Thoracic outlet syndrome is a complex disease, presenting with multiple symptoms arising from a possible combination of subclavian vein, subclavian artery, or brachial plexus compression. Multiple techniques have been used for first rib resection, some of which are no longer used. Current common techniques use a supraclavicular, transaxillary, or infraclavicular approach, each of which has its limitations. Minimally invasive transthoracic approaches have been slow to gain popularity owing to limitations in current video-assisted thoracoscopic surgery instrumentation and technology. We describe a minimally invasive and successful transthoracic approach utilizing the da Vinci robotic system with excellent results and minimal morbidity. The described approach incorporates first rib resection and division of the scalene muscles with removal of the rib in a nonpiecemeal fashion, with clear visualization of the entire rib and the need for minimal dissection around the subclavian vessels and brachial plexus.

Operative Techniques in Thoracic and Cardiovascular Surgery 20:176-188 © 2015 Published by Elsevier Inc.

KEYWORDS Thoracic outlet syndrome, First rib resection, Minimally invasive, Da Vinci robot

Introduction

Surgical approaches to the management of thoracic outlet syndrome (TOS) are varied. The choice of approach may depend not only on the type of TOS but also on the surgeon’s training, the institutional preference and whether being performed by a thoracic or vascular surgeon, and what the indications for the procedure are namely venous, arterial, neurological TOS, or a combination of these.

Common approaches include the supraclavicular approach, transaxillary approach or less commonly, an infraclavicular approach, the latter often being combined with a supraclavicular approach.

Further considerations would include whether a cervical rib is present and also the rare instance of whether a vessel requires repair.

Minimally invasive transthoracic approaches to first rib resection were first described in 1999 by Dunsker et al., but it did not become popular, probably owing to difficulty in performing the procedure with the existing video-assisted thoracoscopic surgery (VATS) instrumentation. Utilizing the da Vinci robotic system (Intuitive Surgical Inc, Sunnyvale, CA) has facilitated dissection in the apex of the chest in a safe and ergonomically comfortable setting, allowing for resection of the first rib and mostly avoiding dissection around the subclavian vessels and brachial plexus and allowing for removal of the rib in a non-piecemeal fashion.

Preoperative Preparation

Other than those patients presenting acutely with vascular TOS, most patients undergo an EMG and nerve conduction velocity (NCV) study as outpatients. Some would be referred with a subclavian arterial ultrasound, which we tend to use as a screening rather than diagnostic study. We prefer to image the subclavian artery and vein either with a conventional angiogram and venogram, or magnetic resonance imaging of the subclavian artery and vein. Imaging of the vessels are done with the arm at rest and in an abducted “stress” position. Either a CXR or neck x-ray is performed to rule out a cervical rib. Should there be a suggestion of a true brachial plexus injury, damage or lesion, we obtain an MRI of the brachial plexus as well.

Operative Technique

Positioning

The patient is positioned in a lateral decubitus position following the administration of general anesthetic using a double lumen endotracheal tube. The bed is positioned about 45° away from the anesthesiologist to facilitate docking of the robot. The “down” arm is positioned adjacent to the patient’s head and the “up” arm (operative side) is positioned in a standard arm support.
Incidences
An initial incision is placed in line with the tip of the scapula halfway between the costal margin and the tip of the scapula. The camera is inserted—a 30° viewing camera—and the chest is inspected. A second incision is then made about 2 interspaces above the initial incision, again in line with the tip of the scapula. The camera is then moved to this incision and the initial incision will then be used to retract the lung inferiorly to visualize the apex of the chest—either by a paddle retractor fixed to the bed, or a curved ring forceps to grasp and reflect the lung inferiorly or the fourth robotic arm.

The anatomy is then closely inspected to determine positioning of the anterior and posterior ports for the 2 robotic arms (Fig. 1). We place them in approximately the fourth ICS (Fig. 2). It is important to position these 2 ports such that they are not too anterior or posterior and are relatively close to the camera port, while not impinging on the movement of the camera. If the ports are placed too anterior or posterior, we find it difficult to dissect the costal-sternal junction and costo-vertebral junction owing to the straight portion of the robotic arm being impeded by the curved chest wall as one approaches the apex of the chest. The correct rib is then confirmed by visualization and inspection of the anatomy.

Robotic Dissection
The robot is then docked, being brought over the head of the patient (Fig. 3). The hook cautery is placed in the right arm and the grasper (we use a long tip forceps) is placed in the left arm. The cautery is placed on a low setting, usually about 20. We use a 30° up-viewing camera.

The pleura on the undersurface of the rib is incised in the center of the rib. Dissection then proceeds medially to the sternum until we reach the cartilaginous joint between the first rib and the sternum (Fig. 4). The joint is clearly defined as the cartilage is soft and easily divided. Dissection then extends posteriorly towards the vertebral body following the curve of the rib. The pleura along the undersurface of the rib is mobilized to the superior and inferior edges of the rib.

Using the electrocautery the full thickness of the cartilaginous joints between the rib and sternum are divided (Fig. 5). Occasionally, a small portion of this joint superiorly is bone and would be divided later using a kerrison rongeur or can be dissected further medially until it again becomes cartilaginous, where it can be divided with the electrocautery.

All muscular and ligamentous attachments to the superior and inferior borders of the rib which are accessible at this stage are now divided until the underlying adventitial and adipose tissue is visualized (Fig. 6).

At this point in time, the robot is temporarily removed.

VATS Dissection
Given the inability of the robotic instruments to divide the rib, it is necessary to perform this portion by VATS. The undocking and redocking of the robot as well as the division of the rib is rapidly performed, adds an additional few minutes to the operative time but improves visualization and safety for the dissection. A 30° viewing camera is placed in the anterior port. Using an endoscopic kerrison rongeur through the posterior-most port or the camera port, the rib is divided posteriorly adjacent to the vertebral body (Fig. 7).

It may occasionally be necessary to switch the access between these ports while dividing the rib to limit the amount of torque placed on the intercostal nerves by the instrument. The full thickness of the rib is divided. We have on occasion used a drill to divide the rib posteriorly either fully or partially. The angle to divide the rib posteriorly can be difficult and we have utilized an angled kerrison to more easily complete this portion of the procedure. Any remaining bony portion of the joint between the first rib and the sternum, if present, is divided at this stage.

Reintroduction of the ROBOT
The robot is then redocked in the same fashion as previously. We initially use a 30° up-viewing camera. The left robotic arm uses a hook cautery (Fig. 8) and the right robotic arm uses a Maryland bipolar forceps. The left arm and hook are used to provide downward traction on the rib, while the Maryland bipolar forceps is used to divide the tissues.

The left arm hooks the superior surface of the rib and applies gentle downward traction, whereas the Maryland bipolar forceps is used to cauterize the remaining muscular and adventitial tissue attachments to the superior surface of the rib. We begin in the center of the rib where the space is widest and dissect medially and laterally as the space above the rib widens. Once the space is widened enough, it is important to completely free one end of the rib, allowing one to be able to turn the rib down as a “trapdoor.” If both ends of the rib are still attached to the surrounding muscle and tissues, it is difficult to reflect the rib down and further dissection becomes blind and hazardous.

As the dissection and division of the muscles off the superior surface of the rib progresses, visualization with a 30° upward viewing camera becomes limited and we switch the camera to a 30° downward viewing camera. This allows us to complete the dissection of all remaining structures off the superior border of the rib (Fig. 9). Some of the adventitial tissue adjacent to the artery and vein is divided by blunt dissection. There is often a ridge or protuberance on the rib adjacent to the vein which extends further than the width of the adjacent rib. This corresponds to attachment of the costoclavicular ligament to the first rib. This is necessarily divided.

Once the rib is freed it is removed from the chest.
We then use the robotic hook electrocautery or a pair of scissors to inspect and free the subclavian vein from what we often find to be a fibrous capsule around the vein. The vein is visualized and the surrounding fibrous tissue is identified. The capsule is grasped and bluntly dissected off the surrounding vein extending both medially and laterally along the vein. As the vein is separated off the capsule, the capsule is divided and the vein is freed.

The surgical field is then irrigated and inspected for hemostasis. We may apply a topical hemostatic agent if the field is not completely dry.
Fig. 1 Inspection of first rib anatomy prior to port placement for robot arms.
Fig. 2 Final location of port sites.
Fig. 3 Robot docked over patient’s head.
Fig. 4 Pleura and periosteum cleared from undersurface of first rib.
Fig. 5 Rib divided anteriorly at sternal-costal joint.
Cut edges of chest wall muscles, partially divided scalene muscles, pleura & underlying fat

Fig. 6 First rib cleared of all inferior attachments.
Fig. 7 Posterior division of first rib adjacent to vertebral body.
Fig. 8 Division of attachments to rib with Maryland bipolar forceps.
Subclavian vessels within pericostal fat bed

Rib flipped inferiorly exposing anterior surface

Fig. 9 Rib flipped inferiorly.
Fig. 10  Preoperative right subclavian angiogram—arm abducted.
Closure
Rib blocks are then applied and the wounds are closed. A small bore chest tube is placed through one of the port sites. The patient is extubated and transferred to the PACU.

Follow-Up
At 3 months postoperatively, we obtain repeat vascular imaging in both the neutral position and with the arms abducted (Figs. 10,11). Thereafter, patients would be followed up every 3 months for at least 1 year. No further imaging studies are obtained unless dictated by the clinical evaluation.

Conclusion
Robotic first rib resection is a safe and effective method for the treatment of TOS providing an alternate technique which avoids the limitations and shortcomings of the alternate approaches.

Reference