Technical Note

Endoscopic-Assisted Transaxillary Approach for First-Rib Resection and Neurolysis in Thoracic Outlet Syndrome

Kozo Furushima, M.D., and Tadanao Funakoshi, M.D.

Abstract: Thoracic outlet syndrome (TOS) is a complex disorder with signs and symptoms resulting from compression of the brachial plexus and subclavian vessels. Although transaxillary first-rib resection is a well-established surgical treatment for patients with symptomatic TOS, this approach sometimes does not allow adequate exposure of the insertion point of the middle scalene muscle to the posterior part of the first rib and neurovascular bundle. The objective of this Technical Note is to describe an endoscopic-assisted transaxillary approach for first-rib resection and neurolysis. An endoscopic-assisted transaxillary approach for first-rib resection in TOS can provide excellent magnified visualization and safely allow sufficient decompression of the neurovascular bundle.

Transaxillary first-rib resection is a well-established surgical treatment for patients with symptomatic thoracic outlet syndrome (TOS).[1-4] The transaxillary approach provides good exposure of the anterior and lateral part of the first rib with an excellent cosmetic result. However, this approach sometimes does not allow adequate exposure of the insertion point of the middle scalene muscle to the posterior part of the first rib and proximal neurovascular bundle. Surgery for TOS involves many complex and intimately related structures; therefore, possible complications are numerous, and they may be severe. Reported complications include brachial plexus dysfunction and fatal subclavian artery or vein injury.[5-7] Recent articles have shown that with the help of an endoscope, safer and less invasive surgery has been achieved.[8,9] In addition, endoscopic-assisted surgery provides excellent visualization of the thoracic outlet. We believe that endoscopic intraoperative observations could provide information on the portion, degree, and pattern of neurovascular entrapment in the thoracic outlet. The objective of this Technical Note is to describe an endoscopic-assisted transaxillary approach for the first-rib resection and neurolysis.

Surgical Technique

An accurate diagnosis of TOS remains challenging owing to its varied symptoms and atypical radiographic findings, which may lead to less objective diagnostic criteria being applied. It is essential that several factors be considered, such as characteristic symptoms, physical examination findings, and imaging studies (Table 1). Possible surgical indications and contraindications are summarized in Table 2.

Position

The patient is placed in the lateral decubitus position and operated on under general anesthesia with local anesthesia. The bed is controlled posteriorly and caudally for the best exposure of both the anterior and posterior extremes of the rib to be resected. To achieve maximal exposure of the contents of the thoracic outlet, it is important to elevate the extremity. Instead of the "wrist-lock technique," the arm position is maintained in 90° of abduction by using the SPIDER2 Limb Positioner (Smith & Nephew, Memphis, TN) to open the costoclavicular space (Fig 1A). Because there is a significant risk of damage to the nerves and blood vessels, it is important to reduce the compression and

From Keiyu Orthopaedic Hospital, Tatebayashi, Japan.

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Address correspondence to Tadanao Funakoshi, M.D., Keiyu Orthopaedic Hospital, 2267 Akoda, Tatebayashi, Japan. E-mail: tfunakoshi@gmail.com

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Table 1. Diagnostic Criteria

Neurologic symptoms
Upper-extremity pain (shoulder, elbow, wrist, and/or finger)
Upper-extremity numbness (shoulder, elbow, wrist, and/or finger)
Loss of range of motion
Motor weakness
Vascular symptoms
Coldness, easy fatigability, pallor, and/or discoloration
Swelling and/or cyanosis
Heavy feeling in upper extremity
Other symptoms
Headache, neck pain, dizziness, and/or tinnitus
Physical examination findings
Tenderness (interscalene triangle and/or subcoracoid space)
Shoulder and elbow function
Wright test
Roos test
Imaging studies
Cervical radiographs (cervical rib and/or stress fracture)
Computed tomography (costoclavicular distance)
3D angiography (artery interruption)
Ultrasound (interscalene distance)
MRI (malignant tumor)

MRI, magnetic resonance imaging; 3D, 3-dimensional.

Table 2. Surgical Indications and Contraindications

Indications
Failure of >6 mo of conservative treatment
Evidence of artery interruption on 3D angiography
Decreasing peak systolic velocity of axillary artery with elevated arm position on Doppler US
<10 mm of narrowing of interscalene region on US
Contraindications
Pancoast tumor
Aneurysm of subclavian artery or vein

3D, 3-dimensional; US, ultrasound.

constriction of the nerves, vessels, and muscles to the shortest duration possible.

Incision and Exposure

The open surgical technique of transaxillary first-rib resection has been described by Roos.[1,10] A 5- to 8-cm incision is made over the third intercostal space at the bottom of the hairline in the midaxillary line between the pectoralis and latissimus dorsi muscles (Fig 1B). A 4.0-mm 30° arthroscope is introduced with an additional small port placed anterior to the latissimus dorsi (Fig 1C). Roos[10] described that a higher transverse incision enters the axial fat nodes and vessels, causing troublesome dissection and bleeding without increasing exposure. Dissection of these soft tissues from the thorax is preferable; therefore, elevation of these soft tissues by a large retractor is critical for opening the ceiling of the operative field and maintaining the viewing and working space.

Identification of Neurovascular Structures and Scalene Muscles

The first rib can be identified by the characteristic flat surface and insertion of the posterior interscalene muscle. The scope allows for visual identification and confirmation of the first rib and the contents of the thoracic outlet (Fig 2 A-C). Roos[10] described the contents of the thoracic outlet, which include the large fluttering blue subclavian vein, the pink pulsatile subclavian artery immediately posterior to the scalenus anterior, and the yellowish T1 root of the brachial plexus immediately posterior to the artery. The area with large fluttering of the subclavian vein or artery in some patients could be a good landmark for identification of the thoracic outlet. These vital structures (subclavian vein, subclavian artery, and brachial plexus) are carefully identified. We have found little to no fluttering of the vessels in some patients. Therefore, we may identify these vital structures behind the regions of no fluttering. The lung does not need to be collapsed during the procedure. The insertion of the scalene and serratus anterior muscles on the first rib must be dissected with special care to avoid opening the cupola of the pleura, which rises above the first rib in contact with the medial and lateral surfaces (Video 1). A long bipolar hemostat is helpful for clear visualization and safe maneuvering during dissection of these muscles from their insertion on the first rib. The addition of a suction tube with endoscopy improves the performance of defogging the mirror surface of the endoscope.

Endoscopic Classification and Interscalene Distance Measurement

The endoscopic classification of the neurovascular bundle patterns is evaluated intraoperatively based on alignment of the nerve, artery, and vein, revealing the following 3 types: parallel, oblique, and vertical. In the parallel type, the artery and nerve travel in parallel (Fig 3A); in the oblique type, the nerves are partially behind the artery (Fig 3B); and in the vertical type, the nerves are totally behind the middle scalene muscle or abnormal band (Fig 3C). In addition, the distance between the anterior and middle scalene muscles at the edge of the first clavicle is measured as the interscalene distance (Fig 2C).

Partial First-Rib Resection

After evaluation of the interscalene space, this muscle is dissected free of its origin at the first rib using an elevator and long scissors parallel to the various muscle patterns and under good visualization, with great care to avoid injury to the subclavian vein immediately anterior to the anterior scalene muscle. A periosteal elevator or custom-ordered elevator (Tanaka Medical Instruments, Tokyo, Japan) is then used to dissect the lateral surface of the rib. The dissection is sequentially carried out on the lateral, inferior, and pleural surfaces of the rib. The first rib is transected anteriorly near the

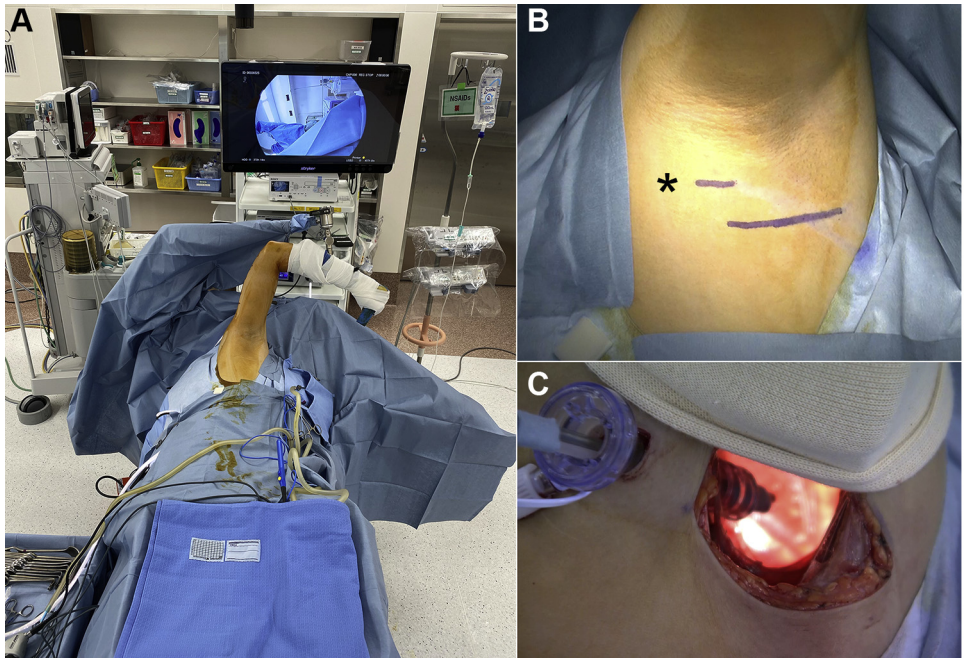

Fig 1. (A) The patient is placed in the lateral decubitus position and operated on under general anesthesia with local anesthesia. The arm position is maintained in 90° of abduction by using the SPIDER2 Limb Positioner. (B) A 5- to 8-cm incision is made over the third intercostal space at the bottom of the hairline in the midaxillary line between the pectoralis and latissimus dorsi muscles. A small port is placed posteriorly (star). (C) A 4.0-mm 30° arthroscope is introduced with an additional small port placed anterior to the latissimus dorsi.

costochondral junction and posteriorly as close to the transverse process as possible in a piece-by-piece fashion. Endoscopic-assisted transection by a rongeur is useful for ensuring safe removal of the first rib. The rongeur is placed as far posterior as possible under visualization (Fig 2 D and E). In our series, a cervical rib was resected through the axial approach in the same manner as the first rib. A longer cervical rib should be resected because it may impinge on or entrap the brachial plexus.[10] We have found that the anterior scalene is attached not only to the first rib but also to the pleura. Therefore, during release of the anterior scalene muscle insertion, pleural injury must be avoided (Fig 2F).

Confirmation of Release of Neurovascular Bundle and Possible Pleural Injury

After partial resection of the first rib, release of the neurovascular bundle should be confirmed. In several cases, we have found relaxation and some space in each of the subclavian vein, subclavian artery, and brachial plexus nerves after the first-rib resection and anterior and middle scalenectomy (Fig 2 G-I). In most cases, we could still find tight and narrow spaces in the vessels and nerves. A congenital fibrous band, usually coming off the tip of such a rib or a long C7 transverse process (abortive cervical rib), inserting at the scalene tubercle, must be removed, not merely divided. The accessory scalenus minimus muscles, which cause entrapment of the neurovascular bundle, should be released carefully. In addition, release and decompression of the brachial plexus are performed under high magnification. Regions with signs of fibrosis, palpated hardness, and a hypertrophic epineural sheath are released to restore softness and ensure sufficient space between the artery and nerve. Finally, we confirm the existence of abnormal band patterns, as reported by Roos.[10] The pleura is inspected by endoscopic visualization while saline solution is infused into the chest and an anesthetist overinflates the lungs. If a pneumothorax is found, a chest drain is inserted and is left in place for 2 days. Pearls and pitfalls of the described technique are summarized in Table 3, and advantages and disadvantages are listed in Table 4.

Discussion

This Technical Note describes that an endoscopic-assisted transaxillary approach for first-rib resection in TOS that provides excellent visualization of the vital structures and surrounding tissue and adequate decompression of the neurovascular bundle with a low incidence of complications. To decompress the brachial plexus completely and permanently, almost the entire first rib must be resected.[11,12] The transaxillary approach may be more suitable for resection of the first rib from the anterior to middle portion than the supraclavicular approach. However, the risk of C8 or T1 cervical root injury is unavoidable because the posterior stump of the first rib lies posterior to the root clearly seen during the operation.[10] Therefore, Roos[10] clearly showed that specially designed rib shears and a root

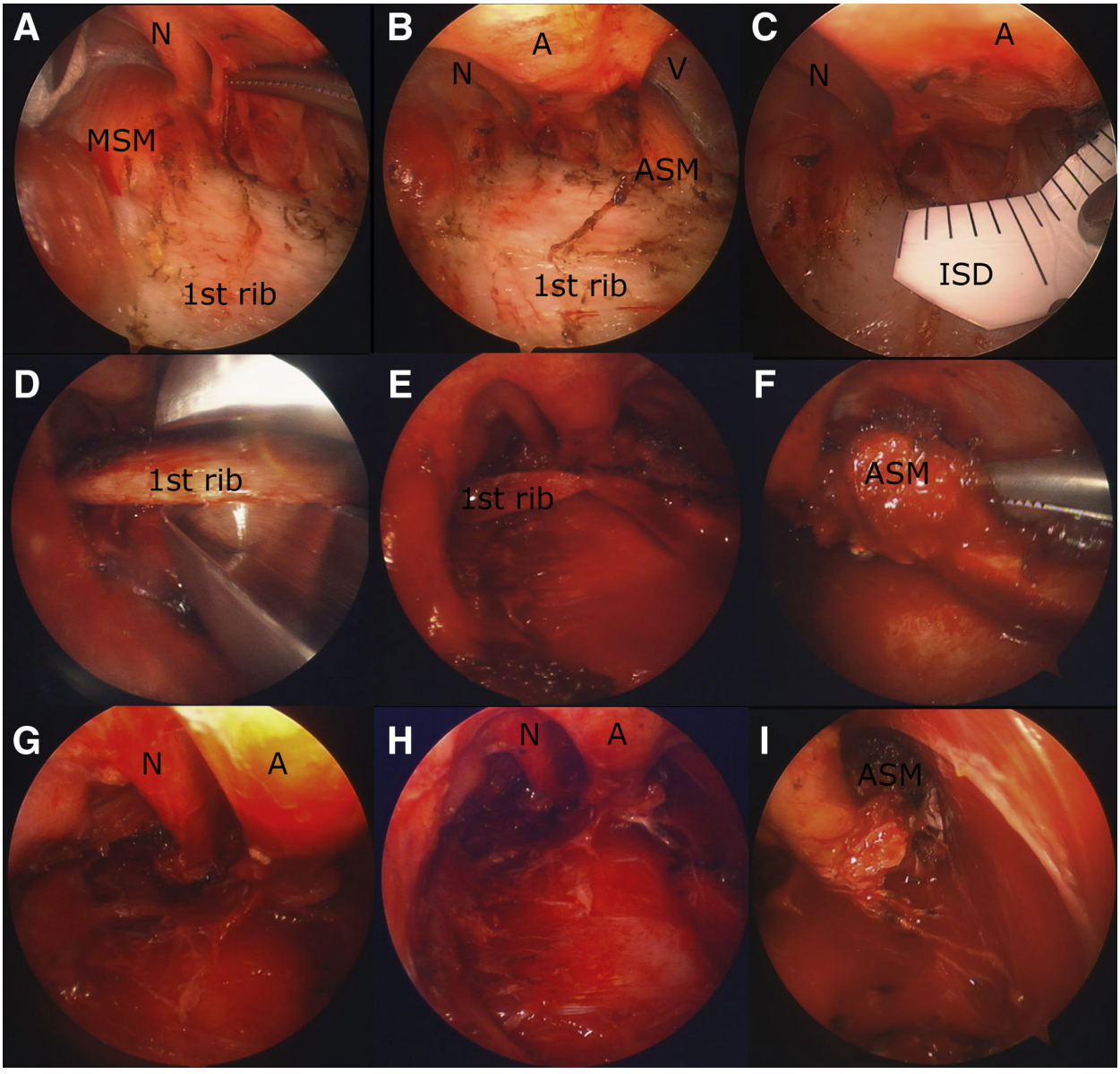

Fig 2. Right transaxillary approach in lateral decubitus position with additional viewing portal. The scope allows for visual identification and confirmation of the first rib and the contents of the thoracic outlet. (A) Nerve entrapment by the middle scalene muscle (MSM) is found. (B) The neurovascular bundle is identified. (C) The distance between the anterior scalene muscle (ASM) and MSM at the edge of the first clavicle is measured as the interscalene distance (ISD). (D, E) The rongeur is placed as far posterior as possible under visualization. (F) At release of the ASM insertion, care must be taken to avoid injury to the pleura. (G) The nerves are relaxed after the MSM has been fully released. (H) The subclavian vein, subclavian artery, and brachial plexus nerves are released after first-rib resection. (I) The ASM is released after full resection from the first rib and pleura. (A, artery; N, nerve; V, vein.)

retractor help remove the posterior stump of the first rib with sufficient safety. We believe that maintaining excellent visualization during the operation is the most important factor for decreasing the risk of neurovascular damage. Moreover, our custom-ordered elevators are useful in aiding endoscopic visualization. In addition to specially designed instruments, control of micro-bleeds and step-by-step decompression of the neurovascular bundle must be performed using a bipolar hemostat. From the perspective of neuralgic symptoms, adequate nerve release and decompression of an entrapped nerve should preferably be performed under a clear magnified view for greater safety. Adequate neurolysis for TOS is considered an important procedure for superior outcomes.[9,13] Endoscopic-assisted surgery would help achieve meticulous

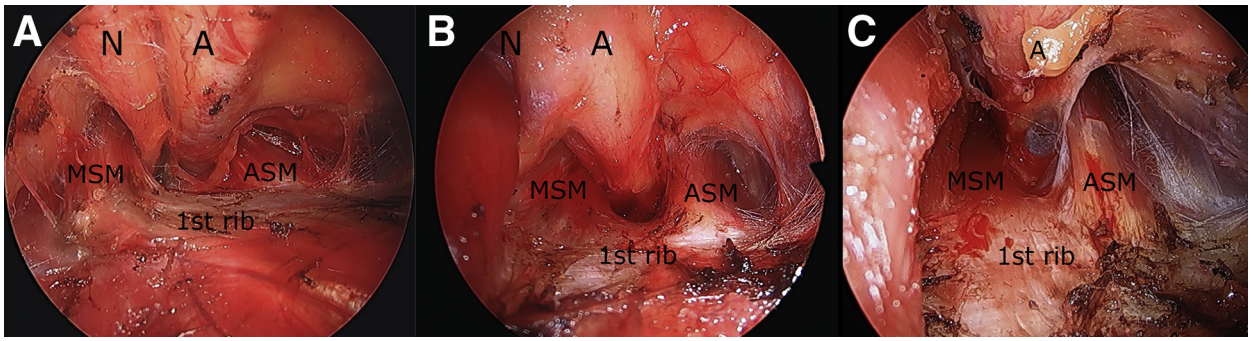

Fig 3. Right transaxillary approach in lateral decubitus position with additional viewing portal. The endoscopic classification of the neurovascular bundle patterns is evaluated intraoperatively based on alignment of the nerve (N), artery (A), and vein, revealing the following 3 types: parallel type (A), in which the artery and nerve travel in parallel; oblique type (B), in which the nerves are partially behind the artery; and vertical type (C), in which the nerves are totally behind the middle scalene muscle (MSM) or abnormal band. (ASM, anterior scalene muscle.)

release and decompression from the middle scalene and the posterior rib during a transaxillary approach.

Several large studies have shown that pneumothorax is one of the most common complications (10.1%-31.6%) associated with first-rib resection.[5,10,11,14,15] Recent studies have shown an improved capability of working at a closer range around the nerve, artery, and vein[8,9] with more refined endoscopes and video cameras. These advances provide a low risk of pneumothorax during the resection of the anterior and middle scalene from the pleura. Potential disadvantages are that the diagnosis of TOS is still complicated by alternative disorders with a similar presentation. Nerve compression at the cervical spine, shoulder, elbow, and wrist may mask the presentation of TOS. In conclusion, an endoscopic-assisted transaxillary approach for first-rib resection in TOS provides excellent magnified visualization, safely allowing sufficient decompression of the neurovascular bundle, with satisfactory surgical outcomes.

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Table 3. Pearls and Pitfalls of First-Rib Resection and Neurolysis

Pearls
Dissection of the soft tissues from the thorax is critical to opening the ceiling of the operative field and maintaining the viewing and working space.
The vital structures (subclavian vein, subclavian artery, and brachial plexus) are carefully identified.
A long bipolar hemostat is helpful for clear visualization and safe maneuvering during dissection.
Endoscopic-assisted transection by a rongeur is useful for ensuring safe removal of the first rib.
The rongeur is placed as far posterior as possible under visualization.
A congenital fibrous band or accessory scalenus minimus muscle, which causes entrapment of the neurovascular bundle, should be released carefully.
Pitfalls
Injury to vital structures, especially the subclavian vein, must be avoided.
The scope should be used with care to avoid breakage by a rongeur.
Because the anterior scalene is usually attached to the pleura, pleural injury must be avoided at release of the anterior scalene muscle insertion.
If a pneumothorax is found, a chest drain is inserted and is left in place for 2 d.

Table 4. Advantages and Disadvantages

Advantages
The transaxillary approach is more suitable for resection of the first rib from the anterior to middle portion compared with the posterior portion.
Endoscopic-assisted surgery decreases nerve injury during the posterior rib stump resection.
Endoscopic-assisted surgery achieves a meticulous release and decompression of the nerves.
Endoscopic-assisted surgery provides a low risk of pneumothorax.
Endoscopic evaluation of the neurovascular bundle patterns will help develop important information related to the appropriate diagnosis and surgical criteria.
Disadvantages
The diagnosis of TOS is still complicated by alternative disorders with a similar presentation.
Nerve compression at the cervical spine, shoulder, elbow, and wrist may mask the presentation of TOS.
Possible complications are numerous and may be severe.
Other regions of entrapment pathology, such as cervical rib and accessory scalenus minimus muscles, may require an additional supraclavicular approach.

TOS, thoracic outlet syndrome.

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