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Safety and efficacy of using a short tunnel versus a standard tunnel for peroral endoscopic myotomy for Ling type IIc and III achalasia: a retrospective study

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Abstract

Background and AIMS Peroral endoscopic myotomy (POEM) for patients with Ling type IIc and III achalasia is associated with a high rate of adverse events. Decreasing the lengths of the tunnel and myotomy may be an effective method for reducing this rate. This study aimed to assess the safety and efficacy of using a short tunnel versus a standard tunnel for POEM.

Method We conducted a retrospective study of 126 patients with Ling type IIc and III achalasia undergoing POEM from January 2013 to December 2016. These patients were divided into a short tunnel group ($n=63$) and a standard tunnel group ($n=63$). The clinical efficacy of the procedure, operative time, length of the tunnel, length of myotomy and rates of adverse events were analyzed.

Results The preoperative features were similar in both groups. No significant differences were found between the two groups in Eckardt score change, lower esophageal sphincter (LES) basal pressure or residual pressure after POEM (all $p>0.05$). The mean lengths of the tunnel and myotomy were 7.6 cm and 4.8 cm, respectively, in the short tunnel group and 11.8 cm and 9.2 cm, respectively, in the standard tunnel group. The mean operative time of the short tunnel group was significantly shorter than that of the standard tunnel group (39.5 min vs. 48.2 min, respectively, $p=0.001$). A significant difference was observed in the rates of procedure-related adverse events between the two groups (9.5% vs. 33.3%, $p=0.001$).

Conclusion The efficacy of the procedure was comparable between the two groups. However, the short tunnel significantly reduced the operation time and the rates of procedure-related adverse events.

Keywords Peroral endoscopic myotomy · Achalasia · Ling classification · Short tunnel

Achalasia is a functional disease that involves esophageal dynamic dysfunction of unknown cause and is characterized by aperistalsis of the esophageal body and failure of the lower esophageal sphincter (LES) to relax, with various symptoms that include dysphagia, weight loss, regurgitation, and chest pain [1]. At present, peroral endoscopic myotomy (POEM) is widely accepted and used as a safe and efficient therapy [2]. The clinical remission rate is as high as 89–100% [3, 4]. However, not all patients with achalasia are eligible to undergo POEM. To explore the indications and contradictions of POEM, the Ling classification was proposed by Linghu in 2011 and published in 2013 [5]. This system is based on the morphological characteristics of the middle and the lower parts of the esophageal lumen because the morphology of the esophageal wall is a key point during performance of the tunnel technique.

According to the Ling classification, standard submucosal tunneling is more difficult to establish in patients with Ling type IIc and III achalasia than in those with other types; moreover, these patients have a higher rate of adverse events than other patients because the esophageal lumen is significantly dilated and tortuous [6]. Therefore,

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it is urgent to develop new technology to solve this problem. Establishing submucosal tunneling and myotomy are critical and are the most challenging and time-consuming steps of the POEM procedure; these steps are closely correlated to the rate of adverse events. A technique modification is needed that reduces the surgical difficulty, shortens the operating time, and decreases the number of operative adverse events while avoiding the need for additional tools and expenses.

Traditionally, a standard tunnel that is approximately 12 cm long [10 cm above and 2 cm below the gastroesophageal junction (GEJ)] is necessary [7]. It is usually very difficult to cross the wide crescent-like structure or diverticulum of patients with Ling type IIc and III achalasia to establish a standard tunnel. Establishment of a short tunnel on the relatively flat esophageal wall is a new method to extend the indications of POEM. The length of the short tunnel is approximately 6–8 cm (4–6 cm above and 1–2 cm below the GEJ).

No study has reported the safety and efficacy of using a short tunnel in POEM for Ling type IIc and III achalasia. Hence, we conducted a retrospective study to compare the safety and efficacy of the short tunnel with those of a standard tunnel to provide a new alternative method of preforming POEM for patients whose esophagi are severely dilated and tortuous.

Patients and methods

Patients

We performed a retrospective, single-center study of 126 patients with Ling type IIc and III achalasia who successfully underwent POEM at PLA General Hospital from January 2013 to December 2016. The study was conducted under the approval of the ethics committee of PLA General Hospital, and informed consent was obtained from all patients.

Whether a short tunnel or a standard tunnel was used for each patient had been decided before the operation. The procedures in both groups were largely performed contemporaneously; a few patients in the first several months of 2013 all underwent the procedure using the standard tunnel. All of the procedures in both groups were performed by two experienced endoscopists (Enqiang Linghu and Ningli Chai), and no difference in the preference for one type of tunnel over the other was indicated. The primary outcome of the study was clinical efficacy at follow-up, which was evaluated by the Eckardt score. The secondary outcomes were procedure-related adverse events, the average and LES basal pressure or LES residual pressures, and procedure-related parameters such as operative time, tunnel length and myotomy length.

Adverse events

Gas-related adverse events were divided into two basic types: major adverse events and minor adverse events. Major events were defined as conditions that resulted in vital sign instability or an intensive care unit stay or required other salvage procedures (such as needle decompression or surgery). Minor adverse events were defined as adverse events that did not call for clinical interventions and did not qualify as major adverse events.

Ling classification

Achalasia was classified according to the Ling classification system: Ling I, smooth without a multi-ring, crescent-like structure or diverticulum structure; Ling II, with a multi-ring or crescent-like structure but without a diverticulum structure; and Ling III, with a diverticular structure. Ling II was further classified into three subtypes: IIa (with a multi-ring structure), IIb (with a crescent-like structure and the midpoint of its inner edge being no larger than 1/3 of the esophageal lumen) and Ling IIc (with a crescent-like structure and the midpoint of its inner edge being larger than one-third of the esophageal lumen).

High-resolution manometry

All patients should complete high-resolution manometry (HRM) before undergoing POEM, which is the gold standard of achalasia treatment [8]. In contrast, using the basal and residual LES pressures before and after POEM, we can measure the improvement of esophageal manometry. This step is similar to that reported in previous studies [8]. We also used the ManoScan instrument (Sierra Scientific Instruments, Inc., Los Angeles, CA, United States) to record the data.

POEM procedure

POEM was performed after the patients fasted for 48 h and underwent EGD to ensure that no food residue remained in the esophageal lumen. During the procedure, patients were kept in a supine position with the right shoulder elevated, and general anesthesia was administered under electrocardiographic (ECG), respiration, blood pressure, and oxygen saturation monitoring. Carbon dioxide gas was used for insufflation with a CO_2 insufflator (UCR; Olympus) during all procedures.

Most patients of both groups received a reverse T entry incision and progressive myotomy during the procedure;

therefore, we next focus on the technical modifications of our procedures and provide a step-by-step explanation (Fig. 1).

Step 1 Reverse T entry incision. First, a 0.8–1.0 cm transversal entry incision was performed with a Triangle Tip Knife (OLKD-640L, Olympus Medical Systems Co, Tokyo, Japan) in an approximately straight path with few turns. Subsequently, a 0.8–1.0 cm longitudinal entry incision was made from the central spot of the transversal entry to the anal side.

Step 2 Establishment of a short submucosal tunnel or a standard tunnel. A short submucosal tunnel had a length of only 6–8 cm, whereas the length of the standard tunnel was 10–14 cm. The posterior wall of the esophagus was always taken into consideration because of the low bending degree. The submucosa on the left and right sides of the entry point was slightly dissected.

Step 3 Progressive myotomy. Only part of the circular muscle was cut using the Triangle Tip Knife (OLYMPUS, KD-640L) at the starting point of the myotomy. Next, the myotomy depth was progressively increased from the oral side to the anal side. Finally, myotomy of the full-thickness muscle was achieved at the cardia.

Step 4 Zippered closure of the reverse T entry. Both the longitudinal and transversal parts of the T entry were longitudinally closed sequentially. The entire closure procedure was similar to pulling up the zipper on a jacket. Generally, 4–7 titanium clips were used.

A video (Video 1 in online supplementary materials) shows the use of a short tunnel with POEM in a patient with Ling type IIc achalasia.

Postoperative treatment

X-ray or chest and abdominal computed tomography (CT) was performed to evaluate gas-related adverse events. All patients were kept fasting for 3 days after the procedure. A liquid diet was started for an additional day. Antibiotics and proton pump inhibitor (PPI) were administered intravenously during the NPO period. An oral PPI was required for at least 4 weeks subsequently. Patients were followed up at 3 months, 6 months, and 1 year after POEM and yearly thereafter. Endoscopy, high-resolution manometry, and 24-h esophageal pH monitoring were performed, if possible.

Statistical analysis

Data were retrospectively collected, and the pre-procedure and post-procedure parameters were compared. Continuous variables were analyzed by Student's *t* test and described as the mean ± standard deviation or median with range. Chi-square tests were used to compare categorical variables. A p value of < 0.05 was considered statistically significant. Data were analyzed using IBM SPSS version 24.0 statistical software (IBM Corporation, Armonk, NY).

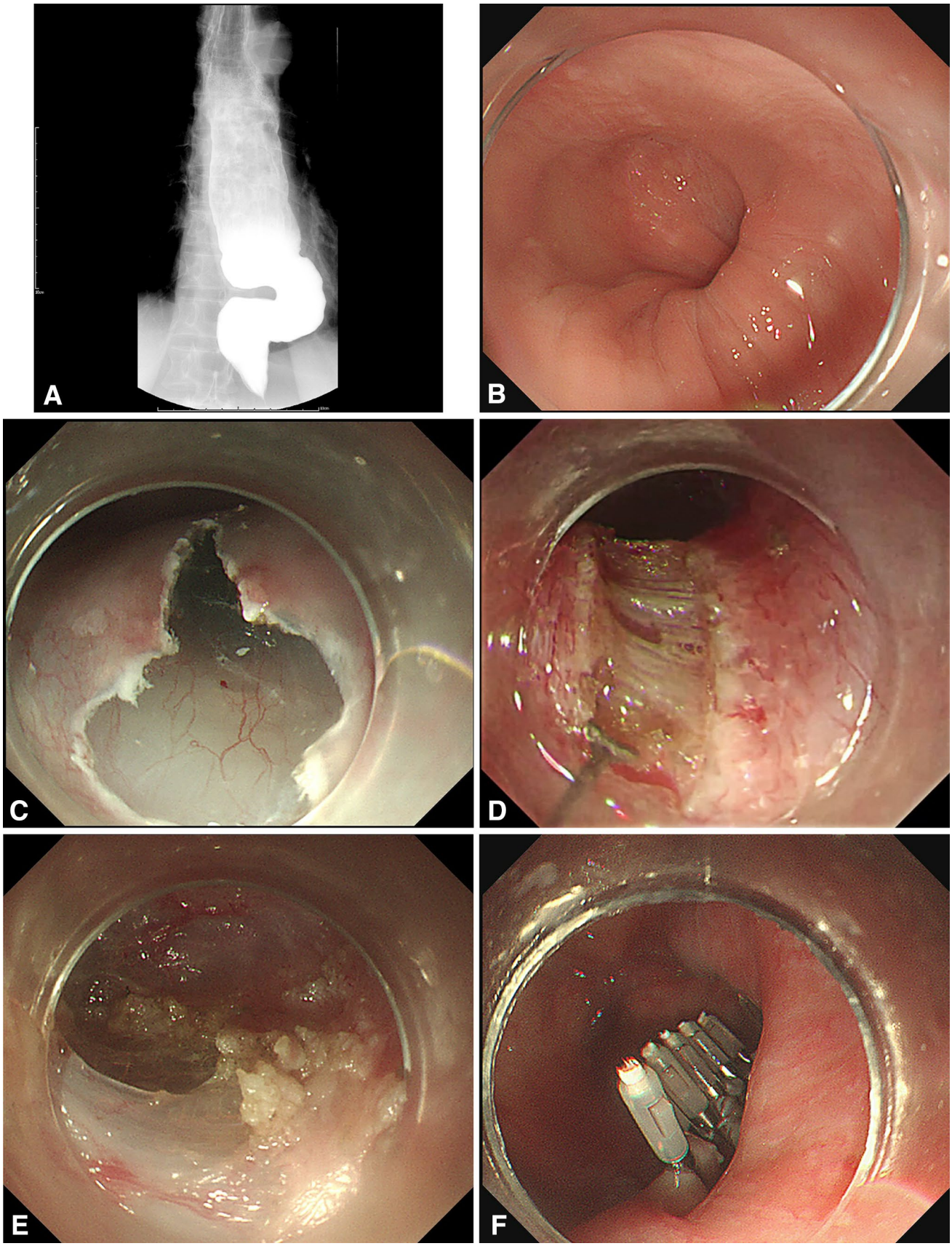
Results

Clinical characteristics of the two groups

In total, 126 patients were enrolled in the study, including 54 males and 72 females, aged from 16 to 79 years (mean 47.6 years). Sixty-three patients received the short tunnel, and the other 63 patients received the standard tunnel. The average disease course of the short tunnel group was 9.4 years (range 1 month–40 years) and that of the standard tunnel group was also 9.4 years (range 1 month–30 years). Before undergoing POEM, 23 patients (36.5%) in the short tunnel group had received previous treatments (13 with balloon dilation, eight with Botox injection, one with Heller myotomy, and one with balloon dilation + Botox injection), whereas 19 patients (30.2%) in the standard group had received previous treatments (ten with balloon dilation, three with Botox injection, one with temporary stenting, one with Heller myotomy, two with balloon dilation + Botox injection, and two with Botox injection + temporary stenting). The Ling classification in the short tunnel group consisted of 53 Ling type IIc patients and 10 Ling type III patients; the Ling classification in the standard group consisted of 54 and 9 Ling type IIc and III patients, respectively. Chicago II was the most common type in both groups (71.4% vs. 82.5%). No significant difference was observed between the 2 groups with regard to gender, age, duration of symptoms, previous treatment, Ling classification or Chicago classification. The clinical characteristics of the two groups are listed in Table 1.

Comparison of procedure-related parameters

As shown in Table 2, patients in both groups successfully underwent POEM without any serious adverse events. The mean operative time of the short tunnel group [39.5 min (range 21–74 min)] was significantly shorter than that of the standard tunnel group [49.2 min [range 23–120 min)], $p = 0.001$. In the short tunnel group, the mean lengths of the tunnel and myotomy were 7.6 cm (6–8 cm) and 4.8 cm (3–6 cm), respectively, whereas those of the standard group were 11.8 cm (10–14 cm) ($p = 0.000$) and 9.2 cm (8–11 cm) ($p = 0.000$), respectively. Progressive full-thickness myotomy was performed in 88.9% (56 cases) of patients in the short tunnel group and 79.4% (50 cases) of patients in the standard tunnel group. The types of myotomy in the remaining patients in the short and standard tunnel groups included inner circular muscle myotomy (0 vs. 2 cases), circular muscle incision + balloon plasty (6 vs 8. cases), and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◂**Fig. 1** Peroral endoscopic myotomy procedures in a patient with Ling type IIc achalasia. **A** The barium swallow test showed a dilated and tortuous esophagus. **B** Endoscopy revealed a crescent-like structure, and the midpoint of the inner edge was larger than one-third of the esophageal lumen. **C** A reverse T entry incision was performed. **D** Partial circular muscle was cut at the starting point of the myotomy. **E** The end of the progressive myotomy. **F** Closure of the tunnel entry with clips

full-thickness muscle myotomy (1 vs. 3 cases). Although the types of myotomy differed among the patients, no significant difference was observed between the two groups ($p=0.142$).

Procedure-related adverse events

Adverse events occurred in 6 (9.5%) patients in the short tunnel group and 21 (33.3%) patients in the standard tunnel group, representing a significant difference ($p=0.001$). In the short tunnel group, four patients (6.3%) exhibited mucosal perforations, all of which were closed with titanium clips and porcine fibrin glue; three of the patients were given nasogastric tubes. Two patients (3.2%) exhibited pneumoperitoneum and were treated by abdominocentesis with a 10-ml syringe. In the standard tunnel group, five patients (7.9%) had mucosal perforation; one patient (1.6%) had pneumothorax; three patients (4.8%) had pneumoperitoneum; 14 patients had subcutaneous emphysema (22.2%), and one patient (1.6%) had pneumomediastinum; all of these events were resolved successfully using the methods employed for the short tunnel group. Among the 14 patients with subcutaneous emphysema, four patients required needle decompression: one developed subcutaneous emphysema and pneumoperitoneum simultaneously, one developed subcutaneous emphysema and pneumothorax simultaneously, and two patients developed severe subcutaneous emphysema. The remaining ten patients did not require clinical interventions. The pneumothorax patient, whose right lung was 80% compressed, was instantly relieved after exhausting 1440 ml of gas. The incidence of the major adverse events of the short tunnel group was lower than that of the standard tunnel group (3.2% vs. 9.5%); no significant difference was observed between the two groups. No massive hemorrhage occurred during the procedure, and no delayed bleeding occurred in either group. One patient developed mucosal injury, limited left pleural effusion and a low fever, and recovered without administration of further positive treatment. Both of these patients were in the standard tunnel group.

Six (9.5%) and 7 (11.1%) patients in the short tunnel and standard tunnel group, respectively, developed a fever on the second day after POEM. One patient in the standard tunnel group experienced bacteremia due to *Propionibacterium acnes*; this patient's temperature returned to normal within 2 days after receiving a third-generation cephalosporin. Procedure-related adverse events are listed in Table 2.

Symptom relief and manometry outcomes

Fifty-seven patients (90.5%) in the short tunnel group received symptom score follow-up, with a mean follow-up time of 20.1 months (6–48 months); in the standard group, 56 patients (88.9%) received follow-up, with a mean follow-up time of 23.6 months (6–48 months) (Table 3). Based on a postoperative Eckardt score of <3, which was defined as successful treatment, no significant difference was observed in the therapeutic success between the two groups (98.2% vs. 98.2%, $p=1.00$). Treatment failure in two patients was mainly caused by regurgitation after surgery; the regurgitation score of both patients was 2, although the dysphagia symptoms were relieved. Both groups of patients showed a significant improvement in the post-treatment Eckardt score. The mean pre/post-treatment differences in the Eckardt scores of the short and standard tunnel groups were 6.7 (2–10) and 6.3 (2–10), respectively, with no significant difference between groups ($p=0.225$).

During follow-up, 14 patients (11.1%) had symptomatic gastroesophageal reflux (six in the short tunnel group and eight in the standard tunnel group), which was relieved in all patients after oral PPI administration. The incidence of reflux esophagitis did not significantly differ between the two groups (9.5% vs. 12.7%, $p=0.571$).

Postoperative manometry was performed in 30.2% of patients in the short tunnel group and 28.6% of patients in the standard group at 3 months postoperatively. The obvious improvement of clinical symptoms and the discomfort related to the manometry procedure are the main reasons that many patients did not receive manometry during follow-up. After treatment, the LES basal and residual pressures of both groups were significantly decreased, and the changes were all statistically significant (all $p<0.01$). No significant difference was found in the degree of decrease of either LES basal pressure or residual pressure between groups ($p=0.832$, $p=0.867$).

Discussion

Inoue et al. reported that patients with obvious esophageal distortion or tortuousness should not be treated by endoscopists with limited practice in POEM [7]. Linghu et al. proposed the Ling classification in 2011, which divided the patients into three types according to the middle and lower esophageal morphology, for the selection of appropriate candidates for POEM and suggested that Ling IIc and Ling III patients are indicated for POEM only when the crescent-like structure or the diverticular structure is not in the

Table 1 Clinical characteristics of the 2 groups

	Short tunnel group ($n=63$)	Standard tunnel group ($n=63$)	p value
Sex, male/female (n)	24/39	30/33	0.280
Age, mean (range) (years)	49.3 (19–79)	45.9 (16–72)	0.196
Duration of symptoms, mean (range) (years)	9.4 (0.1–40.0)	9.4 (0.3–30)	0.762
Previous treatment [n (%)]	23 (36.5)	19 (30.2)	0.359
Balloon dilation	13 (20.6)	10 (15.9)	
Botox injection	8 (12.7)	3 (4.8)	
Temporary stenting	0 (0)	1 (1.6)	
Heller myotomy	1 (1.6)	1 (1.6)	
Balloon dilation + Botox injection	1 (1.6)	2 (3.2)	
Botox injection + temporary stenting	0 (0)	2 (3.2)	
Ling classification [n (%)]			0.803
IIc	53 (84.1)	54 (85.7)	
III	10 (15.9)	9 (14.3)	
Chicago subtype of achalasia [n (%)]			0.292
I	16 (25.4)	9 (14.3)	
II	45 (71.4)	52 (82.5)	
III	2 (3.2)	2 (3.2)	

Table 2 Comparisons of procedure-related parameters and adverse events between the two groups

	Short tunnel group ($n=63$)	Standard tunnel group ($n=63$)	p value
Types of myotomy [n (%)]			0.142
Inner circular muscle myotomy	0 (0)	2 (3.2)	
Full-thickness muscle myotomy	6 (9.5)	8 (12.7)	
Circular muscle incision + balloon plasty	1 (1.6)	3 (4.8)	
Progressive full-thickness myotomy	56 (88.9)	50 (79.4)	
Operating time, mean (range) (min)	39.5 (21–74)	49.2 (23–120)	0.001
Tunnel length, mean (range) (cm)	7.6 (6–8)	11.8 (10–14)	0.000
Myotomy length, mean (range) (cm)			
Esophageal	2.9 (2–4)	6.9 (5–9)	0.000
Gastric	2.0 (1–3)	2.3 (2–4)	0.000
Total	4.8 (3–6)	9.2 (8–11)	0.000
All intraoperative adverse events [n (%)]	6 (9.5)	21 (33.3)	0.001
Mucosal injury	4 (6.3)	5 (7.9)	1.000
Major gas-related adverse events	2 (3.2)	6 (9.5)	0.273
Pneumothorax	0 (0)	1 (1.6)	
Pneumoperitoneum	2 (3.2)	3 (4.8)	
Pneumomediastinum	0 (0)	1 (1.6)	
Subcutaneous emphysema	0 (0)	4 (22.2)	
Minor gas-related adverse events			0.001
Subcutaneous emphysema	0 (0)	10 (15.9)	
Fever (temperature > 38.0 °C) [n (%)]	6 (9.5)	7 (11.1)	0.770

route of tunnel establishment. Chai et al. confirmed that the Ling classification is beneficial for the preoperative safety assessment of POEM and found that Ling type IIc patients had the highest incidences of both gas-related adverse events and mucosal injury [6].

Traditionally, patients with a significantly dilated and tortuous esophagus have been recommended to receive laparoscopic Heller myotomy or esophagectomy by some surgeons, as they believe myotomy will not improve emptying [9–12]. However, the high rates of mortality and adverse

Table 3 Comparisons of Eckardt scores and HRM between the two groups

	Short tunnel group ($n=63$)	Standard tunnel group ($n=63$)	p value
Follow-up period, mean (range) (months)	20.1 (6 to 48)	23.6 (6 to 48)	0.059
Symptom score follow-up rate [n (%)]	57 (90.5)	56 (88.9)	0.770
Treatment success (Eckardt score ≤ 3) [n (%)]	56 (98.2)	55 (98.2)	1.000
Eckardt score, mean (range)			
Pretreatment	7.9 (5 to 11)	7.3 (4 to 11)	0.096
Post-treatment	1.1 (0 to 4)	1.0 (0 to 4)	0.297
Pre–post	6.7 (2 to 10)	6.3 (2 to 10)	0.225
HRM follow-up rate [n (%)]	19 (30.2)	18 (28.6)	0.845
LES basal pressure, mean (range) (mmHg)			
Pretreatment	27.8 (0.7 to 57.7)	29.6 (9.6 to 50.4)	0.682
Post-treatment	15.6 (1.5 to 35.7)	17.7 (3.0 to 38.8)	0.438
Pre–post	12.2 (− 7.2 to 30.8)	11.9 (− 9.7 to 38.4)	0.832
LES residual pressure, mean (range) (mmHg)			
Pretreatment	24.0 (1.0 to 42.8)	21.9 (12.8 to 41.0)	0.331
Post-treatment	12.2 (− 7.2 to 30.8)	11.9 (− 9.7 to 38.4)	0.682
Pre–post	12.0 (− 0.4 to 26.5)	10.6 (− 3.4 to 20.9)	0.867

events cannot be ignored [13, 14]. Recently, Hu et al. and Lv et al. separately reported that POEM is safe and effective for the treatment of sigmoid-type achalasia, but the incidences of mucosal perforations and gas-related adverse events in POEM are higher in this type than in the non-sigmoid type [15, 16]. Therefore, our study is important for exploring the indications of POEM and reducing the rates of adverse events in patients with Ling type IIc and III achalasia.

The tunnel length must be sufficient to provide space for myotomy; the length of the myotomy was at least 8–10 cm and 2–3 cm below the GEJ to ensure clinical efficacy. Patients with Chicago classification III are recommended to undergo a longer myotomy by The International Peroral Endoscopic Myotomy Survey [17]. However, establishing submucosal tunnels in patients with Ling type IIc and III achalasia is difficult and is often accompanied by a high rate of adverse events. The short tunnel was used to solve these problems; the lengths of the tunnel and myotomy were approximately 6–8 cm and 3–6 cm (2–4 cm above and 1–2 cm below the GEJ), respectively. It is necessary to find a fairly straight path with few turns to establish a short tunnel, and the posterior wall of the esophagus is always taken into consideration. The endoscope should be rotated to make mucosa in the left, and the muscularis propria in the right, during submucosal tunneling, and the dissecting plane should always go perpendicular with circular muscular layer to avoid losing the direction. Additionally, we made a reverse T entry incision, which combined the advantages of longitudinal incision and transverse incision. Not only can it allow easier entry and exit of the tunnel for the endoscope and provide more space and freedom for endoscopy in the tunnel, but it can also decrease the difficulty of zippered closure [18]. We preferred to use progressive full-thickness myotomy, which was performed by gradually increasing the depth of the myotomy from a circular myotomy until a full-thickness myotomy is achieved in the cardia. Theoretically, this approach can reduce the clinical reflux complication rate and the length of myotomy [19]. This is the first study to assess the safety and efficacy of a short tunnel compared to a standard tunnel. Our investigation shows that using a short tunnel in POEM for Ling type IIc and III achalasia is feasible, safe and efficacious.

The therapeutic success rates of the two groups were both 98.2%, which were similar to those in previous reports. The Eckardt score and LES pressure of the two groups were significantly reduced after POEM compared to the pretreatment values. However, the data of the two groups did not significantly differ. A previous study showed that the procedure time for patients with a dilated and tortuous esophagus was longer than 1 h [15, 16]. However, in our study, the operating time of both groups was < 50 min. Moreover, a short tunnel decreased the operating time relative to that obtained with a standard tunnel (39.5 min vs. 49.2 min, $p=0.001$). Therefore, we believe that the short tunnel is feasible and that its clinical efficacy is similar to that of the standard tunnel.

Regarding adverse events, the mucosal perforation rates were similar (6.3% vs. 7.9%); however, both rates were lower than those in a previous study [6], which illustrated that surgical experience played an important role. Mucosal perforation was mainly caused by the dilated esophageal morphology and severe fibrosis. All of these cases were closed with titanium clips and porcine fibrin glue; four of the patients were administered a nasogastric tube, and no clinical complications occurred. The incidence of gas-related adverse

events was significantly lower in the short tunnel group than in the standard group, whereas the reflux complication rate was not significantly different between groups. The lack of a significant difference in the rate of major adverse events between the two groups can be attributed to the following: the low incidence of major adverse events during POEM, most of these events requiring no salvage procedures due to advances in the technology, and the relatively small sample size. Wang et al. reported that gas-related adverse events were associated with air accumulation within the tunnel [20]. Because the length of the short tunnel is significantly shorter than the conventional length and the extent of tissue injury is decreased during the operation, the rates of pneumothorax, pneumoperitoneum and other adverse events may, in theory, decrease. Establishing a short submucosal tunnel on a relatively straight wall of the esophagus can not only avoid bypassing the serious esophageal twisting but also allows easier location of the cardia. The outcome of our study supports this opinion.

Our study had several limitations. One limitation was its retrospective design and potential selection bias, as our hospital is a tertiary referral center. Other limitations of the study included a lack of manometry, timed-barium swallow, and 24-h pH testing after POEM in some patients. Future prospective multicenter, randomized trials with larger samples and longer follow-up periods are warranted.

Conclusion

POEM is a safe and efficient treatment for patients with Ling type IIc and III achalasia. Therapeutic success was achieved in 98.2% of the cases. No significant differences between the two groups were observed in the changes in the Eckardt score, LES basal pressure or residual pressure after POEM. Compared to the standard tunnel group, the short tunnel group had a shorter operative time and fewer procedure-related adverse events.

Compliance with ethical standards

Disclosures Longsong Li, Ningli Chai, Enqiang Linghu, Zhenjuan Li, Chen Du, Wengang Zhang, Jiale Zou, Ying Xiong, Xiaobin Zhang, and Ping Tang have no conflicts of interest or financial ties to disclose.

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