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ORIGINAL ARTICLE

The learning curve for single-port transaxillary robotic thyroidectomy (SP-TART): experience through initial 50 cases of lobectomy

Joonseon Park[1] · Il Ku Kang[1] · Kwangsoon Kim[1] · Ja Seong Bae[1] · Jeong Soo Kim[1]

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Abstract
The new da Vinci® single-port (SP) robotic system, which utilizes a smaller incision and work space compared to the previous versions, is suitable for thyroidectomy. This study aimed to evaluate the learning curve for SP transaxillary robotic thyroidectomy (SP-TART) in a single-center. Fifty consecutive patients who underwent SP-TART between October 2021 and April 2022 in Seoul St. Mary's Hospital in Seoul, Korea, were included in this retrospective analysis. We examined the clinicopathological characteristics and short-term surgical outcomes and assessed the learning curve for SP-TART using cumulative summation analysis. The mean operation time was 57.8 ± 14.1 min, and the mean tumor size was 1.0 ± 0.7 (range, 0.3–3.7) cm. The patients were discharged approximately 2 days after surgery, and only two (4%) patients developed postoperative complications, including drainage-site bleeding and surgical site infection. Risk factors for long operation time were thyroiditis, amount of blood loss, and lymph node metastasis. The learning curve for SP-TART was 20 cases for the experienced robotic surgeon. SP-TART is technically feasible and safe with a short incision length and short operation time. It is a valuable alternative operative option with good surgical outcomes and outstanding cosmetic results.

Keywords Learning curve · Robotic surgery · Transaxillary · Thyroidectomy · Da Vinci single-port robotic system

Introduction

Several approaches for thyroidectomy have been developed over the decades [1–5]. Conventional open thyroidectomy (COT), the most commonly used method, requires a cervical incision that is usually longer than 5 cm in length. Therefore, alternative techniques using remote access have been developed to minimize postoperative anterior cervical scar formation [1–10].

Since the introduction of first endoscopic parathyroidectomy by Gagner and colleagues in 1996, endoscopic and robotic systems have been used to develop various methods such as anterior chest, transaxillary, bilateral axillo-breast, retro-auricular, and transoral approaches [1, 3, 4, 11–14]. Many studies have demonstrated that the safety and feasibility were compatible between robotic thyroidectomy and COT [2, 9, 15–17]. Among the various robotic techniques, transaxillary robotic thyroidectomy (TART) remains the most widely used approach since its introduction in 2007 [18, 19]. However, TART has several disadvantages including larger working space, longer operation time due to collision among the robotic instruments, and relatively longer incision in the axillary area.

The newly released fourth-generation da Vinci® single-port (SP) robotic system (Intuitive Surgical, Sunnyvale, CA) might be more suitable in long and narrow working spaces. The da Vinci® SP robotic system has a single cannula that delivers three multi-jointed instruments and a fully wristed three-dimensional high-definition camera with 10–15 times magnification. Therefore, da Vinci® SP-TART requires a shorter skin incision and narrower working space [20].

All new surgical techniques are subject to a learning curve. To the best of our knowledge, no study to date has evaluated the learning curve for SP-TART. Therefore, this study aimed to evaluate the learning curve and surgical outcomes of SP-TART in the first 50 cases performed by a single surgeon and to elucidate risk factors for longer operation time.

✉ Kwangsoon Kim
noar99@naver.com

[1] Department of Surgery, College of Medicine, The Catholic University of Korea, 222, Banpo-Daero, Seocho-Gu, 06591 Seoul, Republic of Korea

Materials and methods

Patients

Fifty consecutive patients who underwent SP-TART from October 2021 to March 2022 in Seoul St. Mary's Hospital in Seoul, Korea, were included in this retrospective analysis. All patients underwent lobectomy, and those patients who underwent total thyroidectomy or lateral neck dissection during the study period were not included in the study. All procedures were performed by a single surgeon (K.K.) with extensive experience in TART who had performed more than 500 cases. The medical charts and pathological reports of 50 patients were reviewed and analyzed.

This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and approved by the Institutional Review Board of Seoul St. Mary's Hospital, the Catholic University of Korea (approval no: KC22RISI0123), which waived the requirement for informed consent due to the retrospective nature of the study.

Surgical procedures

The detailed surgical procedures and techniques for SP-TART have been described [20]. Briefly, the patients were placed in the supine position, with slight cervical extension, under general anesthesia. The arm ipsilateral to the thyroid lesion was raised and fixed (Fig. 1). To place a 28 mm diameter SP-cannula at the surgical inlet, an incision of about 44 mm is required due to the 88 mm circumference of the cannula. However, considering the elasticity of the skin and the fact that in SP-TART, the cannula is not completely inserted into the axilla and serves as an entrance to insert instruments well by positioning it, the 35 mm incision is the most optimal incision size which is smaller than the actual size of the cannula circumference (Fig. 2a). Through a small incision about 3.5 cm in length (Fig. 2), the subcutaneous flap was created above the pectoralis major muscle and below the lower border of clavicle. After opening the superficial layer of the deep cervical fascia, the subplatysmal skin flap was lifted upward and the sternocleidomastoid muscle was exposed. Dissection was continued through the bifurcation of the sternocleidomastoid muscle, which was split into the sternal and clavicular head. After the identification of strap muscles, further dissection was performed under the strap muscles until the thyroid gland was exposed. The upper pole of the ipsilateral thyroid gland and the anterior surface of the contralateral lobe were exposed, and the full flap was lifted using the external retractor (Fig. 3).

Fig. 1 Single-port transaxillary robot-assisted thyroidectomy position with the arm on the lesion side raised

The robotic arms were accessed through a single cannula placed in the 3.5-cm skin incision. A camera was placed at the bottom of the cannula. Two Maryland bipolar dissectors were placed on both lateral-side arms, and a Cadiere forceps was placed on top (Fig. 4).

Surgical technique

Overall, the surgical technique employed in the study was similar to the method described in the previous study of SP-TART, which did not require an additional incision for the assistant [20]. All dissection and vessel ligations were performed through the Maryland bipolar dissectors. First, the upper pole was dissected. Next, the superior thyroid artery and veins were ligated as close to the thyroid gland as possible, with the aim to prevent injury to the external branch of the superior laryngeal nerve. Recurrent laryngeal nerve (RLN) was identified by dissecting the perithyroidal tissue around the lower pole. The thyroid gland was drawn upward using the Cadiere forceps and safely dissected by covering the RLN track with gauze. The central compartment lymph node (LN) dissection was performed from the medial side of the common carotid artery laterally to the inferior thyroidal artery superiorly and to the substernal notch inferiorly. The thyroid gland was carefully separated from the trachea to avoid thermal damage to the RLN at the ligament of Berry. The resected thyroid gland and LNs were removed through the axillary skin incision by an assistant using an endoscopic grasper. The axillary incision was closed with a closed suction drain (Fig. 5).

Assessment of surgical outcome

Surgical outcomes were evaluated based on the medical chart review of all patients to collect data on tumor size, multifocality, extrathyroidal extension (ETE), thyroiditis, number of harvested and metastatic LNs, amount of blood loss, postoperative hospital stay, and postoperative complications. The pathologic stage was classified according to the 8th edition of the American Joint Committee on Cancer/Union for International Cancer Control TNM staging

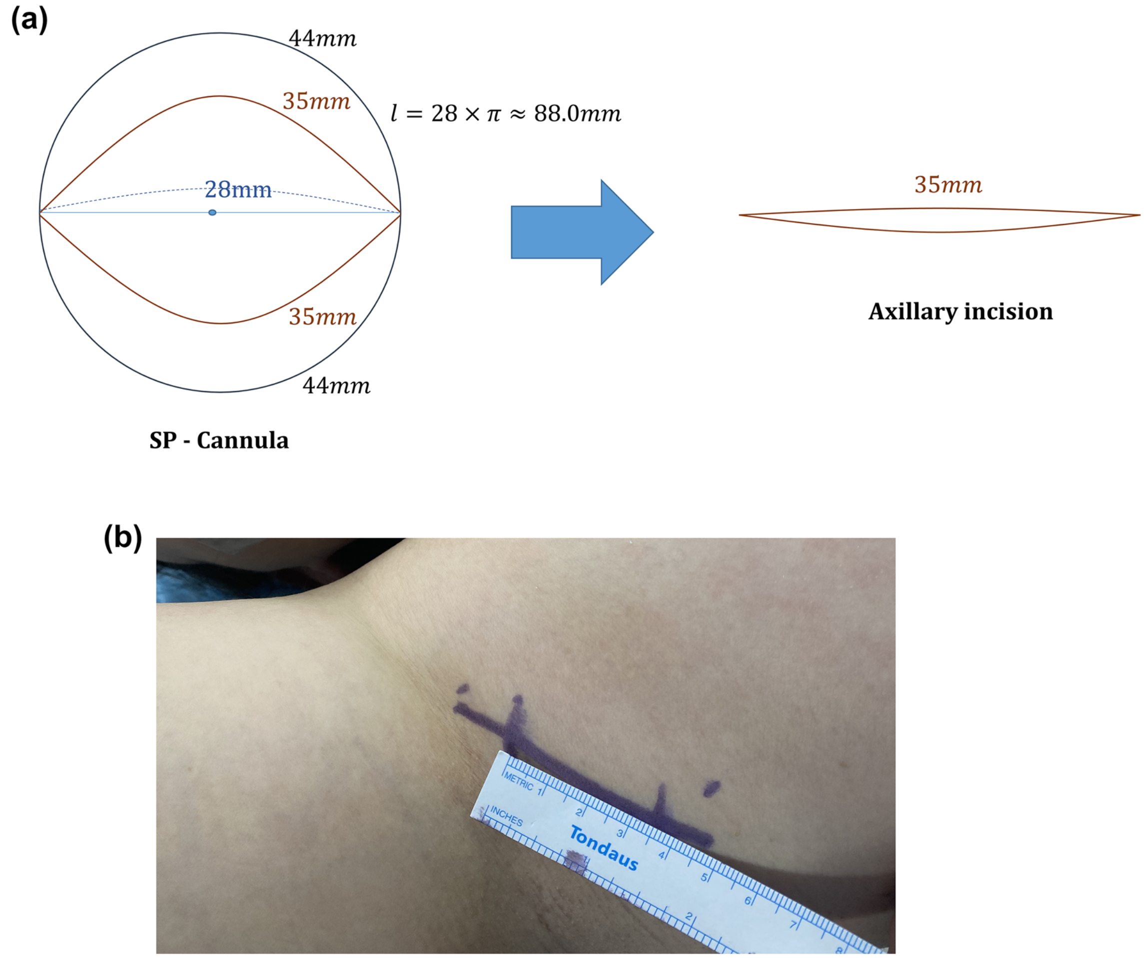

Fig. 2 Skin incision of Single-port transaxillary robot-assisted thyroidectomy. **a** Calculation of incision size according to the SP-cannula size (28 mm). **b** Skin incision, 35 mm in length, along the skin crease

Fig. 3 The flap is lifted using the external retractor

system. The duration of surgical phases, including flap elevation, docking, console operation, and total operation times, was determined.

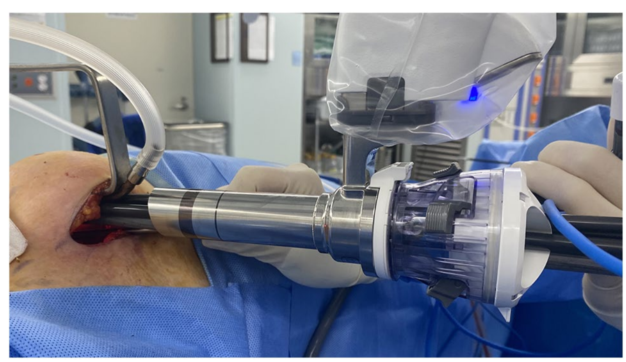

Fig. 4 The robotic instruments inserted through the single cannula

Primary and secondary endpoint

The primary endpoint was the learning curve for SP-TART, and the secondary endpoints were the comparison of the clinicopathological characteristics according to the

Fig. 5 Wound, 3.5 cm in length, after the operation

operation time and the risk factors associated with longer operation time.

Statistical analysis

Continuous variables were presented as means with standard deviation, and categorical variables were presented as numbers with percentages. Normality test was performed for all variables, and Student's *t*-test was used to compare continuous variables. Non-normally distributed variables were analyzed using the Mann–Whitney *U* test. Categorical variables between two groups were compared using the chi-square test. Multivariate logistic regression analyses were carried out to validate which factors were associated with operation time. Odds ratios (ORs) with 95% confidence intervals (CI) were calculated to compare the risk of operation time between the independent factors by using linear logistic regression analysis. The learning curve for SP-TART was evaluated using the cumulative summation (CUSUM) analysis, and the trend of learning outcome was indicated by the slope of the CUSUM curve. The point of overcoming the learning curve was defined as the point where the slope changed from positive to negative. A p value of < 0.05 was considered to indicate statistical significance. All statistical analyses were performed using IBM SPSS Statistics for Windows, version 24.0 (IBM, Armonk, NY, USA) and R package version 4.2.0 (http://www.R-project.org).

Results

Clinicopathological characteristics of patients undergoing SP-TART

Table 1 presents the clinicopathological characteristics of all patients included in the study. Briefly, 48 of the 50 (96%) patients were female. The mean age was 41.8 ± 12.2 (range, 25–66) years, and the mean body mass index was 23.3 ± 3.6 (range, 16.5–32.4) kg/m^2. The mean tumor size was 1.0 ± 0.7 (range, 0.3–3.7) cm, and multifocality was identified in 13 (26%) patients. ETE was confirmed in 25 (50%) patients, including 3 (6%) patients with gross ETE and 22 (44%) with minimal ETE. Thyroiditis was present in 24 (48%) patients based on the pathologic review. The most common pathological diagnosis was papillary thyroid carcinoma in 42 patients (84%). Most of the patients with cancer ($n = 43$) were in T1 category ($n = 40$, 93%) and had stage I cancer ($n = 42$, 97.7%) based on the TNM staging system.

Table 1 Clinicopathological characteristics of patients undergoing single-port transaxillary robot-assisted thyroidectomy

Variables	Values, *n* (%)
Age (years)	41.8 ± 12.2 (range, 25–66)
Female	48 (96.0%)
Body mass index (kg/m^2)	23.3 ± 3.6 (range, 16.5–32.4)
Tumor size (cm)	1.0 ± 0.7 (range, 0.3–3.7)
Multifocality	13 (26%)
ETE	
No ETE	25 (50%)
Minimal ETE	22 (44%)
Gross ETE	3 (6%)
Thyroiditis	24 (48%)
No. of lymph nodes	
Harvested LNs	5.0 ± 4.3
Positive LNs	1.3 ± 2.6
Pathology	
Follicular adenoma	4 (8%)
NIFTP	2 (4%)
PTC	42 (84%)
FTC	1 (2%)
PDTC	1 (2%)
T stage	
T1/T2/T3	40 (93.0%)/2 (4.7%)/1 (2.3%)
N stage	
N*x*/N0/N1a	2 (4.7%)/24 (55.8%)/17 (39.5%)
TNM stage	
Stage I/II	42 (97.7%)/1 (2.3%)

Data were expressed as patient's number (%), or mean ± standard deviation

ETE extrathyroidal extension; *LN* lymph node; *NIFTP* non-invasive follicular thyroid neoplasm with papillary-like nuclear feature; *PTC* papillary thyroid cancer; *FTC* follicular thyroid cancer; *PDTC* poorly differentiated thyroid cancer; *T* tumor; *N* node; *M* metastasis

Intraoperative details and postoperative complications

Table 2 summarizes the surgical outcomes of all patients who underwent SP-TART. The mean operation time was 57.8 ± 14.1 (range, 40–98) min. The flap elevation, docking, and console operation times were 15.8 ± 2.7 (range,

Table 2 Operative details and postoperative complications

Variables	Values, *n* (%)
Total operation time (min)	57.8 ± 14.1 (range, 40–98)
Flap time (min)	15.8 ± 2.7 (range, 12.0–25.0)
Docking time (min)	2.4 ± 0.9 (range, 2.0–5.0)
Console time (min)	25.5 ± 10.4 (range, 14.0–58.0)
Approach site	
Rt	31 (62%)
Lt	19 (38%)
Central lymph node dissection	
Performed	40 (80%)
Not performed	10 (20%)
Blood loss (mL)	7.5 ± 4.6 (range, 3.0–25.0)
Postoperative hospital stay (days)	2.0 ± 0.2 (range, 1–3)
Complications	
Postoperative bleeding	1 (2%)
Surgical site infection	1 (2%)
Vocal cord palsy	0 (0%)
Seroma	0 (0%)

Data were expressed as patient's number (%), or mean ± standard deviation

12.0–25.0), 2.4 ± 0.9 (range, 2.0–5.0), and 25.5 ± 10.4 (range, 14.0–58.0) min, respectively. Central LN dissection was performed in 40 patients. The average amount of blood loss was 7.5 ± 4.6 (range, 3.0–25.0) mL. The mean postoperative hospital stay was 2 (range, 1–3) days, and postoperative complications were observed in two (4%) patients, including one patient with postoperative bleeding and one with surgical site infection. No patient experienced vocal cord palsy or seroma.

Clinicopathological characteristics of patients categorized according to operation time

Next, we determined the clinicopathological patient characteristics associated with operation time. To this end, the 50 patients were categorized into the short and long operation time groups based on the mean operation time of 58 min of the entire cohort. Table 3 shows the comparison of the clinicopathological characteristics between the short operation group including 27 patients and the long operation time group including 23 patients. The rate of thyroiditis was significantly higher in the long operation time group than in the short operation time group (69.6% vs. 29.6%, $p = 0.005$). However, other factors including age, sex, body mass index, approach site, tumor size, multifocality, ETE status, number of acquired LNs, number of metastatic LNs, and TNM stage were not significantly different between the two groups (Table 4).

Table 3 Comparison of clinicopathological characteristics according to the operation time

	Short-time group (≤ 58 min) (*n* = 27)	Long-time group (> 58 min) (*n* = 23)	*p*-Value*
Age (years)	41.6 ± 11.9	42.0 ± 12.7	0.938**
Female	26 (96.3%)	22 (95.7%)	0.908
Body mass index (kg/m^2)	22.9 ± 4.0	23.7 ± 3.2	0.484***
Obesity			0.781
BMI < 25(kg/m^2)	19 (70.4%)	17 (73.9%)	
BMI ≥ 25(kg/m^2)	8 (29.6%)	6 (26.1%)	
Approach site			0.879
Rt	17 (63.0%)	14 (60.9%)	
Lt	10 (37.0%)	9 (39.1%)	
Tumor size (cm)	0.82 ± 0.47	1.21 ± 0.92	0.083**
Multifocality	8 (29.6%)	5 (21.7%)	0.526
ETE			0.777
No ETE	14 (51.9%)	11 (47.8%)	
Gross/minimal ETE	13 (48.1%)	111.5 (52.2%)	
Thyroiditis	8 (29.6%)	16 (69.6%)	0.005
LN metastasis	7 (25.9%)	11 (47.8%)	0.108
Harvested LNs	4.33 ± 3.45	5.74 ± 5.05	0.356**
Positive LNs	0.74 ± 1.51	1.96 ± 3.35	0.095**
T stage†			0.157
T1	23 (100%)	17 (85%)	
T2	0 (0%)	2 (10%)	
T3	0 (0%)	1 (5%)	
N stage†			0.401
Nx	1 (4.3%)	1 (5.0%)	
N0	15 (65.2%)	9 (45.0%)	
N1a	7 (30.4%)	10 (50.0%)	
TNM stage†			0.278
Stage I	23 (100%)	19 (95%)	
Stage II	0 (0%)	1 (5%)	

Data were expressed as patient's number (%), or mean ± standard deviation. A statistically significant difference was defined as $p < 0.05$

BMI body mass index; *ETE* extrathyroidal extension; *LN* lymph node; *T* tumor; *N* node; *M* metastasis

*Chi-square test. **Mann–Whitney *U* test. ***Student *t*-test. †In cases of thyroid cancer

Logistic regression analysis of risk factors associated with operation time

We performed multivariate analysis to determine whether blood loss, thyroiditis, and LN metastasis were significant risk factors. Thyroiditis was a significant independent risk factor for longer operation time (odds ratio [OR], 2.53; 95% confidence interval [CI], 1.77–57.59; $p = 0.009$). The multivariate analysis of the patients with thyroid cancer revealed that LN metastasis was a significant predictor for longer

Table 4 Logistic regression analysis of risk factors associated with long operation time > 58 min

Variables	Simple generalized linear model			Multiple generalized linear model		
	OR	CI	*p*-Value	OR	CI	*p*-Value
Age	1.02	0.93–1.12	0.701			
Sex						
Female	1.00					
Male	70.85	0.16–30884.92	0.169			
BMI (kg/m^2)	0.91	0.66–1.24	0.536			
Approach site						
Rt	1.00					
Lt	3.18	0.42–24.31	0.265			
Tumor size (cm)	7.14	0.85–59.63	0.070	3.44	0.97–12.19	0.056
Multifocality	1.00	0.10–9.75	0.999			
ETE						
No ETE	1.00					
Gross/minor ETE	1.46	0.15–14.57	0.749			
Thyroiditis	65.93	3.55–1225.35	0.005	10.10	1.77–57.59	0.009
Blood loss (mL)	1.40	1.07–1.84	0.013	1.26	1.02–1.55	0.033
Harvested LNs	0.76	0.53–1.09	0.139			
Positive LNs	1.54	0.44–5.37	0.498			
LN metastasis	6.70	0.12–369.92	0.353	6.03	1.08–33.61	0.041

Data are expressed as odds ratio (OR) and 95% confidence interval (CI). A statistically significant difference was defined as $p < 0.05$

BMI body mass index; *ETE* extrathyroidal extension; *LN* lymph node

operation time (OR, 6.03; 95% CI, 1.08–33.61; $p = 0.041$). In addition, the amount of blood loss was a significant independent risk factor for longer operation time (OR, 1.26; 95% CI, 1.02–1.55; $p = 0.033$).

CUSUM analysis of SP-TART

We evaluated the learning curve for SP-TART using CUSUM analysis. The quaternary function that best fit the curve was obtained using the number of cases with a high R^2 value, which is as follows:

$\text{CUSUM} = -2.000 \times 10^{-4} \times (\text{number of cases})^4 + 2.370 \times 10^{-2} \times (\text{number of cases})^3 - 1.408 \times (\text{number of cases})^2 + 3.380 \times (\text{number of cases}) - 6.318$, $R^2 = 0.9953$.

The upward inflection of the CUSUM curve changed to a downward inflection at 20 cases, indicating that the learning curve for SP-TART was 20 cases (Fig. 6).

Discussion

Thyroid cancer has become one of the most common endocrine malignancies with increasing global incidence in recent decades [21–23]. Since thyroid cancer is more prevalent in women than in men at an approximate ratio of about 4:1 [24], the cosmetic concerns, which are related to the quality of life, are an important issue for patients undergoing thyroid surgery [5, 25, 26].

COT, the standard procedure for thyroidectomy [5], is associated with several critical complications such as anterior cervical scar and adhesion formation, discomfort in swallowing, and postoperative nausea/vomiting [27–29]. Huscher et al. introduced endoscopic thyroidectomy with transaxillary approach in 1997 to overcome these disadvantages, and this technique has been developed over the decades [30]. However, despite its advantages, endoscopic surgery continues to suffer from several limitations. First, endoscopic camera is a two-dimensional apparatus and cannot show perspective that can confuse the surgeon; this aspect is critical in thyroid surgery that requires meticulous dissection of tiny vessels and thin nerves. Second, the rigid straight instrument cannot mimic the wrist and finger movements; therefore, it might limit the thyroid surgery in a narrow working space. As a result, surgeons may easily experience fatigue and discomfort and the patient's skin might be overstretched by traction injuries [4, 31]. On the other hand, robotic surgery has several advantages including a three-dimensional view and robotic arms with wrist and fingers, which allow fine and free movement for cervical LN dissection in thyroid surgery [31, 32]. The recently introduced fourth-generation da Vinci® SP robotic system has many advantages relevant to thyroid surgery. The rigid cannula at the surgical entrance site prevents overstretching

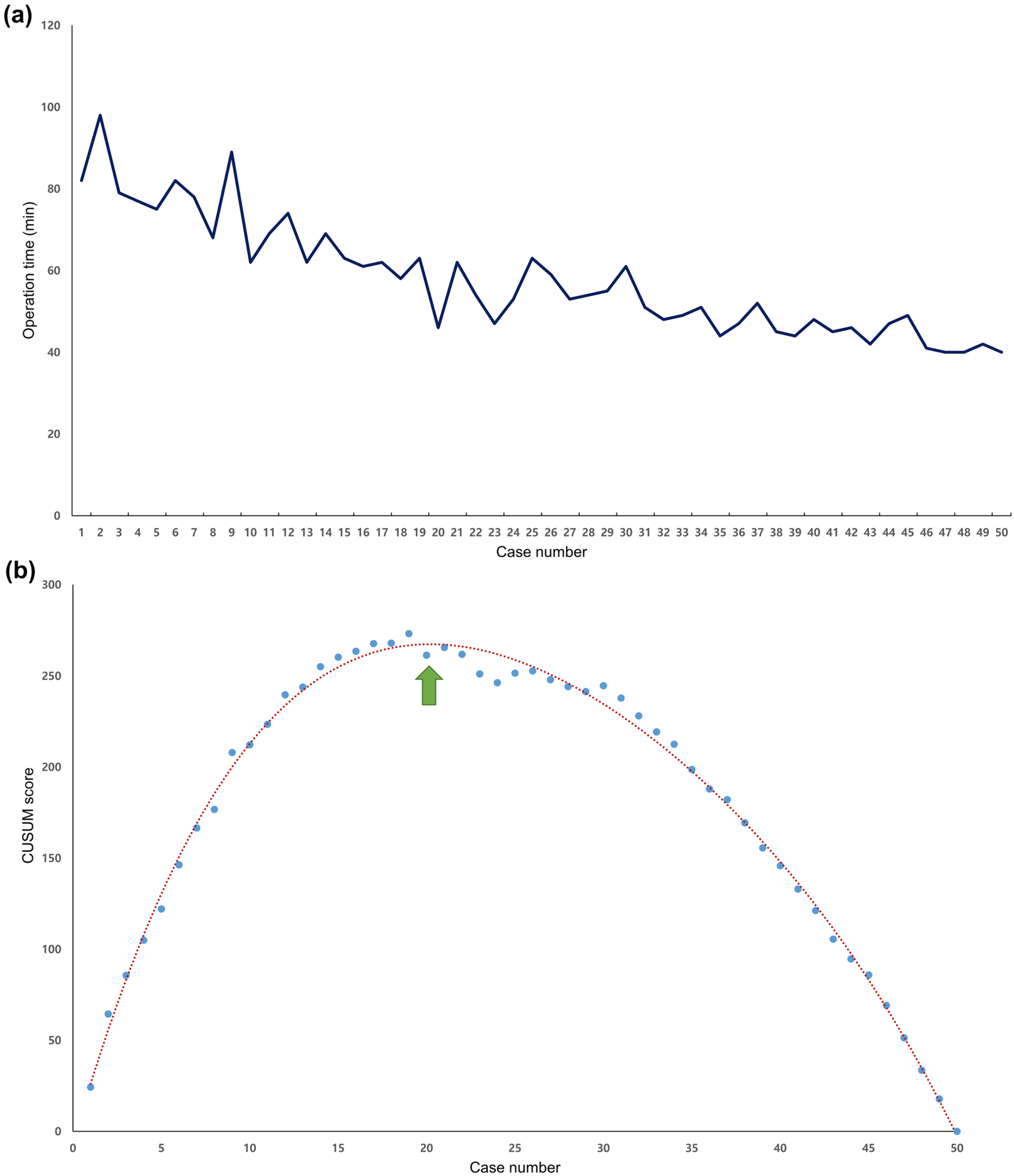

Fig. 6 Operation time of single-port transaxillary robot-assisted thyroidectomy. **a** Operation time of single-port transaxillary robot-assisted thyroidectomy plotted in chronological order. **b** Cumulative summation test of operation time of single-port transaxillary robot-assisted thyroidectomy

of the skin incision, and the fully wristed three-dimensional high-definition camera allows the easy observation of blind spots [33].

Surgeons have to overcome the learning curve in surgery with new instruments. Therefore, we determined the proficiency of our experience with the use of the da Vinci® SP robotic system for TART and calculated the learning curve, which would benefit surgeons considering SP-TART. In parallel to the continued increase in the use of robotic surgery, many studies have examined the learning curve for each approach in thyroid surgery. For example, Kim et al. reported that 40 cases were suitable for beginner surgeons to safely and effectively perform thyroidectomy using the bilateral axillo-breast approach [34]. In addition, Chen et al. reported that the learning curve was 25 cases for experienced endoscopic surgeons to safely and effectively perform transoral robotic thyroidectomy [35]. Before the introduction of the da Vinci SP® robotic system, several learning curve studies were conducted to evaluate TART performed using previous platforms. In a study comparing transaxillary endoscopic thyroidectomy with TART, Lee et al. reported that the operation time reached the plateau after 55–70 endoscopic thyroidectomy cases and 35–45 TART cases [36, 37]. This study is the first to report the learning curve for SP-TART and provides new information and indicators for endocrine surgeons performing SP-TART using the da Vinci SP® system.

We used CUSUM analysis as the most effective method to determine the learning curve. One advantage of the CUSUM analysis is the ability to dynamically evaluate changing and evolving competence [38]. The CUSUM of the operation time was calculated using the function CUSUM $= \sum_{i=1}^{n}(x_i - \mu)$, where x_i is the individual operation time and μ is the average of all operation times. Therefore, the learning curve was intuitively visualized by plotting the CUSUM curve, which represented the dynamic change according to the increase in the number of cases [11, 39]. The learning curve for SP-TART was 20 cases based on the CUSUM analysis. All operations were performed by a single surgeon who was already experienced in endoscopic and robotic surgery using previous versions. Therefore, surgical experience of more than 20 cases might be necessary for beginner surgeons performing SP-TART. However, considering the current robot training system and the qualification requirements of Intuitive Surgical Inc., da Vinci® SP is only accessible to surgeons who have performed more than the standard number of surgeries in the previous versions. This requirement is one of safeguards for a reasonable leap for each surgeon. Considering that the opportunities are made sequentially, the results of this study might be clinically applicable to most robot surgeons.

Our analyses also revealed that SP-TART may be relatively longer in patients with thyroiditis or LN metastasis. In many studies, patients with thyroiditis were considered unsuitable for robotic surgery due to adhesions or bleeding tendency related to fragile tissue and were excluded [1, 4]. Therefore, in cases where thyroiditis is identified before the surgery, the surgeon's decision for proper surgical method is important. In our institution, anti-thyroid peroxidase antibodies are routinely measured in all patients before surgery to differentiate Hashimoto's thyroiditis; this evaluation aids in the surgeon's decision-making. However, the SP system provides an advantage in challenging cases that may be difficult to perform using the previous versions of the robotic system. For example, approximately 50% of the patients in this study had thyroiditis. Despite the longer operation time, the rate of postoperative complications did not significantly increase due to thyroiditis.

LN metastasis is another significant risk factor for longer operation time. Robotic lymphadenectomy is more challenging, and the number of harvested LNs is often less than that achieved with COT; therefore, most surgeons do not perform robotic thyroidectomy in patients with metastatic cervical LNs at the time of preoperative evaluation [4, 8, 40, 41]. However, despite the relatively longer operation time in patients with LN metastasis, many studies demonstrated the safety and feasibility of neck dissection using robotic platforms [42]. Currently, robotic thyroidectomy has been commercialized not only for simple lobectomy but also for more aggressive thyroid cancer surgeries such as that performed in patients with N1b cancer requiring lateral neck dissection [7, 42, 43]. In our institution, we also perform lateral neck dissection using the SP robotic platform. Further studies of SP-TART with a wider surgical extent, such as total thyroidectomy and lateral neck dissection, might be necessary to evaluate the safety, feasibility, and the learning curve for each procedure.

In this study, postoperative bleeding and surgical site infection were the only two postoperative complications observed in one patient each; both patients improved with conservative treatment. Moreover, none of the patients developed vocal cord palsy, in contrast to the relatively higher vocal cord palsy rate of 2–6% reported in previous studies [44, 45]. One potential reason for the observed difference is the ability of the fully wristed three-dimensional high-definition camera to show deeper blind spots, which may lead to fewer injuries during the dissection around the RLN. Second, Maryland bipolar diathermy dissectors might decrease thermal injury. Sutton et al. demonstrated that the temperature at the tip of the Harmonic™ scalpel, which is commonly used in robotic surgeries on previous platforms, was higher than that of the bipolar diathermy dissectors, resulting in significant lateral thermal spread [46]. In addition, postoperative seroma or numbness of the breast skin was not observed in the present study cohort. Chest wall seroma due to the wide dissection from the axilla to the anterior cervical area was reported in approximately 2% of patients undergoing the transaxillary approach using the previous da Vinci® system [41]. However, SP-TART requires a small incision and smaller working space; therefore, lower rate of seroma or breast skin paresthesia might be expected due to the smaller dead space in this approach.

This study has several limitations. First, this was a single-center study based on the retrospective review of the medical charts. In addition, in all 50 cases, surgery was performed by one surgeon, who was already experienced in the previous versions. However, these limitations are also the strengths of this study. The single surgeon experience is associated with reduced bias. Furthermore, the homogeneity in treatment and follow-up approaches in a single-center setting is an advantage of this study.

Conclusion

The learning curve for SP-TART was 20 cases for the experienced robotic surgeon. SP-TART is technically feasible and safe with a short incision length, short operation time, and a low complication rate. It is a valuable alternative surgical option with good surgical outcomes and outstanding cosmetic results. Further studies are warranted to elucidate the safety and feasibility of surgeries with wider extent such as total thyroidectomy and lateral neck dissection.

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Declarations

Conflict of interest The authors have no source of funding and no conflict of interest to declare.

Ethical approval This study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Seoul St. Mary's Hospital, The Catholic University of Korea (IRB No: KC22RISI0123 and date of approval: 2022.05.23).

Informed consent Patient consent was waived due to the retrospective nature of this study.

Data availability Data is available.

Research involving human participants and/or animals All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (Institutional and National) and with the Helsinki Declaration of 1964 and later versions.

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