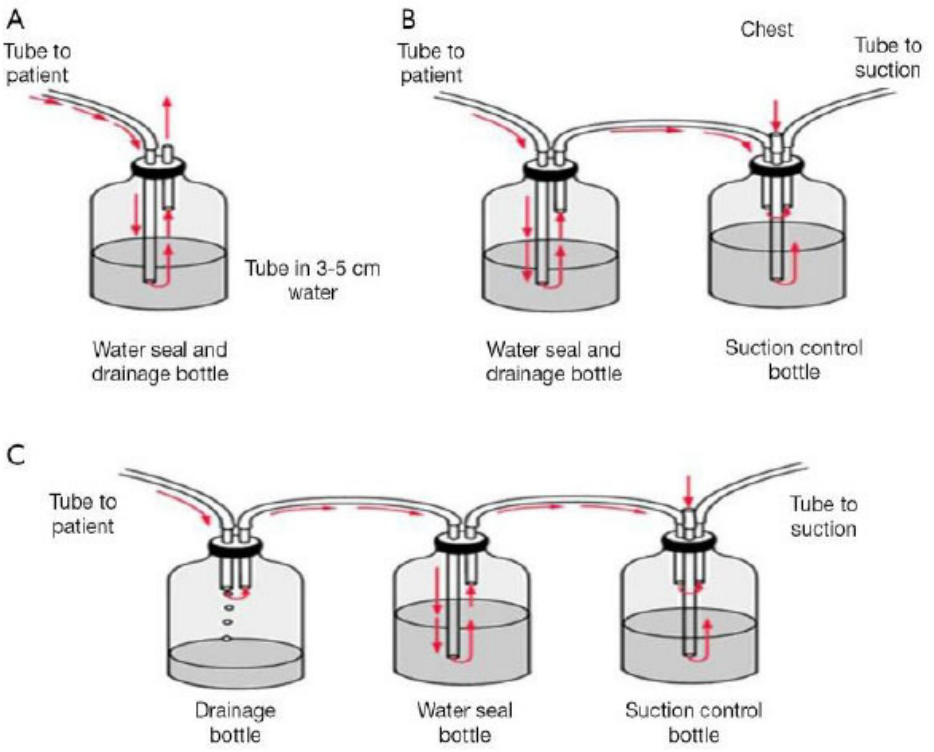

Figure 4. Water-sealed drainage system.[8]

MANAGEMENT

Oxygen therapy

High-concentration oxygen should be administered immediately to patients with pneumothorax to maintain adequate oxygenation (oxygen saturation > 92%). This also reduces the partial pressure of nitrogen, which can accelerate the absorption rate of air within the pleural cavity and facilitate faster lung re-expansion. However, oxygen administration should be done cautiously in patients with chronic obstructive pulmonary disease (COPD) because it may lead to carbon dioxide retention.[6]

Needle decompression

Tension pneumothorax requires urgent decompression to reduce intrapleural pressure. This procedure should not wait for radiological confirmation. Decompression can be performed by inserting a large-bore cannula or venflon needle into the second intercostal space at the midclavicular line on the affected side of the chest (Figure 2). Once the cannula enters the pleural space, an audible rush of air will be heard. This maneuver converts a tension pneumothorax into a simple pneumothorax. The cannula must be maintained in place while waiting for chest tube insertion.[6]

Chest wall thickness can affect the success of needle decompression. Studies show that a 5 cm needle can reach the pleural space in over 50% of cases, while an 8 cm needle reaches over 90%. Sometimes, decompression may still fail even if the needle size is appropriate. After needle

decompression, definitive treatment with chest tube insertion should follow.[7]

Chest tube insertion

Following needle decompression, chest tube insertion is performed. The chest tube is placed in the "triangle of safety," an anatomical area in the axilla bordered laterally by the pectoralis major muscle, anteriorly by the latissimus dorsi muscle, and inferiorly by a horizontal line at the level of the 5th intercostal space (or nipple line). This area is relatively safe for chest tube placement (Figure 3). The patient is positioned sitting or semi-sitting. Aseptic technique and local infiltration anesthesia are applied. After placement, the chest tube is connected to a water-sealed drainage (WSD) system and secured with appropriate sutures (Figure 4). The proper placement is confirmed by observing fluctuation (undulation) in the WSD. A post-procedure chest X-ray is performed to confirm the correct tube position. If malpositioned, repositioning is necessary.[6,8]

The presence of air bubbles indicates ongoing pneumothorax or a fistula causing increased intrapleural pressure. If bubbles appear during both inspiration and expiration, the fistula is large, if only during expiration, it is moderate, if only during forced expiration or coughing, the fistula is small or nearly closed. Lung re-expansion should be gradual to avoid re-expansion pulmonary edema. First-generation cephalosporin antibiotics may be considered after chest tube insertion to prevent empyema and pneumonia. When the lung is fully expanded, indicated by cessation of undulation and clinical improvement, the chest tube can be removed.[2]

For recurrent pneumothorax, pleurodesis may be considered after lung re-expansion to prevent recurrence. Pleurodesis involves adhering to the two pleural layers either mechanically or using irritants such as talc, povidone-iodine, or antibiotics like tetracycline, minocycline, or doxycycline. These substances induce inflammation and cause pleural adhesion.[9]

Surgery

Indications for surgical intervention in pneumothorax include recurrent pneumothorax on the ipsilateral side, bilateral pneumothorax, persistent air leak lasting more than seven days, and a first pneumothorax in patients with high-risk occupations such as divers or pilots. Surgical procedures can be performed by a cardiothoracic surgeon using video-assisted thoracoscopic surgery (VATS) or thoracotomy. Surgery serves as definitive management by resecting blebs or bullae and applying pleurodesis. In more complex cases, pleurectomy may be considered.[10]

COMPLICATION

If tension pneumothorax is not treated promptly, several serious complications may occur. These include increased intrathoracic pressure, massive mediastinal shift toward the opposite side, impaired venous return to the heart, compression of the contralateral hemithorax lung, obstructive shock, and ultimately death. Complications related to needle decompression can also arise, such as bleeding, intrapleural hematoma, pneumonia, atelectasis, and even cardiac tamponade. Chest tube insertion carries potential complications, including bleeding due to intercostal artery rupture, infection, bronchopleural fistula formation, incorrect subcutaneous or intraperitoneal placement of the tube, and damage to the lung parenchyma, mediastinal organs, or neurovascular structures.[11]

PROGNOSIS

Tension pneumothorax can cause rapid death due to inadequate cardiac output or hypoxemia and must be treated immediately as a medical emergency. In general, the prognosis for pneumothorax is good if prompt assistance and intensive treatment are provided, especially in young and otherwise healthy patients. Nearly half of patients with spontaneous pneumothorax may experience recurrence after recovery, whether managed by observation or after chest tube thoracostomy. Recurrence is rare in patients who undergo open thoracotomy. Patients who receive adequate management generally do not experience complications. The prognosis for secondary spontaneous pneumothorax depends on the underlying lung disease.[11]

CONCLUSION

Tension pneumothorax is a type of pneumothorax accompanied by progressively increasing intrathoracic pressure. In tension pneumothorax, a one-way valve mechanism is present, allowing air to enter the pleural space easily but preventing it from escaping. The rising intrathoracic pressure causes a massive shift of the mediastinal organs toward the opposite side of the affected lung, obstructs venous return to the heart, and compresses the lung on the contralateral hemithorax. This leads to circulatory instability, obstructive shock, and potentially death. Rapid and accurate anamnesis and physical examination are essential to diagnose tension pneumothorax without waiting for radiological confirmation. The management principles include oxygen administration and immediate needle decompression, followed by chest tube insertion.

FUNDING

None.

ETHICAL CONSIDERATIONS

This article did not involve human or animal subjects and does not require ethical clearance.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

AUTHOR CONTRIBUTION

All authors contributed equally to the writing of this manuscript.

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