

# Intracostal Nerve-Sparing Versus Pericostal Rib Suturing in Thoracotomy Closure: Impacts on Postoperative Pain and Neuralgia

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## ABSTRACT

**Background:** Thoracotomy remains a fundamental approach in thoracic surgery, but it is frequently associated with significant postoperative pain and the potential development of chronic intercostal neuralgia. The method used for rib approximation during thoracotomy closure plays a pivotal role in influencing these outcomes. Traditional pericostal suturing techniques, which encircle the ribs, have long been the standard. However, this approach risks compressing the intercostal neurovascular bundle, contributing to severe pain and long-term complications. In contrast, newer nerve-sparing methods like intracostal suturing have been developed to mitigate these issues by avoiding direct pressure on intercostal nerves. This review aims to comprehensively compare pericostal and intracostal rib suturing techniques in thoracotomy closure, focusing on their anatomical implications, impact on postoperative pain, long-term neuralgia, functional outcomes, and patient satisfaction. By analyzing current literature and surgical practices, the article evaluates the efficacy, safety, and clinical significance of nerve-sparing approaches in enhancing recovery and reducing morbidity.

## Conclusion:

Pericostal suturing provides reliable rib approximation but at the cost of increased postoperative pain due to nerve compression. Intracostal techniques, while technically more demanding, avoid this complication by rerouting sutures through rib-drilled holes, preserving the intercostal neurovascular bundle. Evidence supports the superiority of intracostal suturing in reducing acute pain, lowering chronic neuralgia incidence, and improving patient-reported outcomes without compromising structural stability. Emerging methods, such as extra-costal closure, show promise but require further validation. Transitioning toward intracostal closure reflects a broader shift toward patient-centered, minimally invasive, and pain-conscious surgical care. Continued innovation and training in nerve-sparing techniques will be essential to improving thoracotomy outcomes and long-term quality of life for patients.

**Keywords:** Thoracotomy closure, intercostal neuralgia, pericostal suturing, intracostal suturing, thoracic surgery techniques.

## 1. INTRODUCTION

The chest wall is a complex anatomical region comprising bones, muscles, blood vessels, and nerves, providing structural support and protection to vital organs such as the lungs and heart. The innervation of the chest wall primarily arises from the cervical and thoracic segments of the spinal cord. A comprehensive understanding of this innervation is pivotal for optimizing surgical outcomes and postoperative pain management strategies [1].

### **Anatomy of the Chest Wall**

The skeletal framework of the chest wall includes the ribs, sternum, and thoracic vertebrae. There are twelve pairs of ribs: true ribs (1–7) that attach directly to the sternum, false ribs (8–10) that attach indirectly, and floating ribs (11–12) without sternal attachment. These are supported by thoracic vertebrae posteriorly and the sternum anteriorly. The musculature includes pectoralis major and minor, intercostal muscles (external, internal, and innermost), serratus anterior, latissimus dorsi, subcostal muscles, and transversus thoracis, each contributing to respiration and upper limb movement. Blood supply comes from the anterior and posterior intercostal arteries and veins. These structures collectively support respiration and protect internal organs [2].

### **Intercostal Nerves**

Intercostal nerves, the principal nerve supply to the chest wall, emerge from the anterior rami of the thoracic spinal nerves T1–T11. Each travels in the intercostal space, accompanying the intercostal artery and vein in the subcostal groove. These nerves provide sensory innervation to the skin and parietal pleura and motor innervation to intercostal muscles. They also contain sympathetic fibers supplying sweat glands and blood vessels. The 12th thoracic spinal nerve forms the subcostal nerve, running beneath the 12th rib [3].

The intercostal nerves branch into the anterior cutaneous, lateral cutaneous, and collateral branches. Between the angles of the ribs and mid-axillary line, multiple nerve components are present. This anatomy emphasizes the risk of nerve injury during thoracic surgery, which may result in postoperative neuralgia. The lateral cutaneous branch exits by piercing the intercostal musculature, and the lower six nerves typically pierce the diaphragm and form plexuses in the abdominal wall [4].

### **Autonomic Innervation in the Thorax**

Autonomic innervation includes the sympathetic trunks and vagus nerves forming cardiac, pulmonary, and esophageal plexuses. The sympathetic trunks run anterior to the ribs and give rise to preganglionic fibers from T1–L2, forming white rami communicantes. The vagus nerve contributes parasympathetic fibers from the medulla, modulating heart rate and bronchial secretions. These fibers converge in the cardiac plexus (around the aortic arch), pulmonary plexus (around bronchi), and esophageal plexus (on the esophagus), contributing to homeostasis of thoracic viscera [5].

### **Thoracic Spinal Nerves**

Each of the twelve thoracic spinal nerves exits the spinal cord through intervertebral foramina. The anterior rami form the intercostal nerves, while the posterior rami supply muscles and skin of the back. Together, these nerves support somatic and autonomic functions, controlling motor activity, transmitting sensory signals, and influencing vascular tone [6].

### **Phrenic Nerve**

The phrenic nerve arises from cervical spinal roots C3–C5, descending through the thorax between the pericardium and pleura to innervate the diaphragm. It plays a vital role in respiration and also supplies the pericardium and diaphragmatic pleura. Dysfunction of the phrenic nerve can lead to diaphragmatic paralysis or referred pain in the shoulder and upper abdomen, complicating postoperative recovery [7].

### **A. Types of Thoracotomy and Closure Techniques**

Thoracotomy is a surgical procedure involving incision into the chest wall to access thoracic organs. Over time, various approaches and closure techniques have evolved to optimize surgical exposure while minimizing patient discomfort and postoperative complications. Tailoring the thoracotomy approach to the pathology and patient condition is essential for clinical success [9].

### **Indications for Thoracotomy**

Thoracotomy can be categorized into diagnostic and therapeutic procedures. Diagnostic thoracotomy is performed for biopsy of inaccessible lung or mediastinal masses. Therapeutic indications include lung resections, esophageal surgeries, decortication, cardiac access in minimally invasive procedures, resection of mediastinal tumors, sympathectomy, repair of diaphragmatic hernias, and trauma management. Each indication necessitates an approach that balances exposure and preservation of function [10].

### **Types of Thoracotomy**

The main types of thoracotomy include posterolateral, axillary (muscle-sparing), and superior sulcus approaches. Posterolateral thoracotomy remains the most commonly used technique, offering extensive exposure by incising from the anterior axillary line to the vertebral border and dividing muscles like latissimus dorsi and sometimes trapezius. Despite superior access, it results in higher postoperative pain [11].

In contrast, axillary thoracotomy aims to preserve muscle and reduce morbidity. Here, the incision is made vertically in the mid-axillary line, preserving the serratus anterior by splitting its fibers. This approach is particularly favored for VATS conversions, offering reduced pain and quicker recovery without compromising visualization [12].

The superior sulcus tumors require specific cervicothoracic or hemi-clamshell approaches. The anterior cervicothoracic approach involves an "L"-shaped incision from the sternocleidomastoid to below the clavicle, while the hemi-clamshell extends into the thoracic cavity. These methods provide

access for complex resections involving thoracic inlet structures. The posterior extension of the thoracotomy allows scapular elevation for access to the thoracic outlet [13].

### **Thoracotomy Closure Techniques**

Standard closure involves approximating ribs followed by muscle, subcutaneous tissue, and skin closure. Rib approximation is a critical step impacting pain and healing. Traditional pericostal suturing involves looping sutures around the ribs, often compressing intercostal nerves and leading to postoperative neuralgia [14].

Intracostal suturing is a nerve-sparing alternative where sutures pass through drilled holes in the ribs, bypassing the neurovascular bundle. This technique has been associated with reduced postoperative pain, shorter hospital stays, and improved early ambulation. Tools such as bone drills are used to facilitate the passage of sutures through the rib body [15].

Extra-costal suturing, a newer method, places sutures around the intercostal muscles rather than directly around the ribs. Preliminary studies report that this method results in decreased pain on day five and six months postoperatively compared to pericostal closure. The technique avoids entrapment of neurovascular structures, further minimizing chronic pain risks [16].

### **B. Methods of Postoperative Pain Control**

Postoperative pain control is critical to enhancing recovery, minimizing complications, and improving patient satisfaction following thoracic surgery. Pain from thoracotomy is notably severe due to muscle splitting and nerve injury. Thus, multimodal approaches combining pharmacological, non-pharmacological, and interventional methods have become standard [17].

#### **Pharmacological Methods**

Opioids are commonly used in the immediate postoperative period. Drugs such as morphine, fentanyl, and hydromorphone are effective but come with risks including respiratory depression and dependency. NSAIDs, including ibuprofen and ketorolac, provide effective anti-inflammatory action and are often used in conjunction with opioids. Acetaminophen is used for its synergistic effects and low side-effect profile. Local anesthetics like bupivacaine and lidocaine are often employed via infiltration or nerve blocks. Adjuvants such as gabapentin, pregabalin, and amitriptyline target neuropathic pain components [18].

#### **Non-Pharmacological Methods**

These methods include physical therapy, which aids in early mobilization and lung function; cognitive-behavioral therapy to help patients manage pain perception; and modalities like TENS and acupuncture. Cold therapy is beneficial in the acute phase to reduce inflammation, while heat therapy aids in chronic stages by increasing circulation and muscle relaxation. These approaches can be particularly useful when integrated into a multimodal pain strategy [19].

#### **Interventional Methods**

Interventional techniques are highly effective for thoracotomy pain. Epidural analgesia involves infusing local anesthetics and opioids into the epidural space, providing robust bilateral analgesia. Paravertebral blocks (PVB) offer unilateral pain control with a lower risk of hypotension compared to epidurals. Intercostal nerve blocks target specific dermatomes for localized analgesia. The Erector Spinae Plane Block (ESPB) is a newer method that blocks dorsal and ventral rami with a favorable safety profile [20].

Spinal cord stimulation is reserved for chronic or refractory pain. It involves implanting electrodes that deliver impulses to modulate pain perception. While expensive, it has shown efficacy in select patients. Nerve blocks and radiofrequency ablation are additional tools for long-term relief in cases of intercostal neuralgia [21].

### **Multimodal Analgesia**

Multimodal analgesia refers to using multiple drugs and techniques to manage pain synergistically. This approach reduces the need for high-dose opioids and minimizes side effects. A regimen might include NSAIDs, acetaminophen, opioids, regional blocks, and physical therapy. Personalizing these combinations to the patient's condition and surgical factors ensures optimal outcomes and minimizes chronic pain development [22].

### **C. Postoperative Intercostal Neuralgia**

Postoperative intercostal neuralgia is a common and distressing complication following thoracotomy. It involves chronic pain due to intercostal nerve damage or irritation and can significantly affect a patient's quality of life. Understanding its mechanisms, diagnosis, and management strategies is essential for comprehensive post-surgical care [23].

### **Pathophysiology of Intercostal Neuralgia**

This condition arises when intercostal nerves are damaged during surgery, compressed by scar tissue, or affected by inflammation. Common causes include trauma from rib retraction, direct nerve injury during closure, or neuropathy secondary to infections like herpes zoster. Nerve compression by pericostal sutures is a known contributor. Chronic inflammation and neuronal hyperexcitability can lead to persistent pain signals even after tissue healing [24].

### **Clinical Features**

Patients describe the pain as sharp, burning, or stabbing. It typically follows the path of a rib from the back to the anterior chest. Symptoms may be aggravated by deep breathing, coughing, or torso movement. Sensory disturbances such as numbness, tingling, or hyperesthesia may also be present. Examination may reveal tenderness along the intercostal space and diminished or heightened sensation in the dermatome [25].

### **Diagnosis**

Diagnosis begins with a thorough history and physical exam, focusing on symptom duration, characteristics, and potential surgical or traumatic causes. Imaging such as chest X-ray, CT, or MRI can reveal rib fractures, surgical changes, or masses compressing the nerves. Electrodiagnostic studies assess nerve integrity and differentiate intercostal neuralgia from other causes of thoracic pain like radiculopathy or costochondritis [26].

### **Treatment Modalities**

Pharmacological treatments include NSAIDs, acetaminophen, anticonvulsants (gabapentin, pregabalin), and antidepressants (amitriptyline, duloxetine). Topical agents such as lidocaine patches and capsaicin creams offer localized relief. For more resistant cases, interventional procedures like intercostal nerve blocks or radiofrequency ablation may provide prolonged benefit [27].

Spinal cord stimulation has been effective in severe cases of refractory neuropathic pain. Surgical neurolysis or nerve decompression may be considered if conservative measures fail. Rehabilitation with physical therapy and psychological support (CBT) can further improve outcomes by enhancing coping strategies and restoring function [28].

### **D. Pericostal Versus Intracostal Rib Suturing in Thoracotomy Closure**

Rib approximation during thoracotomy closure is a critical step that affects both mechanical stability and the incidence of postoperative pain. Traditionally, pericostal suturing has been used, in which sutures are placed around the ribs, potentially compressing the intercostal neurovascular bundle. Intracostal nerve-sparing techniques have emerged as an alternative aiming to reduce this risk by placing sutures through pre-drilled holes in the ribs [29].

Pericostal suturing, although mechanically reliable, often results in compression or entrapment of the intercostal nerves located in the subcostal groove. This can lead to acute pain in the early postoperative period and contribute to chronic post-thoracotomy pain syndromes. Studies have shown a higher incidence of pain and analgesic requirements in patients closed with pericostal techniques [30].

Intracostal suturing techniques offer a nerve-sparing alternative by avoiding the subcostal groove entirely. This is accomplished by drilling holes into the rib and threading the suture through the bone, thus maintaining stability without compressing the neurovascular bundle. The result is a significant reduction in both acute and chronic pain outcomes [31].

Comparative clinical trials have demonstrated that intracostal closure results in decreased opioid consumption and lower visual analog scale (VAS) scores for pain in the immediate postoperative period. Additionally, patients report fewer sensory disturbances and quicker return to baseline activity levels when intracostal techniques are used [32].

Intracostal suturing is technically more demanding and may slightly increase the duration of surgery. However, this time investment is often justified by improved postoperative recovery and reduced

incidence of complications such as atelectasis and pneumonia due to better respiratory effort enabled by reduced pain [33].

Biomechanical studies comparing the tensile strength of pericostal and intracostal closures show comparable outcomes in terms of chest wall integrity. Therefore, the choice between the two techniques can be guided more by patient comfort and long-term outcomes than structural stability alone [34].

Chronic pain following thoracotomy is a major concern, affecting up to 50% of patients with standard pericostal closure. This can severely impact quality of life and necessitate long-term pain management strategies. Intracostal suturing significantly reduces this burden by sparing the intercostal nerve from compression and ischemia [35].

Extra-costal techniques have also been introduced and studied as further refinements. These methods avoid both direct rib encirclement and neurovascular bundle compression by placing sutures around intercostal muscles. Though promising, these techniques require further validation in large-scale studies [36].

Patient-reported outcomes are strongly influenced by the suturing technique. Surveys and qualitative studies indicate higher satisfaction and fewer complaints of numbness or discomfort in patients who underwent intracostal closure. This supports the shift towards patient-centered surgical decision-making [37].

Ultimately, the choice of rib closure technique should be individualized, taking into account patient anatomy, surgical complexity, and pain history. However, current evidence favors intracostal nerve-sparing techniques as the superior method in terms of postoperative pain control and overall patient outcomes [38].

## **Conclusion**

The comparison between pericostal and intracostal rib suturing techniques underscores a significant paradigm shift in thoracotomy closure strategies. Traditional pericostal sutures, while straightforward and structurally sound, are increasingly associated with higher rates of intercostal nerve compression, resulting in heightened postoperative pain and long-term neuralgia. These outcomes not only diminish patient comfort but also delay recovery and increase healthcare utilization.

In contrast, intracostal nerve-sparing closure has demonstrated consistent advantages across multiple studies. By rerouting sutures through drilled rib holes and avoiding the subcostal neurovascular bundle, this technique significantly reduces the incidence of both acute and chronic post-thoracotomy pain. Enhanced patient-reported outcomes, including decreased reliance on opioids and improved satisfaction scores, further support its widespread adoption.

Importantly, the biomechanical integrity of intracostal closure matches that of pericostal methods, alleviating concerns over compromised chest wall stability. Although the technique may introduce

minor increases in operative time, these are outweighed by the long-term benefits in pain reduction and postoperative functionality.

Emerging methods like extra-costal closure offer additional refinement, aiming to optimize nerve preservation while simplifying surgical execution. However, until more robust evidence is available, intracostal suturing remains the most validated and effective alternative to the pericostal approach.

The transition to intracostal suturing reflects an evidence-based response to the evolving understanding of thoracic postoperative pain. As surgical practice becomes increasingly patient-centered, prioritizing nerve-sparing approaches will likely enhance outcomes and reduce the chronic pain burden historically associated with thoracotomy.

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