

# Transumbilical thoracic sympathectomy with an ultrathin flexible endoscope in a series of 38 patients

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## Abstract

**Background** The newest trend in the field of thoracic surgery, thoracic natural orifice transluminal endoscopic surgery (NOTES), is still in the early stages of development and limited to animal experiments. Transumbilical endoscopic surgery could work as a viable intermediate step before pure NOTES. We describe our experiences performing transumbilical–diaphragmatic thoracic sympathectomy with an ultrathin flexible endoscope for palmar and axillary hyperhidrosis in human patients.

**Methods** From April 2010 to January 2012, a total of 38 patients underwent transumbilical–diaphragmatic thoracic sympathectomy. Through the incision in the umbilicus, a newly developed long trocar was inserted into the abdominal cavity. An ultrathin endoscope was introduced through the long trocar and then passed through the rigid incision made in the left and right diaphragm and into the thoracic cavity. The ganglion was ablated at the desired thoracic level.

**Results** Sympathectomy was performed successfully in all patients. Mean operation time was  $68 \pm 16$  (range, 48–107) minutes. There was no mortality and no conversion to open surgery during the operation of any patient. At a median follow-up of 11 (range, 4–12) months after surgery, no diaphragmatic hernia was observed. The rate of palmar hyperhidrosis and axillary hyperhidrosis resolution was 100 and 75 %, respectively.

**Conclusions** Transumbilical endoscopic thoracic sympathectomy is technically feasible and safe, which has the possible advantages of pure NOTES and can be performed in routine clinical practice.

**Keywords** Endoscopic · Natural orifice · Surgery · Thoracic sympathectomy · Transumbilical

Li-Huan Zhu and Wen Wang contributed equally to this study, and both should be considered first author.

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Thoracoscopic sympathetic ganglion resection via 2–4 chest incisions is the only effective and sustainable surgical method for the treatment of palmar and axillary hyperhidrosis (AH) [1, 2]. However, some patients may have postoperative wound-related pain and substantial scarring from the chest incisions [3]. Thoracic natural orifice transluminal endoscopic surgery (NOTES) has recently attracted great interest for its potential to make chest wall incisions unnecessary, decrease postoperative pain, and improve cosmesis. Thoracic pure NOTES (P-NOTES) involves, transesophageal, transgastric, transvesical, or transtracheal endoscopic access to the chest cavity without any parietal incision. So far, most of the procedures have been limited to animal experiments [3–9]. Concerns about closure problems and increased risk of infection impede the widespread adoption of P-NOTES in clinical application.

Embryonic natural orifice transumbilical endoscopic surgery (E-NOTES) is described as an alternative and

competing technology to P-NOTES; its approach is through the umbilicus, the “natural orifice” of the embryonic period. By concealing the solitary incision in the umbilicus, which serves as a “nature scar,” one can achieve the same objectives as P-NOTES. By avoiding the problems of access, closure, and infection, E-NOTES appears to be safer than P-NOTES and offers better cosmesis than does conventional endoscopic surgery [10–12].

In this article, we report our initial experiences of thoracic sympathectomy in humans with an ultrathin flexible endoscope using transumbilical–diaphragmatic access for the treatment of palmar and AH.

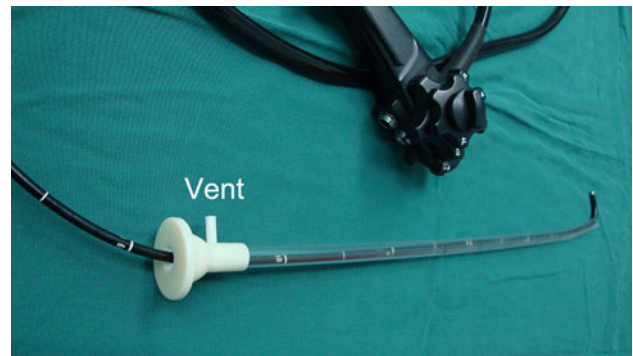
## Patients and methods

### Patient selection

Institutional review board approval was provided for this study. Thirty-eight patients underwent surgery for severe primary palmar hyperhidrosis (PH) with or without primary AH. Criteria for inclusion in the study were: severe primary PH that significantly blocks their daily life and work; inefficacy of conservative treatment such as topical agents, and iontophoresis without relief; patient motivation and determination; and absence of previous thoracic or abdominal surgery. Criteria for exclusion were hyperhidrosis caused by hyperthyroidism; neurotic anxiety; the existence of diseases such as cardiac diseases, pulmonary infections, or pleural or peritoneal diseases that could increase surgical risk; and high risk for general anesthesia.

### Operative technique

Under general anesthesia, the patients were placed in the supine position with the arms abducted and intubated with a dual lumen endotracheal tube. A palmar temperature probe (Skin Temperature Probe TT05A; TGC Instrument Company, Shanghai, China) was placed on the thenar eminence and taped in place. Before the operation, the palmar temperature was kept below 30 °C by immersing the hand in water at 4 °C. Before skin incision, baseline palmar temperature was recorded. A 7 mm incision was made within the umbilicus, and a newly developed long trocar (equipment designed by the authors; 60 cm length, 6 mm internal diameter, 0.5 mm wall thickness) (Fig. 1) was inserted as a guide for an ultrathin flexible endoscope (GIF-XP260N; outer diameter 5.0 mm; instrumental channel diameter 2.0 mm; Olympus Medical Systems, Tokyo, Japan). The trocar was also used to establish pneumoperitoneum, which was achieved by insufflating the abdominal cavity with carbon dioxide at 10 mm Hg (Fig. 2). The anesthetized patients were tilted from a supine horizontal to a 30° reverse Trendelenburg position and then tilted 30° to

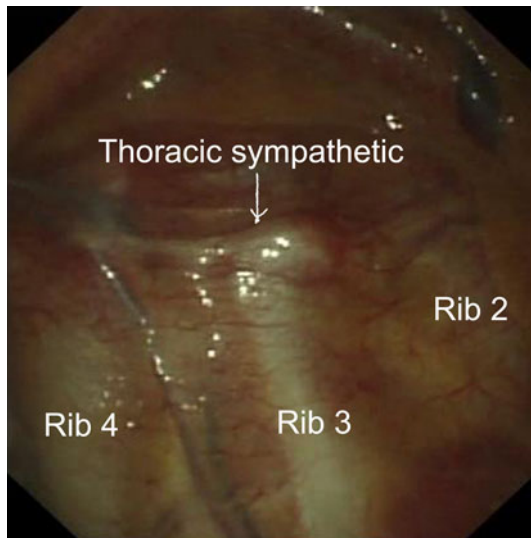


**Fig. 1** A newly developed long trocar. It guides and stabilizes the endoscope body as it reaches the operating position, which is also used to establish pneumoperitoneum

the right. The site of transdiaphragmatic approach was carefully chosen on the muscular pars of the left diaphragmatic dome. Under right lung unilateral ventilation, a 5 mm incision was made with a needle knife (Alton Medical Equipment C., Ltd., Shanghai, China) introduced through the working channel of the gastroscope on the left diaphragm. Subsequently, the needle knife served as a guide wire for insertion of the endoscope into the left thoracic cavity while the pneumoperitoneum was released. The sympathetic chain was identified along the neck of the ribs close to the costovertebral junctions, and the ganglions were localized in the corresponding intercostal space. Generally, the first rib was not visualized in the thoracic cavity, so the uppermost rib that could be seen was the second rib, followed by the third and fourth ribs (Fig. 3). Hot biopsy forceps (Alton Medical Equipment C., Ltd., Shanghai, China) were used to grasp and ablate the T3 ganglia for palmar-only hyperhidrosis and to ablate the T3–T4 ganglia for palmar AH; the nerve of Kuntz



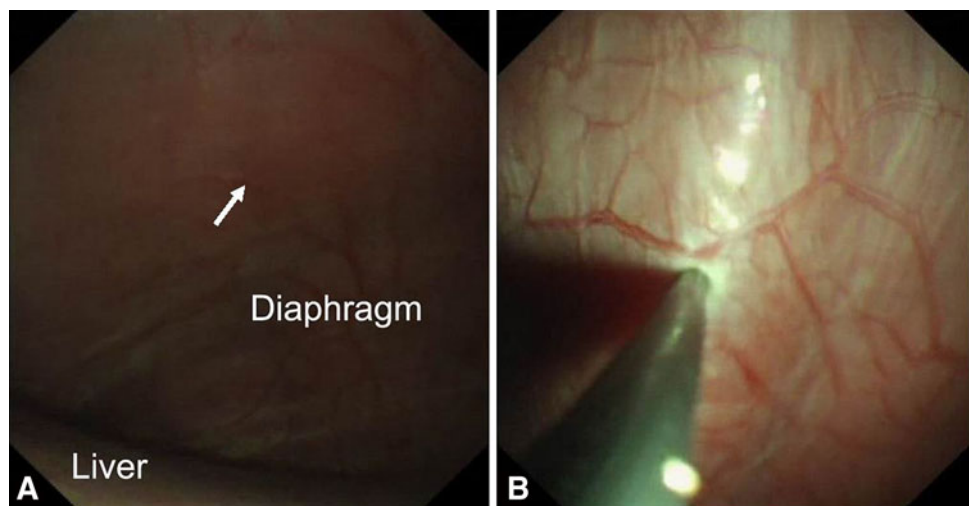
**Fig. 2** The operation setting. The ultrathin endoscope was introduced into the peritoneal cavity through a newly developed long trocar



**Fig. 3** An endoscopic image of the thoracic cavity. The sympathetic chain was identified running along the neck of the ribs close to the costovertebral junctions

was also interrupted (Fig. 4). A palmar temperature increase of 1.5 °C confirmed adequate sympathectomy. Then the endoscope was recurved to check that no hemorrhaging had been caused by the incision in the diaphragm. The left lung was reinflated when the endoscope was withdrawn to the abdominal cavity. The operating table was then tilted 30° to the left. The trocar guided the ultrathin endoscope to the right diaphragm (Fig. 5), and the procedure was performed on the right side in a similar manner. After suctioning the remaining air in the abdominal cavity, the endoscope was withdrawn from the abdominal cavity, and the umbilical incision was closed with an interrupted suture. In this study, neither a chest tube nor an abdominal tube was placed in any patient.

**Fig. 5 A** An endoscopic image of the *right* diaphragm; the *white arrow* indicates the location of the incision.  
**B** A *needle knife* was used to incise the *right* diaphragm



**Fig. 4** The T3 ganglia was grasped and ablated with hot biopsy forceps

### Clinical outcome and follow-up

Operative data, including duration of operation and intra-operative and postoperative complications, were recorded. Discharge was allowed after exclusion of pneumothorax by roentgenography on the first postoperative day. All study patients were scheduled for follow-up hospital visits or telephone calls by one of the authors. The follow-up data collected included resolution of symptoms, postoperative complications, severity of compensatory sweating, and incidence of symptom recurrence.

### Results

During the study period, 38 patients were selected for a sympathectomy as a result of their hyperhidrosis, including 22 men and 16 women with a mean age of 24 (range, 18–38) years. Of these, 24 patients (63.2 %) experienced

**Table 1** Characteristics of patients undergoing transumbilical–diaphragmatic thoracic sympathectomy

Characteristic	Value
No. of patients	38
Age (years), median (range)	24 (18–38)
Female gender, <i>n</i> (%)	16 (42 %)
Affected hyperhidrotic area, <i>n</i> (%)	
Hands alone	14 (36.8 %)
Hands and axilla	24 (63.2 %)

concomitant palmar and AH, and 14 (36.8 %) experienced palmar hyperhidrosis alone. Patient characteristics are listed in Table 1.

Transumbilical–diaphragmatic thoracic sympathectomy was successfully performed in all the patients with a mean operation time of  $68 \pm 16$  (range, 48–107) minutes. No patients had pleural adhesions. There was no conversion to thoracotomy or thoracoscopic surgery during any patient's operation, and there was no evidence of thoracic or abdominal organ injury during the operation. Intraoperative bleeding occurred in 2 patients (5.3 %) when making the incision of the diaphragm, which was successfully controlled by electric coagulation using hot biopsy forceps. In one patient (a 38-year-old man), the right T4 ganglia was covered by lung tissue. We successfully exposed the operative field by rotating the gastroscope and hot biopsy forceps to push away the lung tissue. A small pneumothorax was found on the postoperative chest X-ray in 5 patients (13.2 %), but all resolved completely with conservative treatment. Most patients were discharged from the hospital the day after surgery.

**Table 2** Operative details of patients undergoing transumbilical–diaphragmatic thoracic sympathectomy

Characteristic	Value
Level of sympathectomy	
T3	14 (36.8 %)
T3 + T4	24 (63.2 %)
Operating details	
Operating time (min)	$68 \pm 16$ (48–107)
Increase of palmar temperature (°C)	$2.8 \pm 0.7$ (1.5–4.1)
Postoperative hospital stay (days)	$1.8 \pm 1$ (1–4)
Intraoperative complications	
Bleeding	2 (5.3 %)
Complication immediately after surgery	
Pneumothorax	5 (13.2 %)
Pleural effusion	1 (2.6 %)

Data are presented as *n* (%) or mean  $\pm$  standard deviation (range)

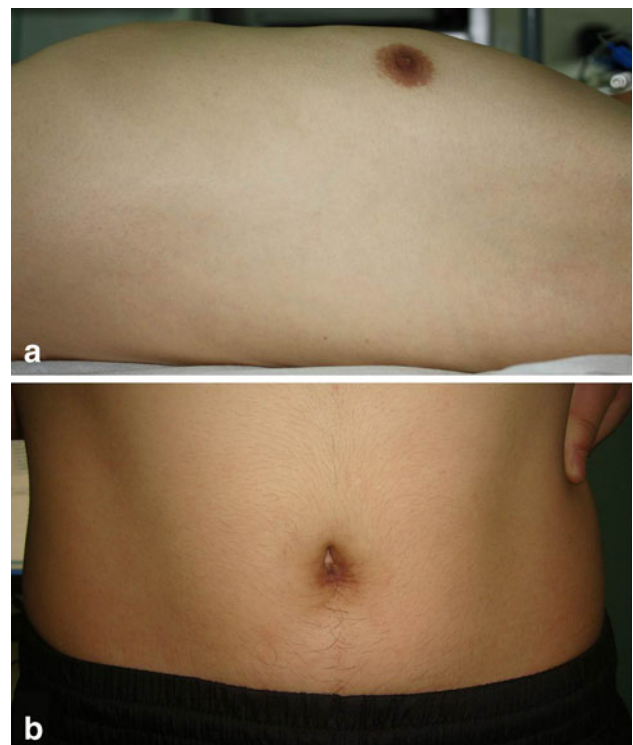
T3 third thoracic level, T4 fourth thoracic level

**Table 3** Postoperative follow-up of patients undergoing transumbilical–diaphragmatic thoracic sympathectomy

Characteristic	PH, <i>n</i> (%)	AH, <i>n</i> (%)
Surgical result of patient		
Complete resolution	38 (100 %)	18 (75.0 %)
Significant improvement	0	4 (16.7 %)
Minimal improvement	0	2 (8.3 %)
Recurrence	0	–
CH	6 (16.8 %)	–
Diaphragmatic hernia	0	–
Horner syndrome	0	–

PH palmar hyperhidrosis, AH axillary hyperhidrosis, CH compensatory hyperhidrosis

Follow-up was 100 % complete (median, 11 months; range, 4–12 months). There was no mortality, no diaphragmatic hernia, and no Horner syndrome. Pleural effusion was diagnosed in one patient 10 days after discharge, which resolved after a single thoracentesis, and no recurrence was detected (Table 2). PH resolved completely on both sides of all patients. AH was completely improved in 18 patients (75.0 %), significantly improved in 4 (16.7 %), and minimally improved in 2 (8.3 %). Compensatory hyperhidrosis (CH) was noticed in 6 patients (15.8 %) (Table 3). All patients were satisfied with the

**Fig. 6** A postoperative image of the abdominal wall of a patient 6 weeks after surgery. **A** There is no surgical scar on the chest. **B** The intraumbilical incision is hidden in the umbilicus

cosmetic results of the surgical incision (Fig. 6), and they were without residual wound-related pain.

## Discussion

Thoracoscopy is the most frequently used diagnostic and therapeutic method for the surgical management of thoracic diseases. Chronic postoperative problems, including chronic pain, numbness, and dysesthesia, are found in 31.4 % of patients [13]. The main explanation for these problems is the trauma experienced by the thoracic wall when the trocars are introduced into the intercostal space. Thoracic NOTES are emerging as alternatives to the classic transthoracic endoscopic surgery with the advantages of avoiding intercostal neuralgia and visible scarring on the surface of the body. A wide variety of natural orifice approaches to the thoracic cavity has been described, including transtracheal [6], transesophageal [3, 5, 7, 14], transgastric–diaphragmatic [15], and transvesical–diaphragmatic [4]. Turner et al. [3] even conducted an animal study to perform endoscopic thoracic sympathetic trunk resection via the esophagus. However, the well-known problems of P-NOTES, such as safe enterotomy creation, infection prevention, tissue manipulation, and, primarily, safe and secure closure of perforations, are major concerns when attempting to access the chest cavity transluminally. That is why most of P-NOTES have not been implemented clinically. It is clear that there is a long way before the pure natural orifice may be used as a pathway to perform thoracic-related surgery [16].

As a step toward P-NOTES, various surgical procedures, including hybrid NOTES cholecystectomy [17], single-incision laparoscopic surgery [12, 18], transvaginal surgery with rigid endoscopes [19], and transumbilical surgery with flexible endoscopes [20]—all adopting the concept of scarless surgery—have recently been integrated into routine clinical medicine, but the embryonic natural orifice transumbilical endoscopic surgery seems to be most feasible. With the intra-abdominal entry point hidden in the umbilicus, E-NOTES is nearly scarless, and it avoids almost all existing problems associated with the P-NOTES technique.

We reported our experience that transumbilical thoracic sympathectomy with an ultrathin flexible endoscope using an ultralong trocar in a series of 38 patients. Our technique was also highly successful in controlling PH and AH, with success rates of 100 and 75 %, respectively. The results are in keeping with previous reports of thoracoscopic sympathectomy [21–23]. CH is the most troublesome complication of sympathectomy [24], which the literature describes as occurring at a rate of 3–98 % [25, 26]. This wide variability in the incidence of CH may be attributable to heterogeneous patient populations, different surgical procedures, or, more

importantly, to a variety of definitions of CH [2]. In our experience, CH occurred in 15.8 % of patients. The use of ablation versus resection may result in fewer cases of CH. Likewise, the division of the chain below the T2 ganglion probably has contributed to this significant decrease in CH as well [27]. Recurrent hyperhidrosis is another potential side effect from hyperhidrosis surgery [2]. Incidence rates vary considerably and have been described as ranging 0–65 % [28, 29]. In our study, there was no clinical recurrence of hyperhidrosis observed within the follow-up period. One possible reason is that the sympathetic ganglion was exactly ablated; another possible reason is that the follow-up time of our study was too short. All these results imply that compared with thoracoscopic sympathectomy, our technique does not compromise the therapeutic effects. Additionally, transumbilical thoracic sympathectomy has several potential advantages. First, this novel procedure obviates the necessity of chest incision, avoiding the chronic chest wound pain associated with traditional thoracoscopic sympathectomy. Second, the scar of the 7-mm incision is invisible within the umbilicus, so the procedure has the same cosmetic result as P-NOTES. Third, the transumbilical access avoids the risk of esophageal puncture-site fistula and mediastinitis—the shortcomings of transesophageal endoscopic thoracic sympathetic ganglionectomy. As a result, it greatly reduces the surgical difficulty of the procedure.

The critical step of the study was making the appropriate choice for the site of the diaphragmatic incision. In our study, the anterior costophrenic angle was selected as the incision site, which provided the following advantages: convenience for the gastroscope to enter into the thoracic cavity, locate the target organ, and perform the surgical operation; avoidance of large blood vessels in the diaphragm; and provision of an ample distance from the heart and pericardium. As the needle knife penetrated the diaphragm, the abdominal positive-pressure gas entered the thoracic cavity and pushed away the lung tissue, preventing it from being injured.

Compared with laparoscopy or thoracoscopy, the ultrathin endoscope is more flexible, making it more capable of torque, retroflexion, rotation, and tip deflection. Its smaller diameter allows for a smaller umbilical incision, providing better cosmetic results. The incision in the diaphragm is only 5 mm, so there is no worry about the occurrence of diaphragmatic hernia. Nevertheless, several limitations to the practical utilization of ultrathin endoscope should be noted. First, it is too thin and soft, lacking sufficient support when it enters the abdominal cavity, thus hindering accurate positioning. (We used an ultralong trocar to solve this problem; the trocar guides and stabilizes the endoscope body as it reaches the operating position.) Second, light intensity and resolution of the ultrathin endoscope is lower than that of the traditional thoracoscopy endoscope,

making it difficult to obtain clear, distant-view endoscopic images and restricting the depth of the operative field. Third, the use of instruments for therapeutic procedures is restricted because of the small diameter of the instrument channel (2 mm). Last, there is currently no effective device to deal with blood loss and pulmonary adhesions. As a result, a patient with severe pulmonary adhesions was not a candidate for the procedure.

The limitations of this study are the small number of patients and a short follow-up time. A larger study cohort with a longer follow-up is required to evaluate the long-term results of this technique.

## Conclusions

To our knowledge, these are the first clinical applications of the trans umbilicus approach with an ultrathin flexible endoscope in the thoracic environment. This study demonstrates that transumbilical–diaphragmatic thoracic sympathectomy is technically feasible and safe, and it eliminates the chest incision. This study adds to the accumulated experience for posterior transvaginal–diaphragmatic- or transcolonic–diaphragmatic-approach thoracic operations; it is a step forward to pure thoracic NOTES. The further advantage of this approach ought to be confirmed by randomized clinical trials.

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