Original Article

Robotic-assisted wire saw resection of high-position rib tumors: a single-center experience

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Background: Rib tumors are typically curable through rib resection, associated with an excellent prognosis. Although transthoracic robotic first rib resection for thoracic outlet syndrome (TOS) has been previously documented, this paper presents our experience and technique in conducting robotic-assisted wire saw resections for high-position rib tumors.

Methods: From January 2019 to May 2022, five patients diagnosed with high-position rib tumors underwent robotic-assisted wire saw resections. For our entire portal approach, we employed two 8-mm working ports, a 12-mm camera port, and a 12-mm assistant port. Data regarding the short-term and clinical long-term treatment effects were collected.

Results: The median operation time was 124.2 minutes (range, 87–185 minutes), with no observed complications. The average intraoperative blood loss was 185 mL (range, 85–410 mL). Chest tubes were typically removed between 1 and 3 days post-operation. The average hospital stay post-surgery was 2.8 days, with a range of 2–5 days. We observed no relevant intraoperative or postoperative complications. No recurrence was reported during routine follow-ups 12 months post-surgery.

Conclusions: Our findings indicate that the technique of robotic-assisted wire saw resection for high-position rib tumors is both feasible and reliable. This provides valuable insights for surgeons to consider robotic-assisted resection for high-position rib tumors.

Keywords: Robotic-assisted thoracic surgery (RATS); high-position rib tumors; first rib resection; wire saw

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Introduction

Rib tumors are relatively rare, particularly those located at higher positions along the rib cage. Surgical resection is the preferred curative treatment, and it typically offers an excellent prognosis for patients. However, when dealing with high-position rib tumors where the tumors involve the first to third ribs, exposing the target rib and achieving complete tumor resection pose significant challenges. Insufficient exposure of the entire rib or incomplete rib resection may result in recurrence or persistence of symptoms (1). As a result, complete tumor removal is often performed through open thoracotomy for a clearer field. Conventional approaches to high-position rib resection often necessitate an elongated or additional incision, which can result in a procedure that is more invasive for patients and may lead to an aesthetically unfavorable scar. Multiple invasive approaches have been described, including the transaxillary, supraclavicular, or subclavicular methods. The choice of approach typically depends on the surgeon's preference and considerations related to pain management, aesthetics, and quality of life (QoL) (2-4).

Robot-assisted high-position rib resection has emerged as a promising alternative approach, particularly for the treatment of thoracic outlet syndrome (TOS) (5). However, cases of robot-assisted high-position rib tumor resection remain rare, and no consensus has been reached regarding the most effective rib resection device. Liu *et al.* (6) reported a pneumatic surgical drill with a blunt tip as one option, achieving favorable results when being used to transect the rib anteriorly and posteriorly. Other studies (5,7) have documented the use of Kerrison rongeurs or Gigli saws for rib cutting at the level of the costovertebral joint. Our center has employed an innovative wire saw (the Gigli saw) technique for robot-assisted complete rib resection, achieving excellent clinical curative outcomes.

Compared to conventional techniques, this robot-assisted approach avoids the need for long skin incisions, leading to improved pain management and aesthetic outcomes. Moreover, enabling precise tissue handling leads to improved outcomes and enhanced protection of delicate structures. Robotic surgery provides a safe and flexible approach to the treatment of high-position rib tumors. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-983/rc).

Highlight box

Key findings

- Robotic-assisted wire saw resection for high-position rib tumors is feasible and reliable.

What is known and what is new?

- Robotic-assisted resection of the first rib has been reported and widely adopted as a promising alternative approach for treating thoracic outlet syndrome (TOS), particularly in cases involving high-position tumor resection.
- We present a simple and efficient method for the complete removal of high-position ribs. This addresses the complex tasks of exposing the target rib and achieving total tumor resection.

What is the implication, and what should change now?

- Da Vinci robot-assisted high-position rib tumor resection provides a better vision of the operative field and reduced trauma, making it a safe, effective, and minimally invasive approach. It offers suggestions on treatment options for surgeons performing high-position tumor resection.

Methods

We conducted a retrospective analysis of clinical data from 5 patients treated at the Affiliated Jinling Hospital, Medical School of Nanjing University between January 2019 and May 2022. Diagnoses and clinical information were collected by reviewing the patients' medical records. All patients routinely underwent chest computed tomography (CT) and intercostal artery angiography, as shown in *Figures 1*,*2*. Demographic and clinical characteristics including age, sex, comorbidities (such as hypertension and diabetes), and symptoms were collected. Surgical-related data, including total operative time, intraoperative bleeding, thoracic drainage tube time, thoracic drainage volume, pain Visual Analogue Scale (VAS) scores, postoperative hospital stay, intraoperative adverse events, complications, and outcomes at 3-month follow-up were also collected. All patients were treated according to the actual clinical needs. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and the Harmonized Tripartite Guideline for Good Clinical Practice from the International Conference on Harmonization. This study was reviewed and approved by the Institutional Review Board of the Nanjing Jinling Hospital (No. 2011NZKY-030-01). The ethics committee waived the need for informed consent from those patients due to the retrospective nature of the study.

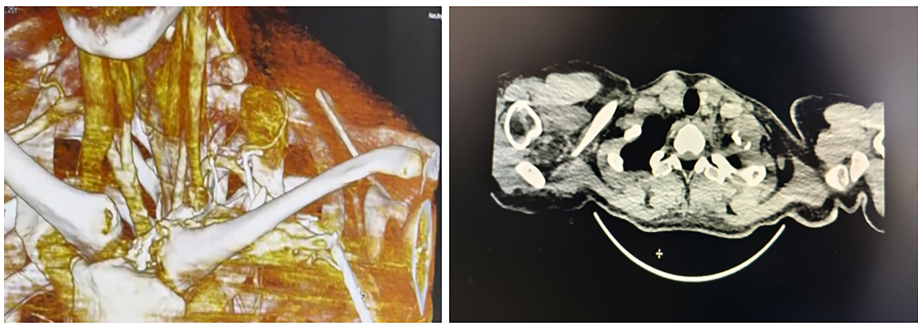


Figure 1 3D imaging and chest CT for high-position rib tumor. 3D, three-dimensional; CT, computed tomography.

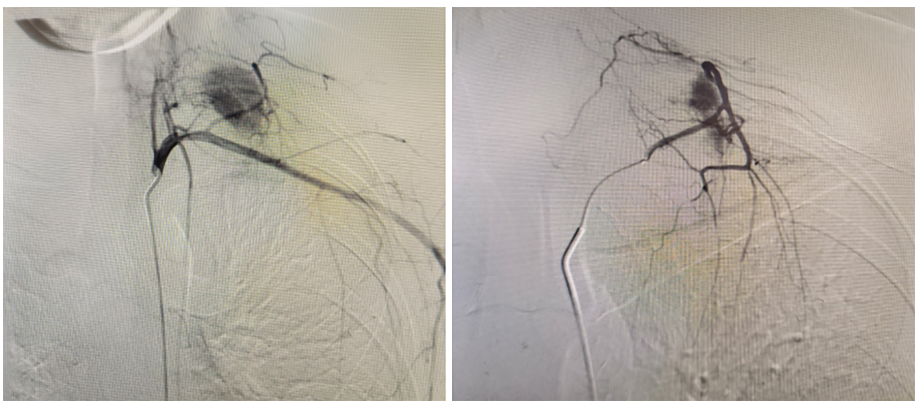


Figure 2 Preoperative intercostal artery angiography for high-position rib tumor.

Surgical technique

In addressing high-position rib tumors, our diagnostic protocol requires not only chest CT scans but also three-dimensional (3D) reconstruction (*Figure 1*). These examinations enable us to delineate the extent of tissues surrounded by the tumor, thereby informing our decision on the most appropriate surgical approach. Additionally, we conduct intercostal arteriography to ascertain the tumor's blood supply and to determine if the major blood vessels at the cervicothoracic junction are included (*Figure 2*). We resort to open thoracotomy in instances where tumor invasion extends to the pulmonary hilum or large vessels. The surgical procedure we advocate that involves the utilization of the Da Vinci Si system (Intuitive Surgical, Sunnyvale, CA, USA) in combination with a wire saw, which we describe in detail in the following sections.

Preoperative preparation was consistent with conventional surgery. Intubation was performed via either double-lumen endotracheal intubation or single-lumen intubation with a bronchial occluder. After intubation, combined intravenous-inhalation anesthesia was administered.

Patients were typically positioned laterally, slightly leaning forward if necessary to expose the high-position rib. Four ports were placed as shown in *Figure 3*. A 12-mm camera port was inserted in the 7th intercostal space (ICS) at the anterior axillary line. Two 8-mm ports were inserted in the 7th ICS at the posterior axillary line and the 4th ICS at the anterior axillary line, serving as the 1st and 2nd working ports, respectively. If necessary, a 12-mm assistant port was created in the 6th ICS of the anterior axillary line.

The pleura of the upper and lower edges of the rib were opened along the high-position rib's anterior rib joint. Intercostal muscle was freed, and the high-position rib was exposed. Blunt dissection of the chest wall muscles over the rib was performed to create a tunnel between the rib and chest wall muscle for cutting off the anterior rib. Special care was taken when dissecting the first rib to protect the left subclavian arterial vein and brachial plexus nerve. The electrocoagulation hook opened the pleura on the tumor

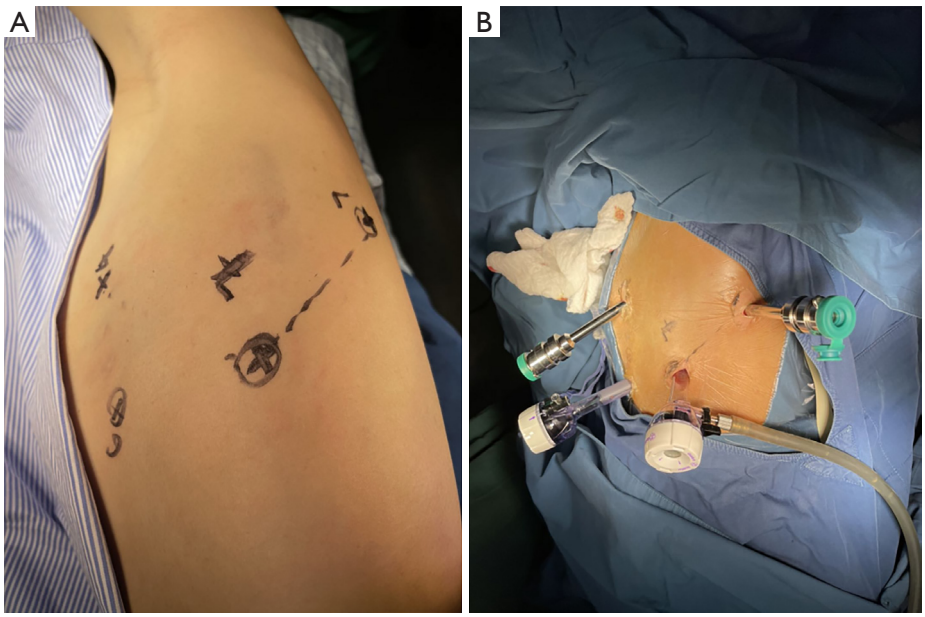


Figure 3 Port positions for robot-assisted resection of high-position rib tumor. (A) A 12-mm camera port was inserted in the 7th ICS at the anterior axillary line. Two 8-mm ports were inserted in the 7th ICS at the posterior axillary line and the 4th ICS at the anterior axillary line, serving as the 1st and 2nd working ports, respectively. If necessary, a 12-mm assistant port was created in the 6th ICS of the anterior axillary line. (B) Trocar placement of thoracic part. ICS, intercostal space.

surface, separated the adhesions between the tissues and the surrounding muscles from the envelope, and removed the tumor intactly. The posterior rib was freed, and the involved bone and the surrounding normal rib bone were removed using a wire saw (*Figure 4*, *Video 1*).

Statistical analysis

This study aimed to assess the safety and feasibility of a modified surgical technique. Data were prospectively recorded using Microsoft Office Excel 2003.

Results

Patient characteristics and anastomotic techniques

We retrospectively analyzed clinical data from 5 patients who underwent robot-assisted thoracoscopic resection of high-position rib tumors at the Affiliated Jinling Hospital, Medical School of Nanjing University, between January 2019 and May 2022. All procedures were performed by the same highly experienced surgeon (Yi J), who developed the technique by combining various steps from different minimally invasive approaches and incorporating new ideas. Patient characteristics are summarized in *Table 1*. Two patients were female (40.0%), with an average age of 52.8 years at the time of surgery (range, 21–57 years). Three patients had rib lesions located in the left high-position rib. Most patients initially presented to the department with upper extremity swelling or paraesthesia. Rib was removed in a nonpiecemeal fashion, with an average length of rib resected of 8.02±2.8 cm.

Perioperative period-related information

Perioperative period-related information is shown in *Table 2*. The median operation time was 124.2 minutes (range, 87–185 minutes). The thoracic drainage volume was 126 mL (range, 55–300 mL), and the thoracic drainage tube was removed between 1 and 3 days post-surgery. Postoperative hospital stays ranged from 2 to 5 days, with a mean duration of 2.8 days. No significant blood loss was recorded during any of the procedures, and there were no conversions to open surgery. No neurovascular injuries or postoperative bleeding complications were observed, and there were no mortalities. Follow-up examinations were scheduled for 2 weeks and 3 months after the procedure. No recurrence was reported during routine follow-ups

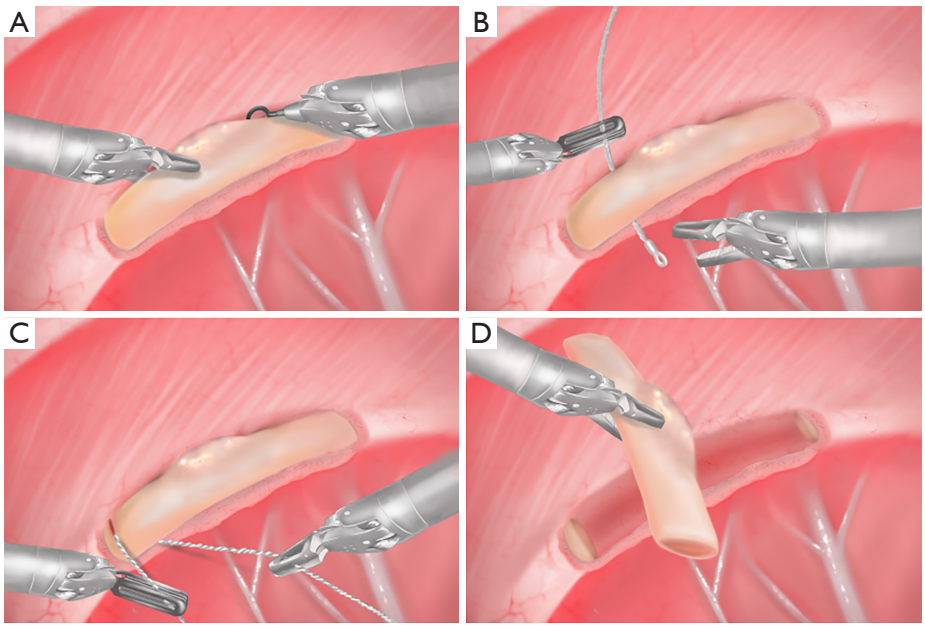
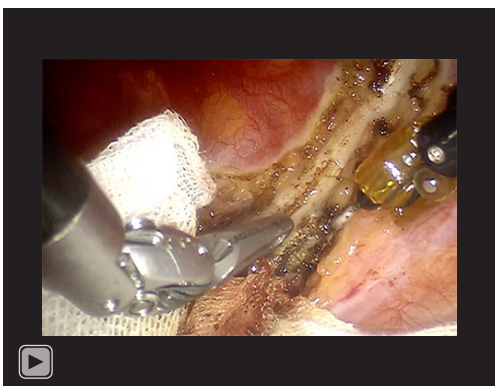


Figure 4 Diagrammatic sketch of robot-assisted high-position rib resection. (A) Open the pleura of the upper and lower edges of the rib along the high-position rib anterior rib joint. (B) Form a tunnel between the rib and the chest wall muscle. (C) Cut off the rib. (D) Remove the rib.



Video 1 Technological process of robot-assisted high-position rib resection.

12 months post-surgery.

Discussion

In recent years, traditional rib resection surgical methods typically require an incision longer than the rib lesions. This necessitates the removal of more chest wall muscles and soft tissue, leading to increased complications, significant postoperative pain, and reduced QoL (8). With advancements in minimally invasive thoracic surgery techniques, an increasing number of open chest surgeries have been replaced by minimally invasive procedures. Robot-assisted rib tumor resection has rarely been reported. Compared to traditional open surgery, the robotic surgery (Da Vinci Si system, Intuitive Surgical) offers the advantages of being minimally invasive, highly flexible, and providing a high-definition 3D field of vision, EndoWrist movement of the robotic instruments (9). The anatomical structures of the 1st and 2nd ribs present unique challenges during surgery, with the first rib featuring important structures such as the costal perichondrium, subclavian vein, anterior scalene muscle attachment, subclavian artery, T1 nerve root, middle scalene muscle attachment, and brachial plexus (10).

The choice of surgical approach is critical, and there is currently no consensus; the surgeon's preference and tumor characteristics remain the primary determining factors. Existing traditional approaches include the axillary and combined cervicothoracic routes (10). A well-designed surgical strategy and choice of approach are crucial. In cases where a patient's high-position rib tumor has an abundant blood supply, we perform preoperative arterial embolization to reduce peripheral blood supply and minimize intraoperative bleeding. Conventional TOS surgery can only remove approximately 2/3 of the first rib. However,

Table 1 The demographic and clinical characteristics

Patient	Sex	Age (years)	Side	Lesion location	Comorbidities	Symptoms	Type of tumor	Length of the rib resected (cm)
1	Female	26	Left	First rib	None	Unilateral swelling	Invasive osteoblastoma	6.0
2	Female	56	Right	Third rib	None	Upper extremity parasthesia	Fibro-osseous lesion	7.1
3	Male	57	Left	First–third ribs	None	Upper extremity weakness & parasthesia	Invasive fibroma	13.0
4	Male	51	Left	First rib	None	Upper extremity parasthesia	Epithelioid malignant tumor	7.0
5	Male	21	Right	First rib	None	None	Fibro-osseous lesion	7.0

Table 2 Perioperative period related information

Characteristics	Patient-1	Patient-2	Patient-3	Patient-4	Patient-5
Operation time (min)	107	87	185	113	129
Intraoperative blood loss (mL)	85	100	410	120	210
Thoracic drainage volume (mL)	55	90	300	80	105
Thoracic drainage tube time (days)	1	1	3	2	2
Pain VAS scores (24 h)	2.5	2.2	3.1	1.8	2.6
Postoperative hospital-stay (days)	2	2	5	2	3
Complications					
ARDS	0	0	0	0	0
Pneumonia	0	0	0	0	0
Wound infection	0	0	0	0	0
Pneumothorax	0	0	0	0	0
Postoperative-urinary retention	0	0	0	0	0
Outcome at 3-month follow-up	Complete relief of symptoms	Complete relief of symptoms	Complete relief of symptoms	Complete relief of symptoms	Complete relief of symptoms

VAS, Visual Analogue Scale; ARDS, acute respiratory distress syndrome.

using endoscopic rongeurs, rib cutters, and periosteal elevators, we are able to achieve complete resection from the costochondral junction to the transverse process. The average length of the resected rib with this method is 5.8±0.4 cm (9,11,12). With the Da Vinci robot, we innovatively employ a wire saw for rib tumor resection, resulting in a larger resection scope while reducing both operative time and trauma. Our average operation time was 124.2 minutes, which is similar to the average operation time of 113.2±55.3 minutes reported in several first rib resection studies (1). In contrast to conventional open surgery, robot-assisted high rib resection minimizes incisions and trauma within the chest, achieving better outcomes than other techniques. This aligns well with the current popular concept of accelerated rehabilitation surgery. Our intraoperative blood loss volume was 185 mL, and the postoperative thoracic drainage volume was 126 mL. Chest drains were removed after approximately 2–3 days. This compares favorably with other techniques. In our study, three out of five patients were discharged on postoperative day two, with an average hospital stay of 2.8 days for the entire cohort. When tumors involve multiple ribs, chest wall reconstruction is not required for the removal of the upper three ribs due to the occlusion

provided by the scapula and clavicle. In cases where more ribs need to be removed, chest wall defects are addressed through active chest wall reconstruction. In conclusion, robot-assisted high-position rib tumor resection provides a better vision of the operative field and reduced trauma, making it a safe, effective, and minimally invasive approach. All patients reported subjective improvement of symptoms.

It is important to acknowledge several major limitations in our study. Firstly, the study design is subject to the inherent limitations of any single-center retrospective analysis. Additionally, selection bias may be present due to the small sample size, as this is still an early experience with robotic-assisted thoracoscopic high-position costectomy. Although our follow-up indicated an improvement in patient symptoms, further validation through a multi-institutional prospective study is necessary to confirm the feasibility and safety of this method.

Conclusions

In conclusion, our data demonstrate that this technique is feasible and reliable. Robot-assisted high rib resection is applicable not only for treating TOS but also for addressing high-position rib tumors.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-983/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-983/dss

Peer Review File: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-983/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-983/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and the Harmonized Tripartite Guideline for Good Clinical Practice from the International Conference on Harmonization. This study was reviewed and approved by the Institutional Review Board of the Nanjing Jinling Hospital (No. 2011NZKY-030-01). The ethics committee waived the need for informed consent from those patients due to the retrospective nature of the study.

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