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Robot-Assisted Retroauricular Anterior Scalenectomy for Neurogenic Thoracic Outlet Syndrome

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Background: This study described the surgical technique of a robot-assisted retroauricular anterior scalenectomy and assessed clinical outcomes and complications for patients with neurogenic thoracic outlet syndrome (nTOS).

Methods: Between February 2014 and August 2016, 5 patients underwent robot-assisted retroauricular anterior scalenectomy using the da Vinci Xi system for nTOS. For clinical assessment, visual analog scale (VAS) symptom score, pinch and grip strength, and disabilities of arm, shoulder and hand (DASH) score were assessed to compare preoperative and postoperative outcomes. Postoperative complications were also reviewed.

Results: The VAS symptom, pinch and grip strength, and DASH scores improved 1 year after the operation. All patients were satisfied with the surgical scars. Temporary postoperative complications, which spontaneously resolved within 3 months, were noticed in 2 patients: one with vocal cord palsy and the other with upper brachial plexus palsy.

Conclusions: The robot-assisted retroauricular anterior scalenectomy for patients with nTOS seems feasible and safe, providing satisfactory cosmetic results.

Keywords: *Robotic surgical procedures, Thoracic outlet syndrome, Neurogenic*

Neurogenic thoracic outlet syndrome (nTOS) is the most frequent type of thoracic outlet syndrome, clinically manifesting neuropathic symptoms by compression of the brachial plexus along with the thoracic outlet. Surgical treatment is considered in patients with nTOS who exhibit substantial disability and are unresponsive to conservative management. Various surgical procedures have been introduced to release the brachial plexus in patients with nTOS. Among them, resection of the first rib,[1] anterior scalenectomy,[2-5] and combined procedures[6-10] have been most widely performed by surgeons. The overall proportion of symptom resolution after surgical treatment has been reported as around 70%, showing similar outcomes between solitary anterior scalenectomy and combined anterior scalenectomy with the first rib resection.[11,12] Those results imply that the primary pathognomonic structure in nTOS might be the anterior scalene muscle (ASM). Furthermore, some surgeons suggested reserving first rib resection in arterial or venous thoracic outlet syndrome with concerns of surgery-related complications, especially pneumothorax, injury to subclavian vessels, and injury to the brachial plexus.[3,13]

The supraclavicular approach has been used to perform the conventional anterior scalenectomy, offering the surgeon an excellent surgical working field. However, it inevitably makes a grossly noticeable scar in the supraclavicular area. Rochlin et al.[10] reported that 21% of excessive scar formation after conventional anterior scalenectomy induced discomfort along with the affected arm usage. This issue becomes apparent in Asians because they are more susceptible to forming hypertrophic scars in response to physical trauma than Caucasians.[14,15] We thought that the robot-assisted retroauricular anterior

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scalenectomy (rRAS) could lessen scar-related discomfort and improve postoperative clinical outcomes compared to the conventional method referenced from precedent robot-assisted surgeries of transaxillary or retroauricular thyroidectomy in Asian countries.[16,17]

At our facility, a robot-assisted anterior scalenectomy to decompress the brachial plexus has been performed via a retroauricular approach for intractable nTOS patients. Herein we describe the surgical technique of rRAS for nTOS and show clinical outcomes and complications after this procedure.

METHODS

The medical records and imaging studies were retrospectively reviewed after obtaining approval of the Institutional Review Board of Yonsei University Health System, Severance Hospital (No. 4-2002-1501). Informed consent was waived.

Between February 2014 and August 2016, 11 patients underwent surgical decompression for nTOS. The surgical indication was typical nTOS, intractable to well-conducted conservative management for at least 6 months. Inclusion criteria were (1) the robotic anterior scalenectomy and decompression of the brachial plexus using a retroauricular approach with the da Vinci Xi system and (2) follow-up data available for a minimum of 1 year after surgery. Exclusion criteria were (1) nTOS after clavicle fractures and multiple rib fractures (n=1), (2) history of other ipsilateral upper extremity diseases, including any other peripheral nerve compression (n=2), and (3) worker's compensation issue (n=1).

The nTOS was diagnosed based on the Society for Vascular Surgery's diagnostic criteria[18]: (1) pain and/or tenderness at the thoracic outlet, (2) distal neurogenic symptoms (often worse with arms overhead or dangling) with provocative maneuvers like Pseudo-Tinel sign, Wright test, and Roos test, (3) absence of other differential diagnosis correlated to patient's symptoms, and (4) relieving symptoms after a properly performed ASM test injection. Plain cervical radiographs, computed tomography angiography with arms overhead, and magnetic resonance imaging were taken to assess pathologic structures affecting the brachial plexus, such as bony abnormalities, fibromuscular abnormalities, or anatomic variants traversing the thoracic outlet. Electrodiagnostic testing was also conducted to rule out other peripheral compressive neuropathies related to the patient's symptoms. When the symptoms persisted for 6 months despite conservative treatments with patient education (altering posture and avoiding specific motion), medication, and physical therapy, surgical decompression of nTOS was considered.

Surgical Procedures

The patient was placed supine under general anesthesia, and the head was contralaterally rotated. The subplatysmal skin flaps were uplifted with the retroauricular skin incision. While supporting the skin flaps with a self-retaining retractor (Sangdosa Inc.), we carefully approached the sternocleidomastoid (SCM) muscle not to damage the great auricular nerve and external jugular vein. The surgical robot (da Vinci Xi robotic surgical system, Intuitive Surgical) was brought into the surgical field. With a face-down 30° dual-channel endoscopic arm centrally located, two 5-mm Maryland forceps (Intuitive Surgical) and one Harmonic curved shear (Intuitive Surgical) were mounted on three instrument arms. The robotic dissection was commenced at the SCM muscle's lateral border (Fig. 1A). The SCM muscle was elevated and retracted anteriorly upward to expose the omohyoid muscle and reveal the ASM's fat pad. While retracting the omohyoid muscle upward distally, the cervical fat pad was longitudinally split, medially preserving the internal jugular vein. The lateral fat pad flap was reflected laterally to expose the transverse cervical artery and vein crossing over the ASM and the phrenic nerve running along the anteromedial aspect of the ASM (Fig. 1B and C). The transverse cervical artery and vein were preserved in 4 patients and transected in 1 patient. The phrenic nerve was raised and made free from the ASM. Then, the ASM was carefully mobilized and incised close to its insertion on the first rib using the Harmonic curved shear. After the complete transection of the ASM, the subclavian artery and branches were visualized (Fig. 1D). The ASM was then dissected proximally and removed piece by piece to the level of its origin in the transverse processes. We also released the prevertebral fascia in cases that enveloped the brachial plexus tightly like a fibrotic band. After sufficient irrigation and bleeding control within the working space, a closed suction drain was interposed, and the skin was closed with a subcuticular running suture. We removed the drain when fluid collection was less than 20 mL/day.

Outcome Measures

Patients visited our outpatient clinic at 2 weeks, 8 weeks, 6 months, and 1 year from the operation, and annually thereafter. Clinical assessments were performed by an independent observer (HC) using the visual analog scale (VAS) symptom score (0 to 10), grip and pinch strength, 2-point discrimination, and disabilities of arm, shoulder

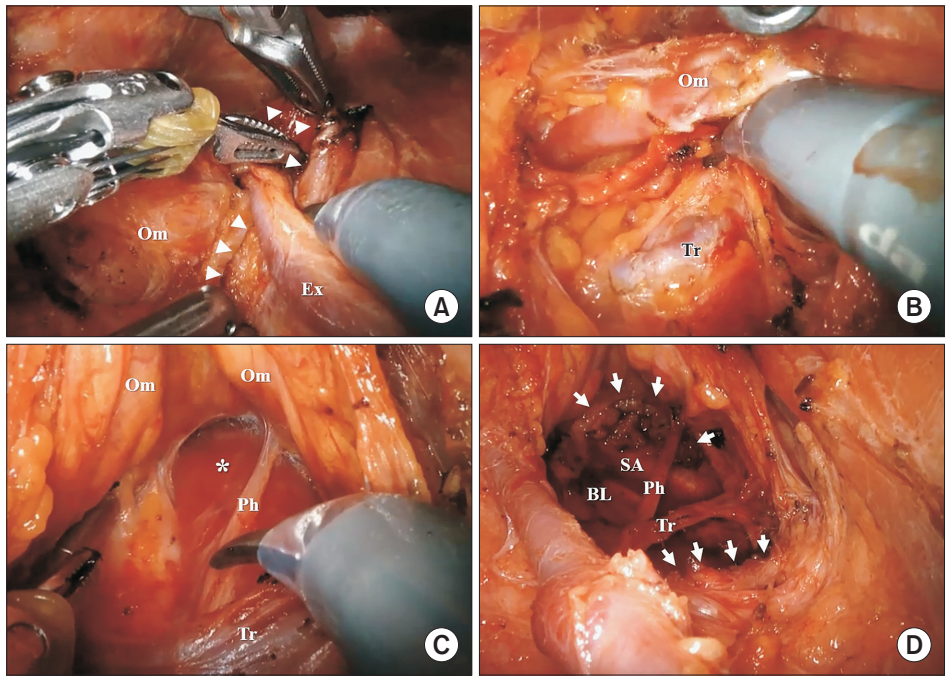

Fig. 1. Robot-assisted retroauricular anterior scalenectomy for a patient with neurogenic thoracic outlet syndrome on the left side. (A) After lifting the subplatysmal skin flap with the self-retaining retractor, the lateral border of the sternocleidomastoid muscle (arrowheads) was longitudinally dissected and elevated together with the external jugular vein (Ex) using an instrument arm. (B) After the dissection of the omohyoid muscle (Om), the transverse cervical artery (Tr) was noticed within the fat pad. (C) The omohyoid muscle was also elevated with an instrument arm, and the anterior scalene muscle (ASM, asterisk) was isolated to be excised. (D) After resection of the ASM at each distal and proximal part (arrows), the middle and lower trunks of the brachial plexus were observed. Ph: phrenic nerve, SA: subclavian artery, BL: brachial plexus lower trunk.

and hand (DASH) score. Pinch and grip strength were gauged using JAMAR hydraulic pinch and grip dynamometers (Asimov Engineering). DASH score (0 to 100) was assessed using a self-reported questionnaire involving 21 items that asked about difficulties with specific tasks, 5 about symptoms, and 4 about social function, work function, sleep, and confidence.[19] The higher scores of DASH represent the greater impairment of the involved extremity. There were no missing data.

RESULTS

Five female patients were included in this study, and their mean age was 41.2 years (range, 25–50 years). The mean duration of symptoms was 7.0 years (range, 3–10 years), and the follow-up duration averaged 16.8 months (range, 12–24 months). All of them had unilateral paresthesia and pain on C8/T1 dermatome. None had cervical ribs or prolonged transverse processes of the first ribs.

At the 1-year follow-up, the VAS symptom score improved from a mean of 7.7 (range, 6–8) to 1.0 (range, 0–3). The grip strength increased from a mean of 17.6 kg (range, 14–29 kg) to 28.5 kg (range, 23–35 kg) ($p < 0.001$), and pinch strength improved from a mean of 7.5 kg (range, 6–11 kg) to 10.0 kg (range, 8–13 kg). The mean DASH score decreased from 66.5 (range, 45.8–78.3) to 14.8 (range, 8.5–24.2).

All patients were satisfied with the postoperative scar because they were within the hairline posterior to the auricle. One patient presented with vocal cord palsy and another with upper cord (C5 and C6) palsy following the operation, and both recovered spontaneously within 3 months.

DISCUSSION

Our results show that all 5 patients with uncontrolled nTOS had improvement in neurogenic symptoms, grip and pinch strength, and DASH score after rRAS without severe postoperative scars and complications.

The clinical diagnosis of nTOS is based on the symptomatic manifestation of the brachial plexus compression along with the thoracic outlet. Patients with nTOS often complain of gradual symptoms that trigger pain, tingling, and numbness in the affected upper extremity, particularly during activity or in elevated arm positions,

which can gradually become disabling. The quality of life was reported to be similar between patients with nTOS and chronic heart failure.[10] Although nTOS is the most common subtype representing 95% of overall TOS, primarily affecting women aged 20–40 years,[8,20] the diagnosis is based mainly on clinical symptoms and subjective physical examinations, with no definitive diagnostic studies to confirm it.[20] A lack of structured diagnostic criteria makes diagnosing TOS (especially nTOS) difficult. Recently, the "Consortium for Outcomes Research and Education of TOS" and the "Society for Vascular Surgery" developed a set of diagnostic criteria for nTOS to assist practitioners in accurately diagnosing and treating patients with symptoms suggestive of nTOS.[18,21]

Although first rib resection alone,[1] anterior scalenectomy alone,[2-5] and the combinations of procedures[6-10] have been most widely described, long-term relief of symptoms after surgery has been reported similarly, approximately 70%. In Sander's case series, the clinical outcomes were identical between anterior scalenectomy alone and combined scalenectomy with the first rib resection.[11] In addition, some surgeons suggested reserving first rib resection in arterial and venous TOS with concerns of surgery-related complications, especially pneumothorax, injury to subclavian vessels, and injury to brachial plexus after first rib resection.[3,13] On the grounds, we performed rRAS using da Vinci Xi in patients with uncontrolled nTOS. All 5 patients had much improvement in their symptoms and functional outcomes, including grip and pinch strength and DASH score.

The da Vinci robotic system is a notable medical advancement and has effectively performed complex operative procedures without serious complications, with smaller hospitalization and better outcomes.[22,23] It has several advantages over conventional endoscopy; (1) multiarticulated instrument arms improve the surgeon's surgical performance; (2) a stable surgical view that is magnified and three-dimensional is provided at a distance from the patient; (3) downscaling of motion that translates surgeon's motion in a robot into a smaller one in actual surgical field enables surgeon's precise movements while reducing physiologic tremors.[16,22-27] Clinicians in different fields have attempted to perform robot-assisted surgical procedures. With this study, we believe the rRAS seems technically available and safe in patients with nTOS if conservative treatment fails.

Various complications have been reported after TOS surgery, including the recurrence of symptoms, complete or transient paralysis (phrenic nerve, brachial plexus, or long thoracic nerve), and vascular injury (subclavian artery or vein). Also, axillary artery thrombosis, hemothorax, pneumothorax, and chylothorax could develop postoperatively. Rarely, the permanent injury of the brachial plexus causing serious sequelae such as paresthesia, motor and sensory deficits, autonomic dysfunction, and at times even death has been reported.[13,28-30] In 2017, Rinehardt et al.[29] reported that only 0.3% of peripheral nerve injuries and 1.4% of spontaneous bleeding required transfusion. Among 1,431 patients who underwent surgical decompression of the brachial plexus using the American College of Surgeons National Surgical Quality Improvement Program database, 8.6% needed reoperations or hospital readmission within 30 days after operation. We did not have severe complications in our case series like those mentioned above. However, 2 of the 5 patients showed temporary paralysis of the vocal cords or upper trunk of the brachial plexus (C5 and 6). We believe these complications might be from a lack of tactile and force feedback to the surgeon, which has been considered a significant drawback to robotic surgery.[30] So, surgeons should be aware of it, especially when handling the functioning nerve system.

This study has several limitations. First, the number of patients was small, and the follow-up period was short without offering meaningful statistical data. As the number of patients indicated for this procedure is limited, a more extended study period is necessary to enroll a sufficient number of patients. Second, it was a retrospective study in one institution. A prospective comparative study between the robotic and the supraclavicular-approached anterior scalenectomy would be necessary to elucidate the role of robot-assisted surgery for nTOS patients.

In conclusion, the robot-assisted retroauricular anterior scalenectomy for patients with nTOS seems feasible and safe, with satisfactory cosmetic results.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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