Original Article

Initial results of uniportal and robot-assisted subxiphoid thymectomy

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Background: We previously reported on subxiphoid uniportal thymectomy (SUT) and subxiphoid robotic thymectomy (SRT). This descriptive study aimed to evaluate the feasibility and safety of both SUT and SRT techniques.

Methods: Between March 2011 and December 2022, 268 patients underwent subxiphoid thymectomy. In cases demonstrating no evidence of invasion into other organs, SUT was selected due to its minimal invasiveness. In cases where the tumor was in contact with the innominate vein or those with suspected invasion into other organs, SRT with additional intercostal ports was selected due to the enhanced operability provided by the robotic system. The patients' backgrounds and the perioperative outcomes of each technique were evaluated.

Results: SUT was performed in 207 patients, while SRT was performed in 61 patients. In the SUT group, 15 patients required an additional intercostal port, and 2 patients required a median sternotomy; the SUT completion rate was 91.78%. The median operative time was 117.00 [interquartile range (IQR), 88.00–148.50] min, with a median blood loss of 5.00 (IQR, 1.00–5.00) mL. Combined resection was performed in 11 (5.31%) patients, and postoperative complications were observed in 4 patients (1.93%). None of the patients in the SRT group required median sternotomy. The median operative time was 203.00 (IQR, 158.00–278.00) min, with a median blood loss of 5.00 (IQR, 5.00–22.00) mL. Combined resection was performed in 14 patients (22.95%), and postoperative complications were observed in 5 patients (8.20%). No mortalities occurred in either group.

Conclusions: Subxiphoid thymectomy is a safe and feasible technique for both early and advanced stages of the disease requiring complex surgical procedures.

Keywords: Subxiphoid approach; thymectomy; robot-assisted thoracoscopic surgery (RATS); video-assisted thoracoscopic surgery (VATS)

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Introduction

Thymectomy is a crucial factor influencing the prognosis of thymic epithelial tumors (1,2). It proves effective in enhancing the quantitative myasthenia gravis score and reducing steroid dosage in patients with non-thymomatous myasthenia gravis (3). Traditional sternotomy, once a prevalent method for thymectomy and extended thymectomy, has given way to advanced techniques, such as video-assisted thoracoscopic surgery (VATS) and

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robot-assisted thoracoscopic surgery (RATS), owing to advancements in medical devices and surgical approaches.

In 2012, we reported a case of subxiphoid uniportal thymectomy (SUT) (4). This innovative surgical approach involves the insertion of a camera and surgical instruments through a single subxiphoid incision along the midline of the body. The surgery was performed with an operative view similar to that of a sternotomy. The advantages of this surgical approach include easy visual confirmation of the bilateral phrenic nerves, good operative view of the innominate vein and neck region, and superior esthetic outcomes. Importantly, the SUT did not result in damage to the intercostal nerves because the surgery was not performed through the intercostal spaces. The prevention of post-thoracotomy syndrome, a chronic pain condition often associated with lateral surgical approaches, is extremely beneficial (5). In 2015, we reported on subxiphoid robotic thymectomy (SRT), a procedure in which robotic arms are inserted bilaterally through the intercostal spaces in addition to the subxiphoid approach (6). SRT offers distinct advantages by allowing surgeons to use articulated forceps under a three-dimensional, clear, magnified operative view and by enabling surgical manipulations not achievable with manually conducted conventional VATS, such as vascular anastomosis (7).

This study was not aimed to examine SUT's superiority over SRT but to evaluate the safety and feasibility of the subxiphoid approach. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-914/rc).

Highlight box

Key findings
- Subxiphoid thymectomy is a surgical technique that can be safely employed for more complex procedures, demonstrating a low complication rate and no mortality. This approach is effective for both video-assisted thoracoscopic surgery (VATS) and robot-assisted thoracoscopic surgery (RATS).

What is known and what is new?
- Few articles have been published showing the results of subxiphoid approach thymectomy.
- This study, highlights its safety and feasibility, as demonstrated by the institution that developed the subxiphoid approach to thymectomy.

What is the implication, and what should change now?
- Although the lateral approach is often selected for thymectomy in both VATS and RATS, the subxiphoid approach can be used for more complex procedures and may become the standard surgical technique in the future.

Methods

Study design and patients

This descriptive study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and approved by the Fujita Health University Ethics Committee on August 10, 2021 (approval No. HM20-566). Written informed consent was obtained from all patients.

Between March 2011 and December 2022, 305 patients underwent thymectomy at Fujita Health University Hospital or Fujita Health University Okazaki Medical Center. Among them, 268 who underwent surgery using the subxiphoid approach were included in this study. The surgical approach selection was guided by specific criteria. The SUT was selected for patients with tumors located caudal to the innominate vein and not suspected of invading other organs. Meanwhile, the SRT was selected for patients with tumors attached to the innominate vein, suspected of invading other organs, and tumors attached to the phrenic nerve.

SUTs were initiated in March 2011, and SRTs in February 2014. Patients with myasthenia gravis underwent extended thymectomies, whereas those without myasthenia gravis underwent standard thymectomies. SUT procedures were performed by 11 surgeons, whereas SRTs were performed by three surgeons. On the day after the surgery, patients were prescribed oral loxoprofen at a dose of 60 mg three times daily, with continuation based on patient requests.

Variables and assessments

The evaluation variables included age, sex, frequency of myasthenia gravis complications, tumor diameter, body mass index (BMI), performance status, procedure performed, operative time, blood loss, presence of combined resection, duration of drainage, postoperative hospital stay, postoperative complications, number of analgesic tablets taken, duration of analgesic treatment, the pathological diagnosis of anterior mediastinal tumors, World Health Organization thymoma classification (8), and Masaoka classification (9). Complications with a Clavien-Dindo classification of grade ≥3, along with the number of patients requiring conversion (conversion was defined

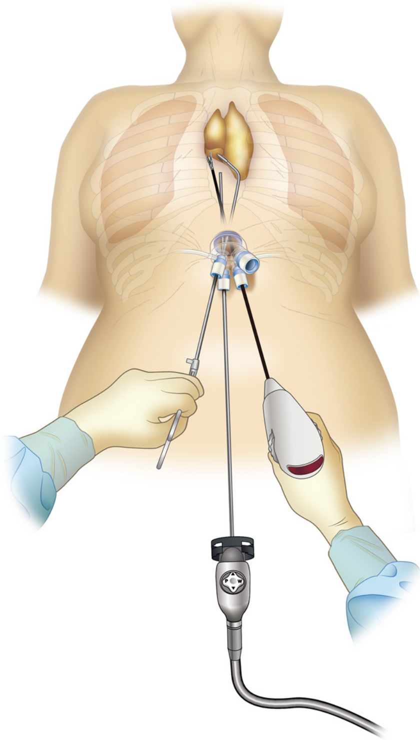
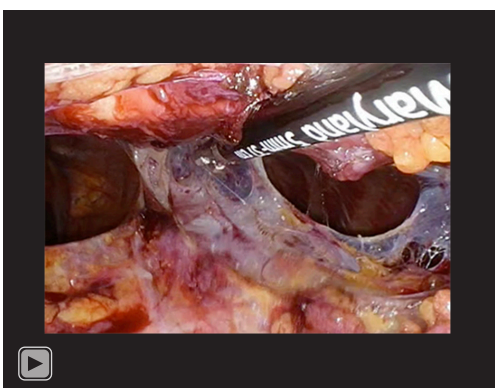


Figure 1 Subxiphoid uniportal thymectomy.



Video 1 Surgical video of subxiphoid uniportal thymectomy. The bilateral phrenic nerves are clearly visible.

as cases requiring an additional intercostal port or median sternotomy), were recorded.

Surgical techniques

SUT

The surgical procedure was performed under general anesthesia. The patient was placed in the supine position with their legs open. Endotracheal intubation was performed using a single-lumen tube. In cases where lung resection or challenging visual confirmation of the phrenic nerve was expected, one-lung ventilation was performed using a double-lumen endotracheal tube. The surgeon stood between the patient's legs to perform the surgery, and the assistant stood on the patient's right side to operate the camera. The surgeon made a 3-cm horizontal incision 1 cm caudal to the xiphoid process. In patients with tumors measuring >5 cm, vertical incisions were made to allow wound extension during tumor removal. The surgeon resected the linea alba through the xiphoid process. Fingers were inserted into the back of the sternum to detach the thymus from the sternum. The linea alba resected from the xiphoid process was resected caudally at 1.5 cm. A space large enough to insert a wound retractor was created between the peritoneum and rectus abdominis muscle. An Alnote® LapSingle (Sejong Medical Co., Ltd., Paju, Korea) access port was used. The device was equipped with four ports that enabled carbon dioxide insufflation. An AirSeal® system (CONMED, Largo, FL, USA) is used for carbon dioxide insufflation, with sufflation performed at 8 mmHg. A LigaSure™ Maryland Jaw (Covidien, Mansfield, MA, USA) was used to detach the thymus from the sternum. The mediastinal pleura was bilaterally incised to open the thoracic cavity. ThoraGate™ tissue grasping forceps (Geister, Tuttlingen, Germany), angled at 50°, were used to grasp, retract, and detach the thymus from the pericardium toward the neck region, while simultaneously confirming the visibility of both phrenic nerves. On the cranial side of the innominate vein, the upper pole of the thymus was grasped with slightly curved ThoraGate™ tissue grasping forceps and the thymus was detached from each structure to expose the right brachiocephalic vein, brachiocephalic artery, and trachea. Finally, the thymic vein was resected, and the thymus was resected en block. The resected thymus was inserted into a bag and removed through the subxiphoid incision (*Figure 1*, *Video 1*).

SRT

The patient was positioned and anesthetized following the same procedure as in the SUT. The da Vinci Si or Xi Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) robotic surgical system was used. A 3-cm vertical incision was made 1 cm caudal to the xiphoid process. Note® LapSingle was then inserted into the subxiphoid incision. The thymus was detached from the sternum using LigaSure™ Maryland Jaw, followed by a bilateral

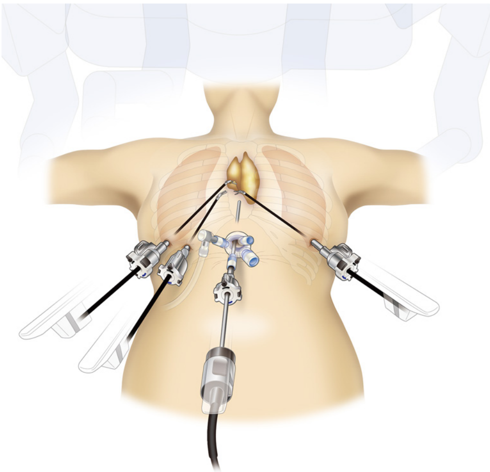


Figure 2 Subxiphoid robotic thymectomy.

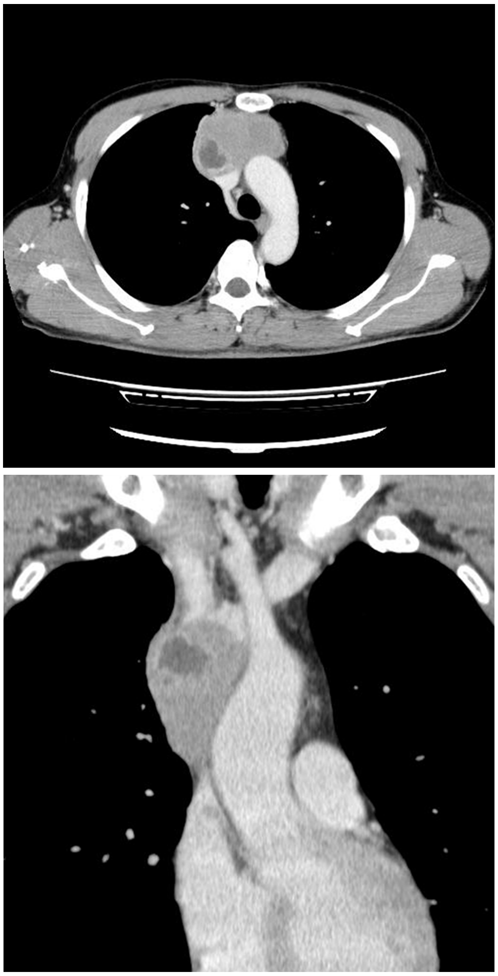
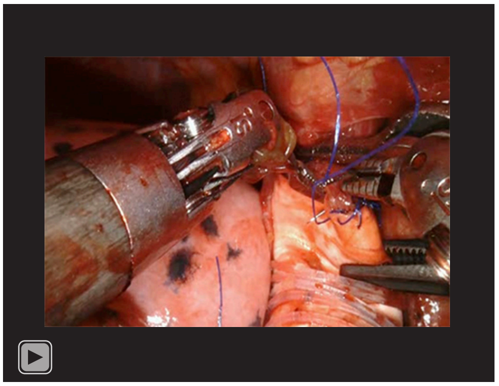


Figure 3 SRT with superior vena cava replacement. SRT, subxiphoid robotic thymectomy.

incision of the mediastinal pleura. Moreover, 8-mm ports were inserted in the right sixth intercostal space along the anterior and middle axillary lines, and an additional 8-mm port in the left sixth intercostal space along the anterior axillary line. The subxiphoid approach makes it difficult to confirm the site at which the phrenic nerve connects to the diaphragm of the left pericardium. Thus, the course of the left phrenic nerve was confirmed. To prevent intraoperative injury to the phrenic nerve, a camera was inserted through the port in the left lateral thoracic region before docking the da Vinci Xi Surgical System. The anterior region 1 cm from the phrenic nerve was marked with a dye, and the course of the left phrenic nerve was confirmed. The camera port was inserted through an 8-mm port of the Alnote® LapSingle, and the da Vinci Xi Surgical System was docked (*Figure 2*). Cadière forceps were affixed to the first arm for retraction, fenestrated bipolar forceps were attached to the second arm for the operator's left hand, a camera was mounted to the third arm, and a SynchroSeal was attached to the fourth arm of the operator's right hand. The assistant performed suction and provided gauze through the Alnote® LapSingle under the xiphoid process. When a camera is inserted into the right lateral thoracic region, the surgical manipulation of the area from the right lower pole of the thymus to the brachiocephalic vein becomes easier. Thus, to observe the right phrenic nerve and diaphragm, surgery was performed with fenestrated bipolar forceps inserted into the port in the right sixth intercostal space along the middle axillary line; a camera was inserted from the port in the right sixth intercostal space along the anterior axillary line; a SynchroSeal, which was used with the operator's right hand, was inserted from the subxiphoid port; and Cadière forceps, used for retraction, were inserted from the port in the left lateral thoracic region. In patients who underwent combined resection of the superior vena cava or artificial vessel replacement, the right sixth intercostal space anterior axillary line was incised by 2 cm, and an Alnote® LapSingle was inserted to clamp the right auricle and superior vena cava (*Figure 3*, *Video 2*).

Statistical analysis

Continuous variables are presented as medians and interquartile ranges (IQRs), while categorical variables are presented as frequencies and proportions. Statistical analyses were performed by comparing the two groups of patients: those who underwent SUT (SUT group) and those



Video 2 Subxiphoid robotic thymectomy with superior vena cava replacement. Using vascular grafts with an 8 mm Gore-Tex ring, an innominate vein-right atrial appendage bypass was performed. After resecting the thymus and anterior mediastinal tumor *en bloc* with the superior vena cava, pericardium, and right lung, the right brachiocephalic vein was replaced with a 10 mm Gore-Tex vascular graft.

who underwent SRT (SRT group). Continuous variables were analyzed using the Mann-Whitney *U* test, whereas categorical variables were analyzed using Fisher's exact test. Statistical analyses were performed using EZR (Easy R, Jichi Medical University Saitama Medical Center, version 4.3.1) (10). P values <0.05 were considered statistically significant. Because the criteria for SUT and SRT were determined by tumor location and local progression, it was difficult to match the patients' background factors. Therefore, the SUT and SRT groups were not compared using propensity score matching.

Results

Results of all patients

The median age of the entire patient cohort comprising 268 patients was 57 (IQR, 47–67) years. Among them, 122 were male and 146 were female. Extended thymectomy was performed in 29 patients with myasthenia gravis, 207 with SUT, and 61 with SRT. The median operation time was 134.50 (IQR, 94.00–176.00) min, with a median blood loss of 5.00 (IQR, 1.00–5.00) g. Conversion was required in 17 cases (6.34%), and postoperative complications occurred in 10 patients (3.73%). The median drainage period was 1.00 (IQR, 1.00–1.00) day, and the median length of postoperative hospital stay was 3.00 (IQR, 3.00–5.00) days. No mortality occurred. The detailed characteristics and perioperative data of all patients are shown in *Table 1*.

Table 1 Patient background and perioperative results for all patients (n=268)

Variables	Value
Age (years)	57 [47–67]
Sex	
Male	122 (45.52)
Female	146 (54.48)
Myasthenia gravis	
+	29 (10.82)
–	239 (89.18)
Tumor size (cm)	3.45 [2.20–5.20]
Surgical approach	
SUT	207 (77.24)
SRT	61 (22.76)
Surgical procedure	
Thymectomy	239 (89.18)
Extended thymectomy	29 (10.82)
Operation time (min)	134.50 [94.00–176.00]
Blood loss (g)	5.00 [1.00–5.00]
Combined resection	25 (9.33)
Conversion	17 (6.34)
Drainage period (days)	1.00 [1.00–1.00]
Postoperative hospital stay (days)	3.00 [3.00–5.00]
Postoperative complication	10 (3.73)
Number of analgesic tablets	42 [21–56.25]
Duration of analgesic medication (days)	14 [7–18.25]

Categorical variables are reported as n (%), while continuous variables are reported as median [IQR]. SUT, subxiphoid uniportal thymectomy; SRT, subxiphoid robotic thymectomy; IQR, interquartile range.

SUT group

The median age of patients was 57 (IQR, 47–67) years, with 95 men and 112 women. Anterior mediastinal tumors were identified in 194 patients with a median tumor size of 3.10 (IQR, 1.80–4.50) cm. Myasthenia gravis was observed in 23 patients (11.11%). Thymectomies and extended

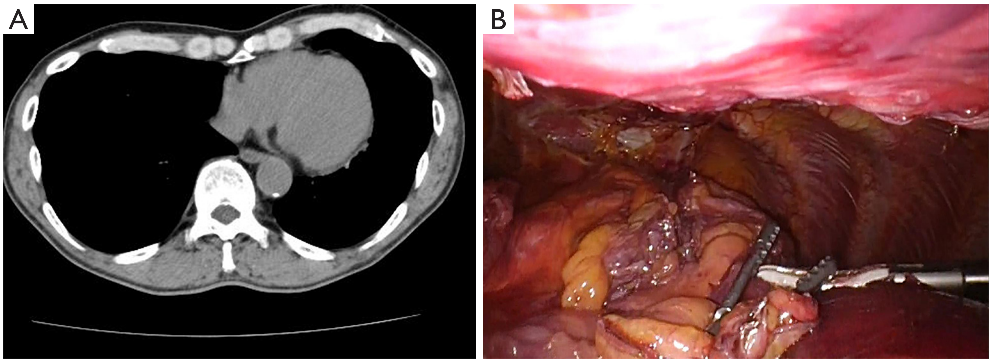


Figure 4 We performed a SUT. However, due to the patient's funnel chest, which obstructed full visualization of the thymus gland, we placed a 5 mm port in the left fifth intercostal space to complete the surgery. (A) Computed tomography image showing the patient's funnel chest; (B) sternal deformity obstructing an adequate operative view. SUT, subxiphoid uniportal thymectomy.

thymectomies were performed in 184 and 23 patients, respectively. The median operation time was 117.00 (IQR, 88.00–148.50) min, and the median amount of blood loss was 5.00 (IQR, 1.00–5.00) g. Combined resection was required in 11 cases (5.31%): nine for the lungs, two for the pericardium, and one for the innominate vein. All 17 patients who required conversion underwent SUT, and the SUT completion rate was 91.78%. A port was placed in the intercostal space of 15 patients. Overall, four cases required hemostatic manipulation, four faced challenges with poor visualization, three involved suturing the pericardium, two encountered difficulties due to funnel chest deformity (*Figure 4*), one involved dissection of the innominate vein, and one faced challenges with tumor dissection. In two patients, VATS was converted to sternotomy. In one patient, the conversion was required because of heart injury, whereas in the other patient, it was prompted by suspicion of invasion of the great vessels. The median drainage period was 1.00 (IQR, 1.00–1.00) day, and the median length of postoperative hospital stay was 3.00 (IQR, 3.00–4.00) days. Postoperative complications were observed in 5 patients (2.42%): postoperative hemorrhage in two cases, empyema in one case, chylothorax in one case, and phrenic nerve paralysis in one case. Of the patients with postoperative hemorrhage, one underwent endoscopic hemostasis, and the other underwent hemostasis through sternotomy. Patients with diaphragmatic nerve palsy underwent diaphragmatic suture placement. The pathological diagnoses included thymoma in 70 patients (36.08%), other cancers in 3 patients (1.55%), and benign disease in 121 patients (62.37%).

SRT group

The median age was 56 (IQR, 48–68) years; there were 27 men and 34 women. The median tumor size was 5.00 (IQR, 3.30–7.00) cm. Myasthenia gravis was observed in 6 patients (9.84%). Thymectomy was performed in 55 patients, and extended thymectomy was performed in 6 patients. The median operation time was 203.00 (IQR, 158.00–278.00) min, and the median amount of blood loss was 5.00 (IQR, 5.00–22.00) g. Combined resection was required in 14 cases (22.95%): seven for the lungs, seven for the pericardium, nine for the innominate vein, two for the phrenic nerve, and one for the superior vena cava. Among the patients who underwent combined resection of the innominate vein, one underwent artificial vessel replacement, and the other underwent innominate vein-right auricle bypass surgery. The patient who underwent combined resection of the superior vena cava underwent right brachiocephalic vein-superior vena cava bypass surgery and innominate vein-right auricle bypass surgery. None of the patients underwent a conversion to sternotomy. The median drainage period was 1 (IQR, 1–1) day, and the median length of postoperative hospital stay was 4 (IQR, 3–7) days. Postoperative complications were observed in 5 patients (8.20%): postoperative hemorrhage in one case, respiratory failure in one case, chylothorax in one case, phrenic nerve paralysis in one case, and recurrent nerve palsy in one case. The patient who developed chylothorax underwent thoracic duct ligation using the lateral approach. The postoperative pathological diagnoses consisted of thymoma in 41 patients (67.21%), other cancers in 6 patients (9.84%), and benign diseases in 14 patients (22.95%).

Table 2 Patient characteristics

Variables	SUT (n=207)	SRT (n=61)	P value
Age (years)	57 [47–67]	56 [48–68]	0.69
Sex			0.88
Male	95 (45.89)	27 (44.26)	
Female	112 (54.11)	34 (55.74)	
Myasthenia gravis			>0.99
+	23 (11.11)	6 (9.84)	
Tumor size (cm)	3.10 [1.80–4.50]	5.00 [3.30–7.00]	<0.001
BMI (kg/m^2)	22.49 [20.56–25.41]	22.42 [19.44–25.91]	0.31
Performance status			0.03
0	206 (99.52)	58 (95.08)	
1	1 (0.48)	2 (3.28)	
3	0	1 (1.64)	

Categorical variables are reported as n (%), while continuous variables are reported as median [IQR]. SUT, subxiphoid uniportal thymectomy; SRT, subxiphoid robotic thymectomy; BMI, body mass index; IQR, interquartile range.

Table 3 Perioperative data

Variables	SUT (n=207)	SRT (n=61)	P value
Surgical procedure			>0.99
Thymectomy	184 (88.89)	55 (90.16)	
Extended thymectomy	23 (11.11)	6 (9.84)	
Operation time (min)	117.00 [88.00–148.50]	203.00 [158.00–278.00]	<0.001
Blood loss (g)	5.00 [1.00–5.00]	5.00 [5.00–22.00]	<0.001
Combined resection	11 (5.31)	14 (22.95)	<0.001
Lung	9	7	–
Pericardium	2	7	–
Innominate vein	1	9	–
Phrenic nerve	0	2	–
Superior vena cava	0	1	–

Categorical variables are reported as n (%) or n, while continuous variables are reported as median [IQR]. SUT, subxiphoid uniportal thymectomy; SRT, subxiphoid robotic thymectomy; IQR, interquartile range.

The SUT group had a shorter operative time (117.00 *vs.* 203.00 days, P<0.001), less blood loss (5.00 *vs.* 5.00 g, P<0.001), and shorter postoperative hospital stay (3 *vs.* 4 days, P<0.001) than the SRT group. Additionally, the SUT group used fewer analgesic tablets than the SRT group (36 *vs.* 57 tablets, P<0.001) and used analgesics for a shorter duration (12 *vs.* 19 days, P<0.001). Conversely, SRT resulted in larger tumor diameters than SUT (3.10 *vs.* 5.00 cm, P<0.001) and required more combined resections (P<0.001). No mortality was observed in both groups. Details of the perioperative results and pathology of the SUT and SRT groups are presented in *Tables 2-5*.

Table 4 Postoperative data

Variables	SUT (n=207)	SRT (n=61)	P value
Drainage period (days)	1 [1–1]	1 [1–1]	0.16
Postoperative hospital stay (days)	3 [3–4]	4 [3–7]	<0.001
Postoperative complication	5 (2.42)	5 (8.20)	0.051
Postoperative hemorrhage	2	1	
Phrenic nerve paralysis	1	1	
Chylothorax	1	1	
Empyema	1	0	
Recurrent nerve paralysis	0	1	
Respiratory failure	0	1	
Number of analgesic tablets	36 [21–51]	57 [36–98]	<0.001
Duration of analgesic medication (days)	12 [7–17]	19 [12–42]	<0.001

Categorical variables are reported as n (%) or n, while continuous variables are reported as median [IQR]. SUT, subxiphoid uniportal thymectomy; SRT, subxiphoid robotic thymectomy; IQR, interquartile range.

Table 5 Pathologic diagnosis

Variables	SUT (n=194)	SRT (n=61)	P value
Thymoma	70 (36.08)	41 (67.21)	–
WHO classification			0.38
A	5	3	
AB	20	6	
B1	19	10	
B2	19	12	
B3	2	4	
C	4	4	
Micronodular thymoma	0	1	
Sclerosing thymoma	1	1	
Masaoka classification			0.01
I	42	16	
II	26	19	
III	1	5	
IV	0	1	
Malignant lymphoma	2 (1.03)	3 (4.92)	–
Seminoma	0	2 (3.28)	–
Carcinoid tumor	1 (0.52)	0	–
Malignant melanoma	0	1 (1.64)	–
Benign disease	121 (62.37)	14 (22.95)	–

Categorical variables are reported as n (%) or n. SUT, subxiphoid uniportal thymectomy; SRT, subxiphoid robotic thymectomy; WHO, World Health Organization.

Discussion

In this study, the initial results of VATS and RATS were examined using a subxiphoid approach. As neither serious complications nor mortality were observed in either group, the subxiphoid approach was considered a safe and feasible technique for surgical procedures, including those with high technical difficulty.

Thoracic surgeons commonly employ the lateral approach in various operations, making it a frequent choice for thymectomy performed in both VATS and RATS (11,12). However, the disadvantages of the lateral approach include difficulty in locating the superior pole of the thymus or contralateral phrenic nerve and challenges in observing the entire innominate vein when tumors are in close proximity. The subxiphoid approach, in which a camera is inserted from the midline of the body, enables surgery to be performed with an operative view similar to that of sternotomy. Thus, surgeons can easily confirm the presence of both the phrenic nerves and observe the entire innominate vein. In surgical approaches through the intercostal space, intercostal nerve injury is inevitable, and post-thoracotomy syndrome, which is characterized by chronic pain, occurs in 30–40% of cases (13). Performing SUT is extremely beneficial because it is not performed through any intercostal space; therefore, it does not cause post-thoracotomy syndrome.

Although SUT offers significant benefits by avoiding intercostal spaces and the associated post-thoracotomy syndrome, they introduce challenges due to interference among the instruments inserted through a single incision. Efficient SUT execution requires familiarity with the dedicated instruments and specific surgical manipulations. Four cases, in which one additional port was added to the lateral thoracic region due to a poor visual field, ranged from the start of SUT to the 25th case. Among the subsequent patients, no additional port was required because of poor operative view. As surgeons and assistants become more accustomed to the SUT approach, the number of patients requiring conversion can be reduced. Surgeons new to performing SUT need to gain experience in performing surgery in 24–38 cases before becoming proficient in the surgical approach (14,15). The operation time of 114 min and amount of blood loss of 4.0 g in SUT performed is comparable with the previously reported operation time of 65.0–200.0 min and amount of blood loss of 23.1–138.8 g in thymectomy performed through the lateral approach (16). A slightly long learning curve is a disadvantage; however, reducing the number of cases required to become proficient with SUT may be possible if subxiphoid dual-port thymectomy, in which an additional port is placed in the right intercostal space (17), is performed immediately after the introduction of the subxiphoid approach. Insertion of a port into the right lateral thoracic region is safe when added to the lateral thoracic region. If a port is added to the left lateral thoracic region, surgeons may damage the heart during port insertion because of the short distance between the left lateral chest wall and the heart.

The advantage of SRT is that it enables surgeons to use articulated forceps under a three-dimensional, clear, and magnified operative view and perform surgical manipulations that are difficult to execute in conventional manual VATS, such as vascular anastomosis. Previous studies comparing RATS using the lateral thoracic and subxiphoid approaches reported similar or shorter postoperative hospital stays, less postoperative pain, and more cases of combined resection of innominate veins than the lateral thoracic approach (18-20). Similarly, the innominate veins are the most commonly resected organs. When the lateral approach is used for tumors located near the innominate vein, the tumors obstruct the view of the entire innominate vein; thus, the vein cannot be taped in cases of hemorrhage. In contrast, the midbody view of the subxiphoid approach allows observation of the proximal and distal sides of the innominate vein, even in the presence of a tumor, allowing taping and clamping of the innominate vein in cases of bleeding. Based on these advantages, SRT was used to replace the artificial vessel of the superior vena cava and innominate vein (7).

No patients in the SRT group required conversion. This seemed to be attributable to the good operability of the SRT, which facilitates suturing such that minor hemorrhages can be treated. One of the disadvantages of robot-assisted surgery is the lack of proof that patient benefits are commensurate with its high cost; RATS has higher costs than VATS. However, SRT has made it possible to perform difficult procedures, such as artificial vessel replacement, in a minimally invasive manner, which is not possible with conventional VATS. We believe that this benefits the patient and is worth the cost of the treatment. One disadvantage of SRT is that intercostal neuropathy can occur due to the insertion of ports into the sixth intercostal space in both lateral thoracic regions. Many analgesic tablets were consumed by the SRT group, and they were treated with oral analgesics for a long duration. In the SRT, the robotic arms were inserted through the sixth intercostal space on each side, facilitating better maneuverability for resecting the inferior pole of the thymus. Additionally, there are reports of the combined use of subxiphoid and subcostal arch approaches (21). This combined approach effectively avoids intercostal neuropathy. Thus, minimally invasive SUT was selected for patients undergoing surgery with low technical difficulty and SRT for patients undergoing surgery with high technical difficulty.

The SRT group had a longer operative time and considerable blood loss. This was attributed to the fact that the SRT group included more patients with large tumors that were difficult to operate on and who underwent combined resection than the SUT group. In one patient who underwent artificial vessel replacement, the amount of blood loss increased because the arm struck and damaged another vascular anastomotic site outside the visual field during vascular anastomosis. As the visual field is small in robot-assisted surgery, caution should be exercised to avoid damage outside the visual field. Complication rates of 3.7–20.0% and 5.6–19.0% have been reported for VATS and RATS through the lateral approach, respectively (22,23). The complication rates for SUT and SRT were 2.42% and 8.20%, respectively, which are comparable to those reported previously. The rate of SRT was slightly higher, which we attribute to the fact that SRT is indicated for surgeries with high technical difficulty.

One limitation of this study is that it was a single-center retrospective study. The surgeons included both residents and specialists, and the surgical techniques used were inconsistent.

Conclusions

This study demonstrated that subxiphoid thymectomy is safe and feasible for almost all anterior mediastinal tumor resections and thymectomies. We believe that the subxiphoid thymectomy approach is less invasive compared to the lateral intercostal approach currently used in many institutions and has the potential to become the standard approach for thymectomy, even in cases where median sternotomy was previously considered necessary. Consequently, this approach may establish itself as the preferred approach for thymectomy in the future. Future studies should examine the long-term prognosis of patients who undergo surgery using a subxiphoid approach.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work and ensure that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by the Fujita Health University Ethics Committee on August 10, 2021 (approval No. HM20-566). Written informed consent was obtained from all patients.

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