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# Robotic bilateral axillo-breast versus endoscopic bilateral areola thyroidectomy outcomes of 757 patients

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**Background:** Remote endoscopic thyroidectomy (ET) and robotic thyroidectomy (RT) seem to be beneficial in selected situations to avoid anterior neck scars. There are limited data in the literature to determine whether RT *via* a bilateral axillo-breast approach (RT-BABA) is superior to ET *via* a bilateral areolar approach (ET-BAA). Therefore, the aim of this study was to evaluate the surgical outcomes of RT-BABA versus ET-BAA.

**Methods:** Between May 2013 and May 2022, 757 patients who underwent RT-BABA or ET-BAA at a high-volume Chinese thyroid center were included. Intraoperative and postoperative outcome parameters were collected and retrospectively analyzed. The moving average method was used to evaluate the learning curve.

**Results:** The proportion of patients older than 45 years was greater in the RT group than in the ET group (14.8% vs. 7.4%,  $p < 0.001$ ). The percentage of overweight patients was greater in the RT group (28.8% vs. 9.5%,  $p < 0.001$ ). The number of patients treated for malignant lesions was higher in the RT group (86.8% vs. 75%,  $p < 0.001$ ). The rate of thyroiditis was higher in the RT group (10.9% vs. 6.6%,  $p < 0.001$ ). Surgical time was significantly shorter in the RT group (140 vs. 165min,  $p < 0.001$ ). Drainage volume was higher in the RT group (100 vs. 85ml,  $p < 0.001$ ). Postoperative hospital stay was shorter in the RT group ( $3.04 \pm 0.44$  vs.  $3.67 \pm 0.89$  days,  $p < 0.001$ ). The cost in the RT group was higher ( $49627 \pm 2795$  vs.  $25094 \pm 3368$  yuan,  $p < 0.001$ ). Transient vocal cord dysfunction was lower in the RT group (2.9% vs. 8.0%,  $p = 0.003$ ). There

was no significant difference between the two groups in the number of central lymph nodes sampled, positive lymph nodes, neural monitoring (EMG) results, and rate of transient hypoparathyroidism. The learning curve for RT was 26 cases, and the operative time for ET was constant throughout the study.

**Conclusions:** RT-BABA is as safe and feasible as ET-BAA. RT-BABA performed better in some surgical outcomes. Further prospective studies are needed to confirm the safety of RT-BABA.

#### KEYWORDS

endoscopic surgery, thyroidectomy, robotic-assisted surgery, morbidity, cost, learning curve

## Introduction

In recent decades, minimally invasive thyroid surgery has gained increasing popularity (1, 2). With the introduction of endoscopic techniques, several advantages have been demonstrated in terms of cosmesis, length of hospital stay, degree of postoperative pain, blood loss, voice quality, and faster return to normal activities (3–6). These benefits have also been demonstrated for oncologic resections (7).

The introduction of robotic-assisted systems took minimally invasive thyroid surgery to the next level. The robotic surgical system was introduced to thyroid surgery by Kang in 2009 (8). The Endowrist™ function with its improvement of comfort and maneuverability, filtering of tremor and movements by the computer system, high-resolution 3-dimensional binocular vision with the possibility of magnification, fluorescence, and finally a stable platform with a surgeon-operated camera can even be considered as a revolution and new dimension in thyroid surgery (2, 3, 9, 10). As a result, various endoscopic thyroidectomy approaches (ET), including transaxillary, bilateral areola, facelift, and transoral approaches, have been transferred to robotics (2). To our knowledge, few studies have compared surgical outcomes between robotic thyroidectomy *via* the bilateral axillary thoracic approach (RT-BABA) and endoscopic thyroidectomy *via* the bilateral areola approach (ET-BAA). Therefore, the aim of this study was to evaluate the surgical outcomes of RT-BABA versus ET-BAA.

## Materials and methods

### Study design

A retrospective, comparative observational study.

### Setting

A major thyroid surgery center, i.e., the Department of Thyroid Surgery, China-Japan Union Hospital of Jilin University, Changchun, China.

### Time frame

May 2013 to May 2022.

### Preoperative assessment

All patients were examined according to International guidelines (11). All surgical indications were approved by a multidisciplinary board.

### Inclusion and exclusion criteria

We retrospectively studied patients > 18 years old who underwent endoscopic thyroidectomy *via* a bilateral areola approach and robotic thyroidectomy *via* a bilateral axillo-breast approach. The detailed inclusion and exclusion criteria for ET and RT are summarized in Table 1. Only one surgeon (DQZ) had experience in robotic and endoscopic surgery. ET vs. RT were selected based on instrument availability and surgeon preference, with no specific selection criteria.

### Data collection

Data were obtained retrospectively from electronic databases. Demographic data (age, sex, and BMI) and outcome

TABLE 1 Detailed inclusion and exclusion criteria for ET and RT.

Selection and exclusion criteria	
Selection criteria	
Papillary thyroid cancer with low-risk factors <sup>a</sup>	
Dominant benign nodule with a diameter <5 cm, whereas cystic nodule could be 6 cm or greater	
The patients needed a cosmetic requirement	
Exclusion criteria	
General factors	
Clinical history of radiation or surgery on the neck or chest	
Preoperative dysfunction of voice cord	
Thyroid-related factors	
Advanced cancer	
Local invasion	
Posteriorly located lesions	
Diffuse or adhesion or fixation enlargement of lymph node	
Evidence available of local or distant metastases	
Graves' disease	
Severe thyroiditis	
Associated parathyroid disease	

<sup>a</sup>Low risk factors including lesion size <4 cm, age <55 years, no prior radiation, no distant metastases, no lymph node metastases, no extrathyroidal extension, no aggressive variant, and no first-degree family history of thyroid carcinoma.

parameters were extracted, including conversion to open surgery, intraoperative and postoperative complications (30-day morbidity), operative time, postoperative length of hospital stay, blood loss, discharge home, costs, electromyographic (EMG) changes in recurrent laryngeal nerve (RLN) (12). The time from skin incision to closure was the operative time. Learning curve of two techniques had been made with moving average method, every 5 patients was a group (the moving average period was set to 5). The cost included the expense of perioperative examination and surgical treatment. Reason of RLN injury was repeatedly confirmed by viewing the video. All patients underwent fiberoptic laryngoscopy before surgery and on the first day after surgery (13). According to the examination results, normal vocal cord movement or vocal cord paralysis was detected (13). Those who recovered within 6 months were considered as temporary vocal cord paralysis, and those who did not recover within 6 months were considered as permanent (13). Hypoparathyroidism is defined as parathyroid hormone below 15pg/ml. Transient hypoparathyroidism recovering within 6 months, and permanent hypoparathyroidism lasting longer than 6 months (14). Discharge criteria consisted in adequate pain control with

oral medication, and soft food well-tolerated, mobilization, and self-support.

## Technology overview and surgical techniques

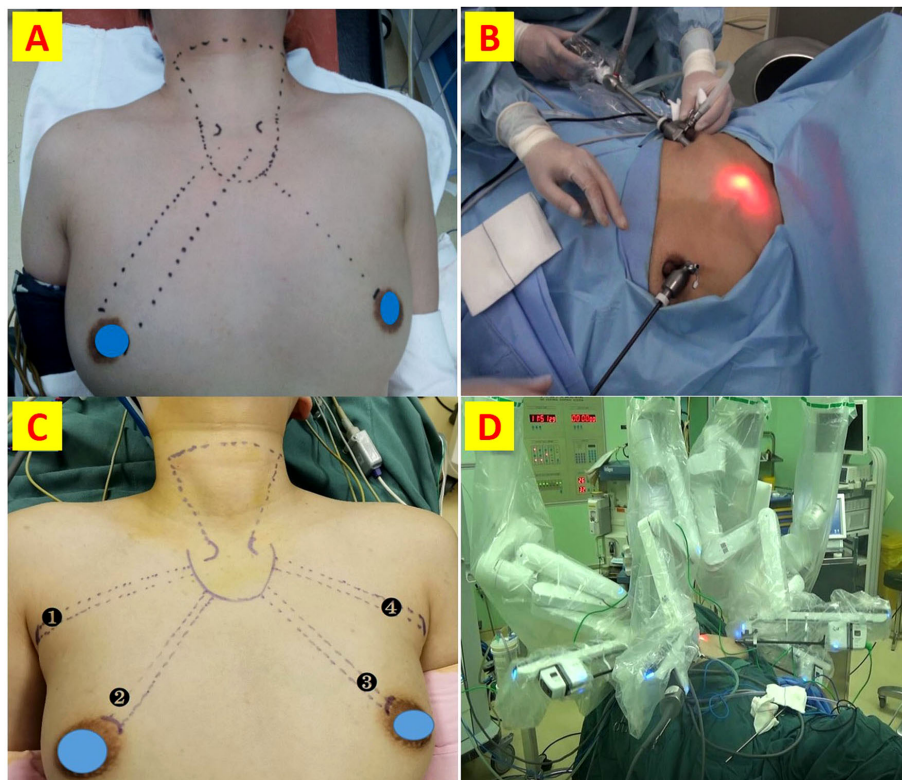
Detailed procedures for ET-BAA and RT-BABA have been reported previously (Figure 1) (3, 5, 14). ET-BAA was performed with Olympus endoscopic surgical system, and RT-BABA was performed with a fourth-generation da Vinci<sup>®</sup> Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) in this study. The main difference between two techniques was summarized in Table 2. ET-BAA consisted of a 10-mm curved incision made along the edge of the right areola at 2-4 of the clock to use a 10-mm trocar and a 30-degree endoscope. Bilateral 5-mm incisions were made along the borders of the areola, and two 5-mm trocars were used as main and auxiliary operating ports. CO<sub>2</sub> was maintained at 6 mmHg. RT-BABA included two 10-mm axillary incisions and two 10-mm areolar incisions on the left and right sides. The right areolar incision was used as a camera port. The left areolar incision and bilateral axillary incision were each placed in the trocar for connection of the ultrasound scalpel, Maryland forceps, and grasping forceps. CO<sub>2</sub> was continuously introduced at a pressure of 6 mmHg to maintain the surgical space.

## Statistical analysis

Results were analyzed using SPSS Statistics version 23 (SPSS Inc., Chicago, IL, USA). Continuous variables are presented as means with standard deviations (mean ± SD) when the data were normally distributed and as medians with interquartile ranges (IQRs) when the data were abnormally distributed. Categorical variables are expressed as percentages. The independent samples t-test was used to compare continuous variables between the two groups. The Mann-Whitney test was used to compare discontinuous variables, whereas the chi-square test was used to compare categorical variables. Differences were considered statistically significant if the p-value was less than 0.05.

## Results

The detailed data of the patients are summarized in Table 3. A total of 757 patients were enrolled in this study (364 patients in the ET and 393 patients in the RT group). All surgeries were successfully completed, and there were no cases of conversion to open surgery. Figure 2 reflects the changing trend of robotic and endoscopic thyroidectomy in our center from 2013 to 2022.



**FIGURE 1**  
Detailed procedures for ET-BAA and RT-BABA. (A) Surgical incision and approach for ET; (B) port insertion for the bilateral areola approach; (C) Surgical incision and approach for RT; (D) robotic arm placement and surgical scenarios.

### Demographic and pathologic characteristics

As shown in **Table 3**, patients in the RT group were significantly older (33 vs. 31 years,  $p < 0.001$ ). In the RT group, 58 (14.8%) patients were older than 45 years and in the ET group, 27 (7.4%) were older (**Figure 3**). The median body mass index (BMI) was  $22.5 \text{ kg/m}^2$  in the RT group and  $21.2 \text{ kg/}$

$\text{m}^2$  in the ET group ( $p < 0.001$ ). The proportion of overweight patients ( $\text{BMI} \geq 25 \text{ kg/m}^2$ ) was greater in the RT group than in the ET group ( $p < 0.001$ ) (**Figure 3**). The sex ratio was similar between the two groups ( $p > 0.05$ ). Regarding the pathological results, there were 341 (86.8%) malignant lesions in the RT group and 273 (75%) in the ET group (**Figure 3**). Thyroiditis was detected in 43 patients in the RT group (10.9%) and 24 patients in the ET group (6.6%) (**Figure 3**). There was no significant difference in the number of central lymph nodes and positive lymph nodes sampled between the two groups ( $p > 0.05$ ).

**TABLE 2** The main differences between the two technologies.

	RT	ET
<b>Vision</b>		
Enlarge	10-15 times	4-6 times
3D	yes	no
Stable	yes	no
<b>Instrument</b>		
slender	yes	yes
Rotate 360 degrees	yes	no
<b>Manipulator</b>		
	3	2

### Perioperative outcomes

The median operation time was significantly shorter in the RT group than in the ET group (140 vs. 165 min,  $p < 0.001$ ) (**Figure 4A**). Total drainage volume was higher in the RT group than in the ET group (100 vs. 85 ml,  $p < 0.001$ ) (**Figure 4B**). Postoperative hospital length of stay was shorter after robotic thyroidectomy ( $3.04 \pm 0.44$  vs.  $3.67 \pm 0.89$  days,  $p < 0.001$ ) (**Figure 4C**). Although there was no difference in intraoperative EMG changes of the RLN between the two groups (12.3% vs.

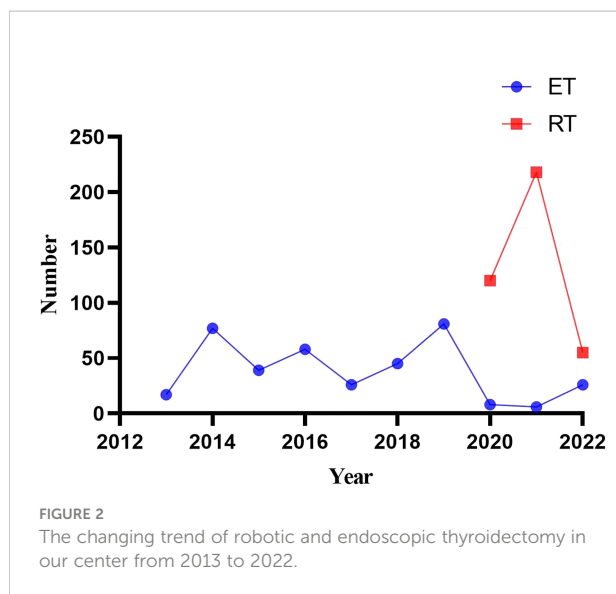
TABLE 3 Demographics, pathological characteristics and Perioperative outcomes of patients.

Characteristics	ET(n=364)	RT(n=393)	P-value
Age (median [IQR]), years	31(25, 38)	33(28, 40)	<0.001
<45	337(92.6)	335(85.2)	<0.001
≥45	27(7.4)	58(14.8)	
<b>Sex</b>			
Male	34(9.5)	38(9.7)	0.926
Female	325(90.5)	355(90.3)	
BMI(median [IQR]) ,kg/m <sup>2</sup>	22.5(19.3, 23.2)	21.2(20.5, 25.4)	<0.001
<25	319 (90.5)	280 (71.2)	<0.001
≥25	44 (9.5)	113 (28.8)	
<b>Pathology</b>			
Benign	91(25)	52 (13.2)	<0.001
Malignant	273(75)	341 (86.8)	
Tumor diameter, mm	5.8 ± 4.9	6.3 ± 4.4	0.135
Thyroiditis	24 (6.6)	43 (10.9)	0.035
<b>LN status of CND</b>			
Retrieved LNs	4.0 ± 3.1	4.4 ± 3.4	0.127
Positive LNs	0.8 ± 1.5	0.9 ± 1.5	0.558
Operation time(median [IQR]) ,min	165 (135, 200)	140 (120, 165)	<0.001
Total amount of drainage(median [IQR]) ,ml	85 (70, 100)	100 (85, 110)	<0.001
Postoperative hospital stay time(mean ± SD) ,day	3.67 ± 0.89	3.04 ± 0.44	<0.001
Cost(mean ± SD), yuan	25094 ± 3368	49627 ± 2795	<0.001
EMG changes of RLN	46 (12.6)	51 (12.9)	0.139
Reason of RLN injury			0.268
Compression	36 (78.3)	46 (90.2)	
Tumor invasion	2(4.3)	1 (2.0)	
Vascular heat conduction	8(17.4)	4 (7.8)	
<b>Postoperative complication</b>			
Transient VCD	29 (8.0)	11 (2.9)	<0.001
Permanent VCD	0	0	
Transient HPT	5(1.4)	1(0.3)	0.083
Permanent HPT	0	0	

VCD, Vocal cord dysfunction; HPT, Hypoparathyroidism.

9.7%,  $p = 0.139$ ), the rate of transient vocal cord dysfunction was lower in the RT group than in the ET group (2.9% vs. 8.0%,  $p = 0.003$ ) (Figure 5). The elucidated mechanisms among 97 RLN lesions were included compression, vascular heat conduction and tumor invasion. In ET group, 36 cases (78.3%) were compression, 8 (17.4%) vascular heat conduction, 2 (4.3%)

tumor invasion. In RT group, the main causes of RLN injury were compression ( $n=46$ , 90.2%), followed by vascular heat conduction, ( $n= 4$ , 7.8%) and tumor invasion ( $n = 1$ , 2.0%). There was no difference in the reason of RLN injury between the two groups ( $p > 0.05$ ). The rate of transient hypoparathyroidism was also similar in the two groups (Figure 5). The mean cost of



robotic thyroidectomy was  $49627 \pm 2795$  yuan compared with  $25094 \pm 3368$  yuan for endoscopic thyroidectomy (Figure 4D) ( $P < 0.001$ ).

## Learning curve

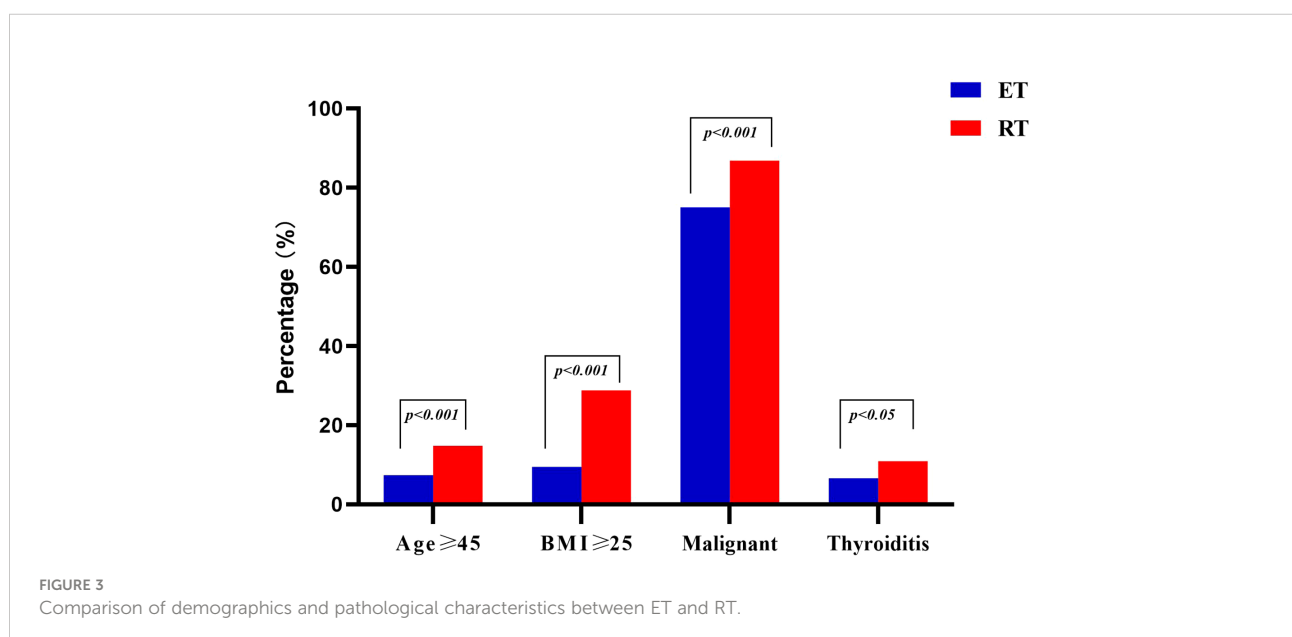
In 396 consecutive robotic-assisted procedures, the learning curve was generated using the moving average method. The operation time decreased significantly after approximately 26 cases and gradually stabilized (Figure 6A). The operation time for ET was constant throughout the study (Figure 6B).

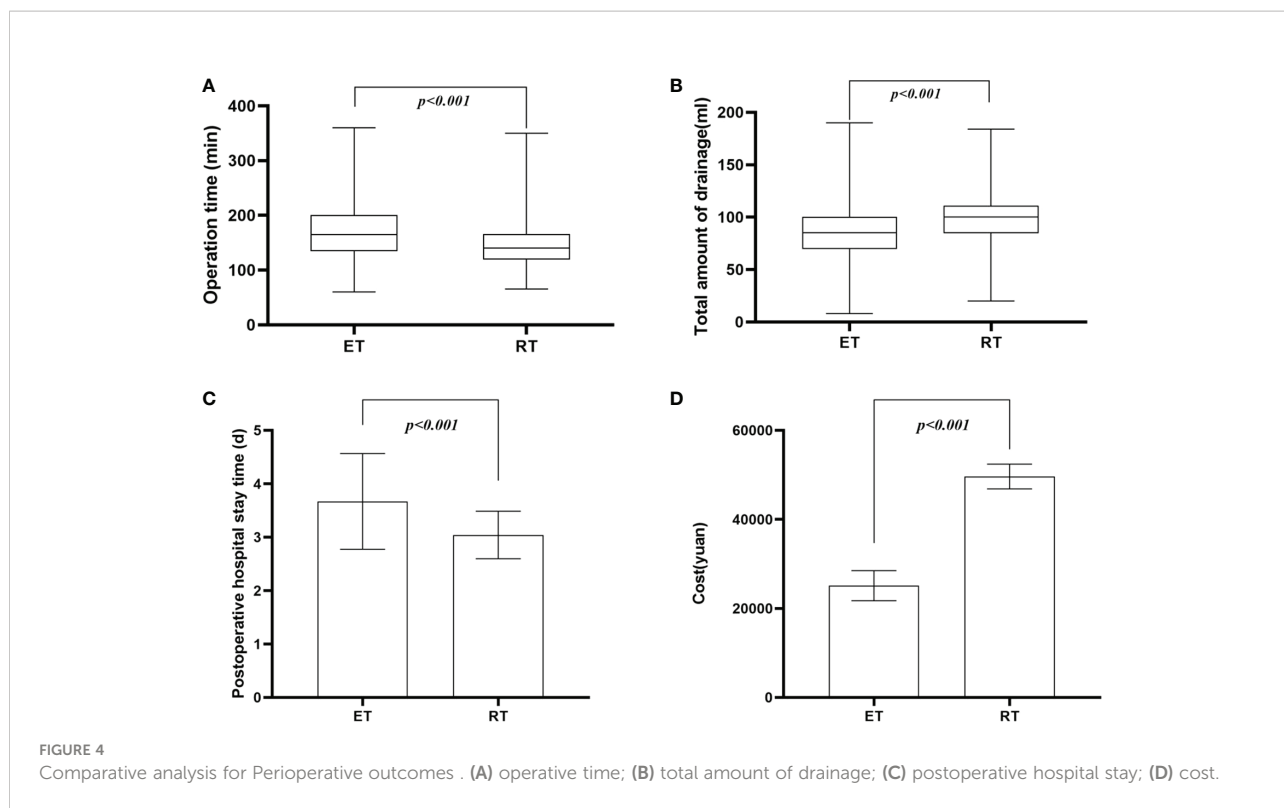
## Discussion

In recent decades, minimally invasive techniques have gained considerable importance in thyroid surgery (3–6). According to the latest studies, ET consolidates its advantages compared to the traditional open approach (6). Recently, authors have advocated the safety and satisfactory results of robotic thyroidectomy (3–6). As the Table 2 shown, robotic surgical system has technical advantage compared with endoscopy. The da Vinci robotic surgical system provide a three-dimensional 15-fold magnified stable view, which eliminates the fatigue caused by the shaking of surgical field. Unlike ET, surgical instruments in RT provide surgeons with a wider range of stimulated movements than the human hand to complete flexible and natural operations, allowing for delicate operations in tight spaces. Furthermore, the appearance of the third robotic arm leads to a huge physical and labor saving compare to ET. However, the actual benefit of robotic thyroid surgery versus ET in the treatment of thyroid disease is still debated today. Preliminary results are encouraging and supportive of the robotic platform, but issues with operative time and cost present a significant obstacle to ultimately overcoming the robotic system versus ET.

In our study, we report several years of experience with mini-invasive surgery for thyroid disease at our institution involving a specialized endocrine surgeon. ET was performed *via* a bilateral areolar approach, and RT was performed *via* a bilateral axillo-breast approach. The previous studies in our center have shown that both approaches have favorable cosmetic effect (3, 15).

In our study, patients in RT group were older than those in ET group. On the one hand, it reflects the increasing acceptance





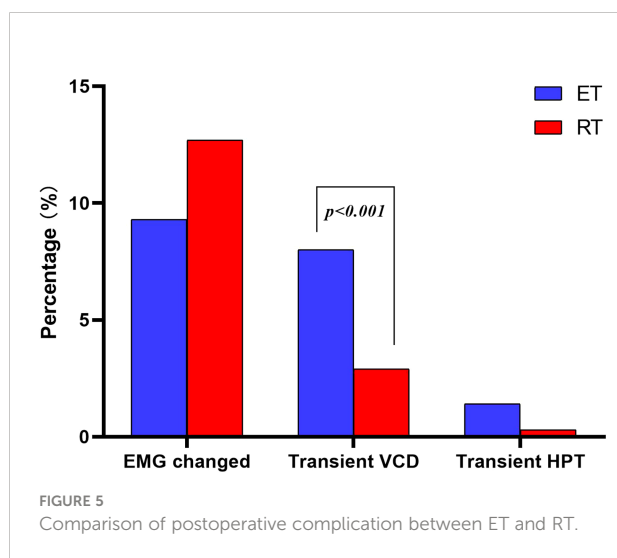
of minimally invasive thyroid surgery, especially robotic thyroid surgery. On the other hand, minimally invasive thyroid surgery is no longer the patent of young women, and has also become the choice of many middle-aged and elderly patients.

We found RT group had 113 operations (28.8%) on overweight patients ( $BMI > 25 \text{ kg/m}^2$ ), and ET group had 44 (9.5%). This was mainly attributed to the technical superiority of robotic surgical system. A study performed in the Korea

reported that BMI was an independent risk factor for prolonged operative time and that the longer operative time was due to the extended times needed for flap dissection (16). But in a retrospective study comparing patients who had undergone the RT-BABA, there was no difference in operative time between patients with BMI below  $25 \text{ kg/m}^2$  and those above  $25 \text{ kg/m}^2$  (17). Regarding pathological results, RT group had more patients with malignant tumor, and patients with thyroiditis. Although there was no statistical difference in the ability of lymph node dissection, the RT group showed an increasing trend in the number of central lymph nodes and positive lymph nodes.

Presently, RT-BABA appears to require a shorter operation time compared with ET-BAA. Similar to other literatures (18, 19), there is an obvious learning curve for RT. The learning curve of our study is 26 cases. However, no obvious learning curve was observed in ET. The total amount of drainage was greater in RT group than because we adopted a strategy of increasing flushing in RT. Although the findings revealed that ET group had similar risk of RLN injury, the incidence of temporary postoperative vocal cord palsy was significantly higher in ET group (8.0%) compared to RT group (2.9%).

The strength of this study is the large sample size. The study was conducted in a center with high volume and established experience in minimally invasive surgery. However, this study has some limitations. It is a monocentric study of a nonrandomized patient series based on a retrospective



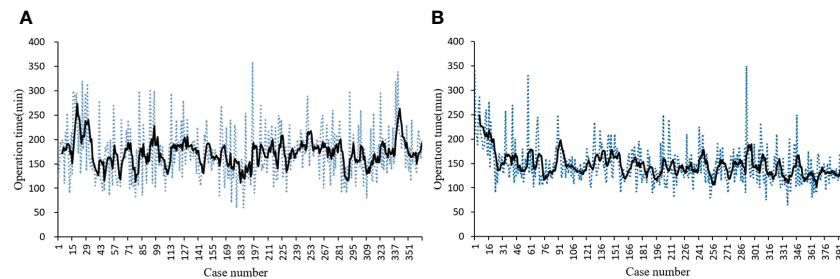


FIGURE 6  
Learning curve. (A) Learning curve for ET-BAA; (B) Learning curve for RT-BABA.

database. Further multicenter prospective randomized studies are needed to confirm our results for a larger number of surgeons in comparable high-volume centers.

In conclusion, the real superiority of RT is seen in more difficult cases, including elderly patients, overweight patients, bilateral thyroidectomy and thyroiditis. In addition, thyroidectomies seem to receive greater benefits from the robotic approach, with a lower complication rate (RLN injury), operative time, hospital stay, learning curve than ET. However, robotic thyroidectomy also has some drawbacks. First, RT is more expensive than ET. Secondly, RT lacks haptic feedback, which places higher demands on the operator's eye-hand coordination. Furthermore, real-time suction cannot be performed unless occupying one robotic arm. It is believed that with the upgrading of technology and the innovation of theory, robotic thyroidectomy will be further promoted.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving human participants were reviewed and approved by This study was approved by the Medical Ethics Committee (protocol no.2019002). The patients/participants provided their written informed consent to participate in this study.

## Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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