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# Cumulative sum analysis for evaluating learning curve of endoscopic lateral neck dissection

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## Abstract

**Objectives** Endoscopic lateral neck dissection (LND) can be a scarless procedure if a surgeon has performed a sufficient number of operations to become skilled at the techniques involved. Here, we examine the learning curve for a surgeon who performed 53 endoscopic LND procedures via chest approach.

**Methods** Surgical outcomes for 53 patients with papillary thyroid carcinoma who underwent endoscopic LND via chest approach between February 2017 and November 2022 were retrospectively reviewed. The surgeon's learning curve was evaluated using a cumulative sum graphic model (CUSUM).

**Results** A CUSUM analysis was applied to 53 patients (10 males, 43 females) with a mean age of 41.4 y who underwent endoscopic LND via chest approach. The best model for the curve was determined to be a third-order polynomial equation as follows: $CUSUM_{OT} = -0.007 \times \text{patient number}^3 - 0.666 \times \text{patient number}^2 + 55.721 \times \text{patient number} - 72.964$. This equation has a high $R^2$ value of 0.929. The peak operative time (OT) occurred at the 30th case. Consequently, the learning curve model was divided into two phases: phase 1 (1–30 cases) and phase 2 (31–53 cases). OT (307.9 ± 63.8 min vs. 232.4 ± 44.2 min, respectively; $p < 0.001$), blood loss (50 mL vs. 20 mL, respectively; $p = 0.001$), and complications (43.3% vs. 13.0%, respectively; $p = 0.038$) decreased significantly in phase 2 compared to phase 1.

**Conclusions** The learning curve of endoscopic LND via chest approach was found to involve 30 cases. With greater experience, the surgery was completed with shorter OT and fewer complications. This approach may be an alternative for patients who desire cosmesis. Furthermore, the present data and experience insights regarding endoscopic LND via chest approach may help other surgeons to pass the learning phase more safely.

**Keywords** Papillary thyroid carcinoma, Endoscopic lateral neck dissection, Chest approach, Learning curve, Cumulative sum graphic model

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## Introduction

In 1996, endoscopic parathyroidectomy was first reported [1]. Since then, various endoscopic and robotic approaches have been developed and improved to achieve less visible scars and better cosmetic results. Most recently, endoscopic and robotic approaches are commonly used to perform total thyroidectomy and central lymph node dissection [2, 3].

Over 30% of papillary thyroid carcinoma (PTC) patients have been diagnosed with cervical lateral lymph node metastasis [4–8]. For these patients, lateral neck dissection (LND) is an effective treatment to improve prognosis [9, 10]. However, complete endoscopic LND is a technically challenging procedure, and has only been reported in a few studies [11–13]. In our previous study, we have demonstrated the feasibility of endoscopic LND via chest approach by summarizing early cases [14].

Due to the complexity and difficulty of performing endoscopic LND, surgeons need sufficient experience with the procedure to attain proficiency. An alternative approach to obtaining surgical experience is to study the learning curve of a procedure. To date, little attention has been focused on the learning curve for endoscopic LND via chest approach.

Cumulative sum (CUSUM) is an analytic technique for detecting change. Here, the CUSUM was applied to evaluate a learning curve for endoscopic LND via chest approach with a graphic model. These data may help other surgical teams' progress through the learning phase more safely and rapidly.

## Materials and methods

### Patients and inclusion criteria

This study was approved by the Institutional Review Board (IRB) for ethics at the Guangdong Provincial Hospital of Traditional Chinese Medicine (Guangdong, China). Clinical data for 53 patients with PTC who underwent endoscopic LND via chest approach at our center between February 2017 and November 2022 were retrospectively assessed. All 53 patients were operated on by the same surgical team, with You Qin serving as the main surgeon. This surgical team completed over 2000 cases of endoscopic thyroidectomy in total. We had extensive experience and stable operative time in endoscopic thyroidectomy before moving on with the endoscopic lateral neck dissection. Inclusion criteria for the present study were: (1) confirmed case of PTC with metastatic lymph nodes at levels II, III, or IV based on ultrasonography, computed tomography, fine needle aspiration cytology, or intra-operative exploration; and (2) patients elected to undergo endoscopic surgery. Exclusion criteria were: (1) invasion of surrounding tissues; (2) level I/V metastatic lymph nodes; (3) distant metastasis; (4) past medical history of neck surgery or radiotherapy; and (5) inability to tolerate anesthesia or surgery.

### Operative procedure

Before surgery, neck ultrasound and CT scans were performed to evaluate the tumor in the thyroid gland and the neck lymph node status for the patient. The pre-surgery TNM stage of the included patients were cT1-3N1bM0.

The position of the patient and surgical team was shown in Fig. 1. Three trocars were needed in this surgery. A 10-mm trocar was set parasternally at nipple level. A 5-mm trocar was set at the 10–11 o'clock position on the left side of the areola, while another 5-mm trocar was set at the 1–2 o'clock position on the right side of the areola (Fig. 2). A 30°angled camera was used during surgery. Besides, the CO2 was insufflated at a pressure of 6 mmHg with high flow. In order to more accurately locate the recurrent laryngeal nerve and parathyroid glands, we used nerve monitoring and carbon nanoparticles during

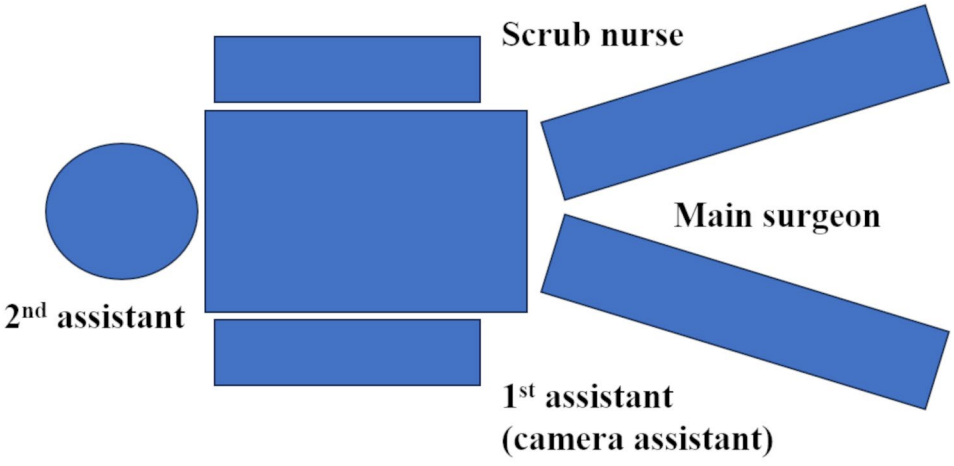



**Fig. 1** The position of the patient and surgical team

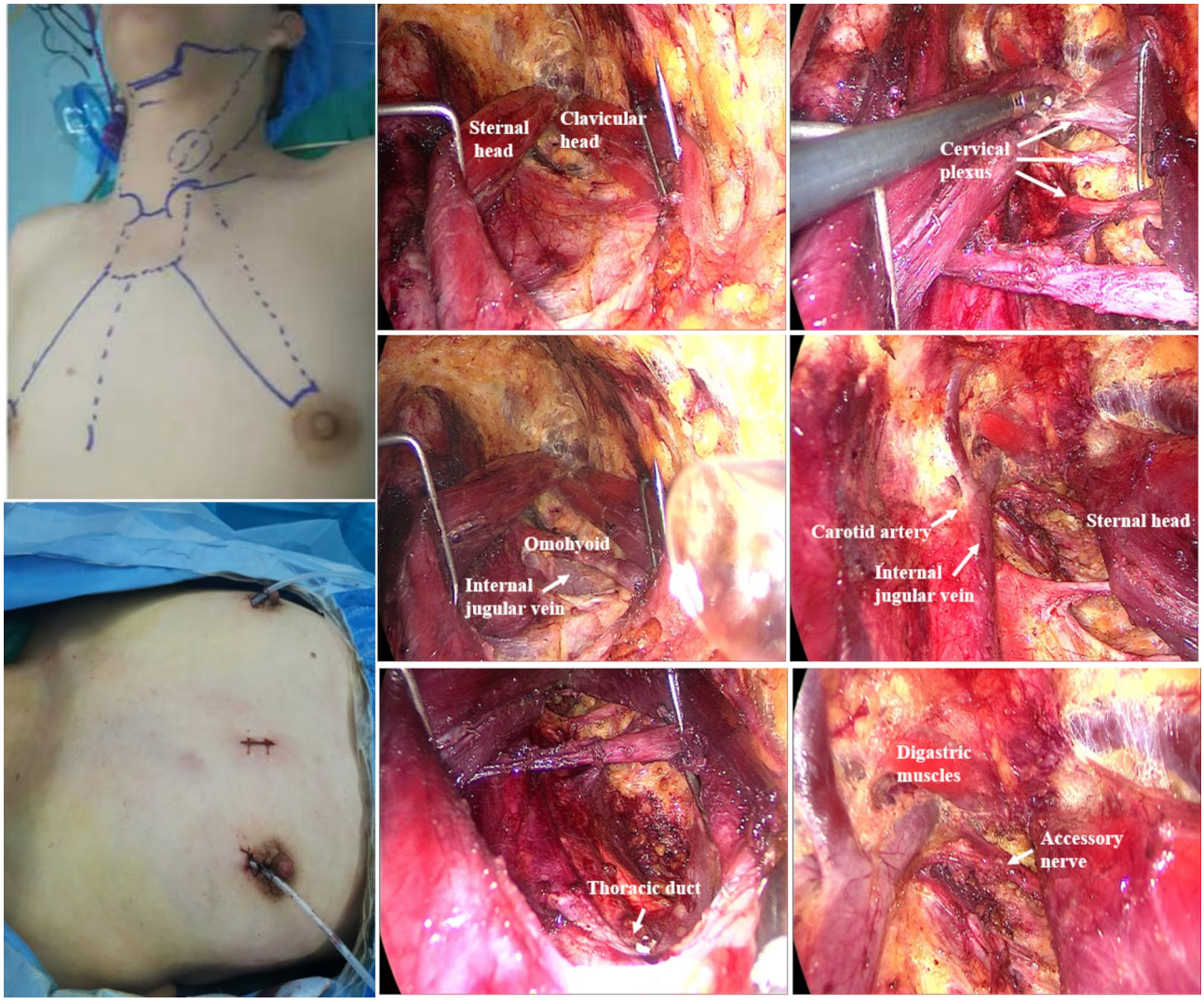



**Fig. 2** Endoscopic LND via chest approach. (**A**) Design of trocar placement before surgery; (**B**) Drainage tube placement after surgery; (**C-H**) Photos taken during surgery

surgery. After establishment of initial working space, we completed total thyroidectomy and central neck dissection at first. Then endoscopic LND started from establishment of working space. The posterior border of the sternocleidomastoid (SCM) and the posterior belly of the digastric muscle were regarded as lateral and superior boundary, respectively. Afterwards, the SCM is incised longitudinally at the clavicular level between its sternal head and clavicular head, extending to the level of the carotid bifurcation superiorly. At this point, the surgical assistants insert two retractors and pull the sternal head and clavicular head on both sides. With the help of retractors, dissection of lymph nodes between the SCM and sternohyoid muscle, exposure of the internal jugular vein (IJV) and omohyoid, dissection of lymph nodes at level IV and III were performed in turn. Subsequently, we change the position of the retractor to expose the space between the cervical anterior muscles and the SCM so that we completed the dissection of lymph nodes at carotid triangle. The final step was dissection of lymph nodes at levels IIa and IIb. The lower edge of the digastric muscle and the posterior border of the SCM were regarded as superior and lateral boundary, respectively. Precautions observed for each surgical step of the endoscopic LND procedure have previously been described [14]. After endoscopic LND, we taken out resected lymph nodes using a specimen bag from the 10-mm trocar. Then the operative field was rinsed to determine no bleeding and drainage tubes were placed. Finally, the operation was completed to close the linea alba cervicalis and chest incisions. It should be noted that all surgical cases included in this study were performed using ultrasonic shears. Previous study has proven that ultrasound shears was more effective at achieving haemostasis [15].

All patients were diagnosed with papillary thyroid carcinoma in final pathological anatomy report and the TNM stage were pT1-3N1bM0. Besides, radioiodine (I131) therapy was administered 3 months after surgery.

### Learning curve analysis

The OT for each patient was documented chronologically from the first case to the last case to evaluate the progress of endoscopic LND. The $CUSUM_{OT}$ for the first patient was calculated according to the difference between the OT of the first patient and the mean OT of all the enrolled patients. The $CUSUM_{OT}$ for the second patient was the $CUSUM_{OT}$ of the first patient plus the difference between the OT of the second patient and the mean OT of all the enrolled patients. Similarly, the $CUSUM_{OT}$ for the remaining patients were determined. CUSUM analysis was used to analyze the learning curve.

### Statistical analysis

Statistical analysis was performed using the Chi-square test or Fisher's exact test or Wilcoxon rank sum test or independent Student's t-test as required. All analyses were considered statistically significant when the *p*-value less than 0.05. SPSS18.0 software was used for statistical analysis.

**Table 1** Clinical outcomes of PTC patients who underwent endoscopic LND via chest approach

| Variable | Value |
|---|---|
| Age | 41.4 ± 12.7 |
| Gender (Female/Male) | 43 / 10 |
| Tumor size (cm) | 1.6 ± 1.0 |
| Hospital stay (d) | 5.7 ± 1.5 |
| Blood loss (mL) | 42.0 ± 44.2 |
| Operative time (min) | 275.1 ± 67.3 |
| Transient hypocalcemia | 24 |
| Permanent hypocalcemia | 1 |
| Vocal cord paralysis | 0 |
| No. of retrieved lymph nodes | 30.5 ± 11.3 |
| Lateral | 21.9 ± 8.9 |
| Central | 8.7 ± 6.5 |
| Complications of lateral neck dissection | 17 |
| Lymphatic leakage | 2 |
| Cervical plexus injury[a] | 8 |
| Accessory nerve injury | 3 |
| Hypoglossal nerve injury | 1 |
| Internal jugular vein injury | 3 |
| Other complications[b] | 0 |

[a] Identification of cervical plexus injury is based on intraoperative cervical plexus transection; [b] including phrenic nerve injury, carotid artery injury and postoperative bleeding

## Results

### Patient cohort and surgery outcomes

All 53 of the enrolled PTC patients successfully underwent endoscopic LND (including endoscopic total thyroidectomy and central neck dissection). In addition, none required conversion to open surgery. Of the 53 patients, 43 (81.1%) were female and the average age of the cohort was 41.4±12.7 y. Mean tumor size was 1.6±1.0 cm and the numbers of lymph nodes retrieved from the lateral and central compartments were 21.9±8.9 and 8.7±6.5, respectively. The average OT for all of the cases was 275.1±67.3 min. Mean blood loss was 42.0±44.2 mL.

Postoperatively, the mean hospital stay after surgery was 5.7±1.5 d. Lymphatic leakage and accessory nerve injury were observed in 2 (3.8%) and 3 (5.7%) patients, respectively. Eight patients (15.1%) had cervical plexus injury, one patient (1.9%) had hypoglossal nerve injury, and three patients (5.7%) had IJV injury. Transient and permanent hypocalcemia occurred in 24 patients and 1 patient, respectively. Based on the Clavien–Dindo classification, most complications in this study are grade I complications. It should be mentioned that both IJV injury and accessory nerve injury are repaired endoscopically during surgery. Nerve injury and hypocalcemia are classified as a grade II complication. Neurotrophic drugs and calcium are routinely used postoperatively in these cases. Vocal cord paralysis, postoperative bleeding, carotid artery injury, or phrenic nerve injury were not reported (Table 1). During the follow-up period of 38.8±15.7 months, all the patients remain survival and tumor recurrence was not detected.

### Learning curve analysis

OTs for the individual PTC patients were plotted according to the chronological sequence of their cases (Fig. 3). CUSUM analysis was subsequently performed to establish a learning curve for endoscopic LND based on these cases (Fig. 4). The best model for the curve was determined to be a third-order polynomial equation as follows: $CUSUM_{OT} = -0.007 \times \text{patient number}^3 - 0.666 \times \text{patient number}^2 + 55.721 \times \text{patient number} - 72.964$. This equation has a high $R^2$ value of 0.929. The $CUSUM_{OT}$ revealed a curve exhibiting a positive slope from the initial case to case 30, while a negative slope after case 31 was observed. Thus, the curve helped identify a learning phase (cases 1–30) and a mature phase (cases 31–53), according to slope.

### Differences in clinical outcome according to Phases determined by CUSUM learning curve analysis

Clinical outcomes between phase 1 and phase 2 are presented in Table 2. The OT in phase 1 was 307.9±63.8 min, which was significantly longer than that in phase 2

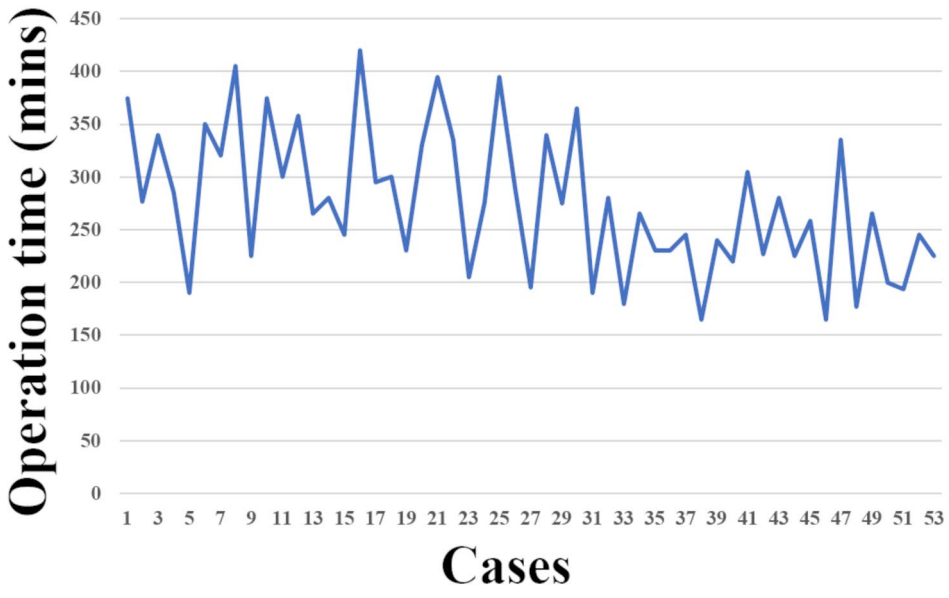



**Fig. 3** OT of endoscopic LND plotted according to cases examined in chronological sequence

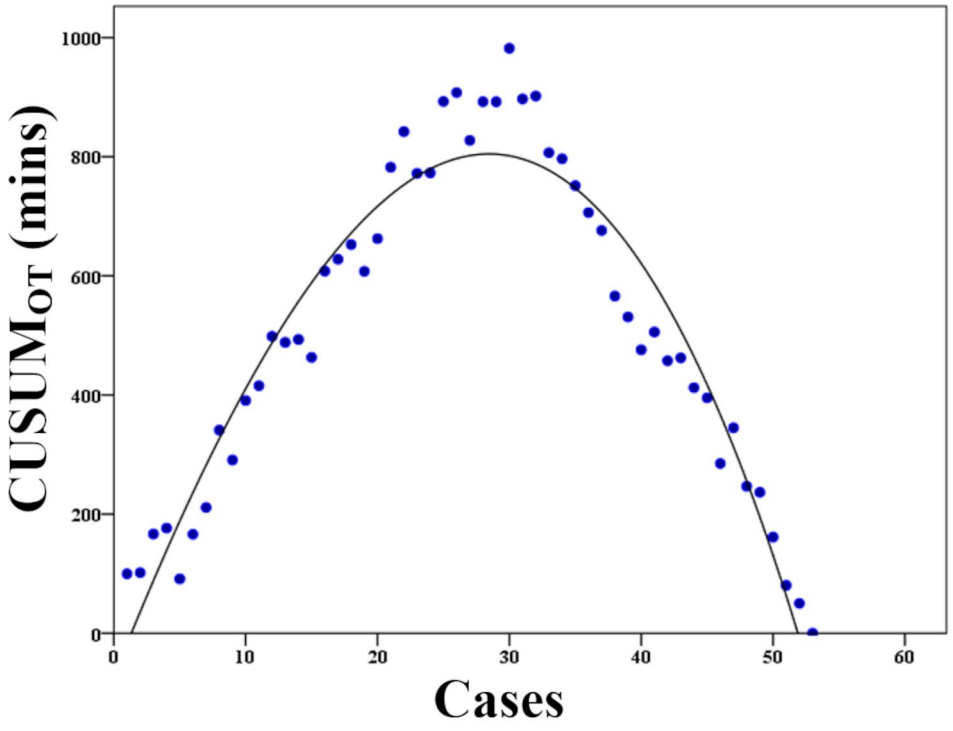



**Fig. 4** Learning curve for endoscopic LND according to the CUSUM method

(232.4±44.2 min). The amount of blood loss in phase 1 was 50 ml, and that in phase 2 was 20 ml, and the difference was statistically significant. As for complications of lateral neck dissection, of the 30 patients in phase 1, 13 developed complications. One patient had lymphatic leakage, 7 patients had cervical plexus injury, 3 patients had accessory nerve injury, 1 patient had hypoglossal nerve injury and 2 patients had internal jugular vein injury. Complications occurred in 3 of the 23 patients in phase 2, including 1 case of lymphatic leakage, 1 case of cervical plexus injury, and 1 case of jugular vein injury. The complication rate of phase 1 was significantly higher than that of phase 2.

**Table 2** Comparison of clinical outcomes between phases

| Variable | Phase 1 ($n=30$) | Phase 2 ($n=23$) | *p*-value |
|---|---|---|---|
| Age | 41.0 ± 12.8 | 42.0 ± 12.9 | 0.782 |
| Gender (Female/Male) | 23 / 7 | 20 / 3 | 0.552 |
| Tumor size (cm) | 1.15 (0.2, 4.3) | 1.2 (0.15, 3) | 0.336 |
| Hospital stay (d) | 5.5 (4, 11) | 5 (3, 9) | 0.089 |
| Blood loss (mL) | **50 (10, 300)** | **20 (5, 100)** | **0.001** |
| Operative time (min) | **307.9 ± 63.8** | **232.4 ± 44.2** | **< 0.001** |
| Transient hypocalcemia | 14 | 10 | 0.817 |
| Permanent hypocalcemia | 1 | 0 | 1.000 |
| Vocal cord paralysis | 0 | 0 | / |
| No. of retrieved lymph nodes | 32.1 ± 12.0 | 28.3 ± 10.3 | 0.221 |
| Lateral | 22.9 ± 8.8 | 20.6 ± 9.0 | 0.348 |
| Central | 9.2 ± 7.3 | 8.0 ± 5.4 | 0.523 |
| Complications of lateral neck dissection | **13**[a] | **3** | **0.038** |
| Lymphatic leakage | 1 | 1 | 1.000 |
| Cervical plexus injury | 7 | 1 | 0.127 |
| Accessory nerve injury | 3 | 0 | 0.249 |
| Hypoglossal nerve injury | 1 | 0 | 1.000 |
| Internal jugular vein injury | 2 | 1 | 1.000 |

[a] One patient experienced cervical plexus injury and accessory nerve injury

In addition, no significant differences in age, gender, tumor size, hospital stay after surgery, transient hypocalcemia, permanent hypocalcemia, vocal cord paralysis and/or number of retrieved lymph nodes between the two phases were observed.

## Discussion

Neck appearance after open LND has been shown to negatively impact patient quality of life [16, 17]. Therefore, many different approaches for achieving "scarless" LND have been reported, including robotic approaches [18–20] and endoscopic approaches [21, 22]. However, due to the high cost of robotic instruments, the former have had limited application. In contrast, endoscopic LND via a chest approach is currently the most popular method among endoscopic approaches [11, 14, 21, 23]. Since the learning curve has not been examined for the latter approach, CUSUM was applied in this study. The mature phase on the CUSUM curve indicates that the learning curve for the procedure has been overcome. Moreover, it was observed that surgeons needed to have completed 30 cases to gain proficiency with endoscopic LND.

When comparing phase 1 and phase 2 of the CUSUM curve in the present study, the incidence of complications and volume of blood loss decreased significantly in phase 2. Thus, a sufficient number of surgical cases (in this study, 30 cases) are needed for surgeons to achieve shorter OTs and reduce possible complications. While the OT in phase 1 was longer, there was no significant difference in the number of retrieved lymph nodes in phase 1 compared with phase 2. In addition, recurrence did not occur during phase 1. Taken together, these data reveal that even for beginners, as long as they exhibit sufficient patience and adherence to the techniques required to complete LND, oncological safety can be achieved during the learning phase.

Yan et al. [12] previously reported 155 cases of endoscopic LND via chest approach. The OT in the present study (275.1±67.3 min) versus in Yan's study (278.2±38.6 min), as well as the number of retrieved lateral lymph nodes (21.9±8.9 vs. 22.9±9.9, respectively), are similar. We suggested that 275 min is too long to be attractive to patients and surgeons. In this study, the mean operative time in mature phase was 232.4±44.2 min, significantly shorter than that in the learning phase (307.9±63.8 min). Therefore, we firmly believe that with the accumulation of experience, operative time can be reduced. In addition, the incidence of lymphatic leakage (3.8% vs. 2.6%, respectively) and accessory nerve injury (5.7% vs. 3.9%, respectively) in the present study were slighter higher than in Yan's study. We hypothesize that a lack of experience during the learning phase leads to a high incidence of complications. As the number of surgical cases increases, the incidence of complications and blood loss should gradually decrease. The conclusions of this study support this hypothesis.

Regarding the management of postoperative complications, we provide some of our methods for reference. For lymphatic leakage, we usually apply a pressure bandage to the site of leakage. If this conservative treatment fails, ligation of the thoracic duct is performed. When dealing with IJV injuries, we use a 5−0 prolene suture for endoscopic vascular repair. While this is a rather challenging approach, all three cases of IJV injuries have been

successfully repaired. Regarding nerve injury, the primary treatment is administration of neurotrophic drugs following surgery. Use of prolene suture to perform nerve repair endoscopically has also been undertaken. However, neither of these methods have achieved satisfactory results.

Our further suggestions regarding endoscopic LND are as follows. First, from early experience, we conclude that the risk of complications increases during hemostasis. However, as proficiency improves, both blood loss and complications are significantly reduced. Therefore, we advocate that surgeons in their early experience pay attention to the protection of thick vessels, such as facial vein, IJV, and communicating branches of the internal and external jugular veins. Second, a fixed surgical team can facilitate advancing the learning curve as safely as possible. Third, the establishment of surgical space is of great significance for the successful completion of endoscopic LND. The establishment of space requires the surgeon to be familiar with anatomy, especially the meticulous technique of capsular dissection. In addition, the surgical space should be large enough. The space range is dissected to the lateral edge of the posterior border of the sternocleidomastoid and to the superior edge of the posterior belly of the digastric muscle. Besides, it is necessary to fully free the sternocleidomastoid muscle to facilitate the dissection of lymph nodes below the muscle. Finally, we suggest that endoscopic LND should be performed at centers with experience in endoscopic thyroidectomy via chest approach. The procedures required for endoscopic LND are complex and difficult. It is nearly impossible for a completely inexperienced surgeon to calmly respond to emergencies that may arise during surgery, and patient safety must be of utmost concern. Serious complications can also affect the confidence of a surgeon while completing the operation. Therefore, endoscopic thyroidectomy should be learned first. We suggested that a surgeon should have at least 100 cases of experience in endoscopic thyroidectomy before moving on with the endoscopic lateral neck dissection. Dr. You Qin performed the first endoscopic thyroid surgery via chest approach in 2006, and is also an expert in endoscopic gastrointestinal surgery and endoscopic hernia surgery. Thus, he possesses proficient techniques in endoscopic surgery.

Some limitations of our study should be acknowledged: First of all, in our experience, higher BMI with short neck or fatty tissue does complicate the dissection and prolong the operation time. A long, slender neck is the "ideal" patient's neck for surgeons. Unfortunately, we did not collect relevant data in the early stage, so we cannot make further analysis and discussion at present. We believe that further limiting the external factors that influence the outcome can result in a more reliable learning curve. Second, this is a single-center study with a specific number of cases, and our main surgeon had extensive experience with endoscopic thyroidectomy. Given differences in sample size, variability in surgeon experience, and interference from external factors that affect outcomes, this learning curve may not be replicated by other surgeons or applicable to all clinical scenarios. Third, the study was retrospective. We hope to design prospective studies in the future and include open LND cases to verify the safety and effectiveness of endoscopic LND.

In summary, endoscopic LND requires a fixed surgical team to accumulate experience, so as to improve the feasibility and safety of surgery. Based on the present data, we estimate that a main surgeon with previous experience in endoscopic thyroid surgery may be able to overcome the learning curve of endoscopic LND after 30 cases. It is anticipated that our experience may help other surgical teams to progress through the learning curve of endoscopic LND more smoothly and safely.

#### Abbreviations

| | |
|---|---|
| LND | Lateral neck dissection |
| CUSUM | Cumulative sum |
| OT | Operative time |
| PTC | Papillary thyroid carcinoma |
| IRB | Institutional Review Board |
| SCM | Sternocleidomastoid |
| IJV | Internal jugular vein |

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#### Author contributions
ZXC and XRZ designed the concept of this study. JMD, YC, JBC, FSP, ZHL and XBZ collected the datasets. ZXC and XRZ analyzed the data and wrote the manuscript. BX and YQ revised the manuscript. All authors have read and approved the manuscript.

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#### Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

### Declarations

#### Ethics approval and consent to participate
The study protocol was approved by the Institutional Review Board for ethics at the Guangdong Provincial Hospital of Traditional Chinese Medicine. The research reported in this paper was in compliance with the Helsinki Declaration. Informed Consent to participate was given by all patients.

#### Consent for publication
Written consent to participate included permission to access specimens and clinical details, and to publish findings.

#### Competing interests
The authors declare no competing interests.

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