



# Elective use of an uncuffed small-bore cricothyrotomy tube with balloon occlusion of the subglottic airway

## Utilisation d'une sonde de cricothyrotomie à petit calibre sans ballonnet avec occlusion sous-glottique par ballonnet en chirurgie réglée

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### Abstract

**Purpose** To conduct a qualitative observational study on positive pressure ventilation through a percutaneous uncuffed small-bore cricothyrotomy tube with balloon occlusion of the subglottic airway to minimize supraglottic leak.

**Clinical features** Ten consecutive procedures were performed in the nine men enrolled in this study. The demographics of the participants were: aged 50–73 yr, weight 48–87 kg, American Society of Anesthesiologists class I–II, and scheduled for endoscopic submucosal dissection via flexible endoscopy for en bloc resection of superficial meso- and hypopharyngeal cancer. The airway was initially secured with a supraglottic airway (SGA) under sevoflurane-based anesthesia, and a cricothyrotomy was then performed using a Portex<sup>®</sup> Minitrach II uncuffed

cricothyrotomy tube (4-mm internal diameter). Following SGA removal, a Coopdech<sup>®</sup> bronchial blocker was orally or nasally inserted, and the balloon was inflated to occlude the trachea immediately beneath the glottis. The ventilator setting was initially based on observation of chest motion and end-tidal carbon dioxide tension and then readjusted according to arterial blood gas levels. All procedures were completed within a median time of 149 min. Effective ventilation was achieved in all patients despite mild hypercapnia (PaCO<sub>2</sub> of 58 mmHg at maximum) in some patients. SpO<sub>2</sub> levels were maintained at ≥ 98%.

**Conclusion** This technique provides effective intraoperative ventilation and easy endoscopic access, and it countermeasures against the likely complication of postoperative laryngeal edema. Moreover, there is no need for conventional tracheostomy or prolonged intubation. This approach establishes a curative and less invasive pharyngeal cancer therapy. Certain adverse outcomes can be avoided, including impaired speech and swallowing, possible delayed closure of the stoma, or a compromised cosmetic outcome.

**Author contributions** Takashi Suzuki, the principal investigator, conceived the study design, supervised data collection, and drafted the manuscript. Haruo Ikeda was involved in the design of the study. Taito Iwamoto, Hitomi Sano, and Megumi Hashimoto were involved in data acquisition. Megumi Hashimoto and Katsunori Oe provided critical input into the interpretation of studies and the early versions of the manuscript. Haruhiro Inoue and Kazuyuki Serada made intellectual contributions to the manuscript.

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### Résumé

**Objectif** Réaliser une étude observationnelle qualitative sur la ventilation en pression positive via une sonde percutanée de cricothyrotomie à petit calibre sans ballonnet avec occlusion sous-glottique par ballonnet afin de minimiser les fuites supra-glottiques.

**Éléments cliniques** Dix interventions traditionnelles ont été réalisées auprès des neuf hommes participant à cette étude. Les données démographiques des participants étaient les suivantes: âge 50–73 ans, poids 48–87 kg, classe I–II selon l'American Society of Anesthesiologists, et

devant subir une dissection sous-muqueuse endoscopique par endoscopie souple pour une résection en bloc de cancers méso- et hypopharyngés superficiels. Les voies aériennes ont d'abord été maintenues à l'aide d'un dispositif supraglottique sous une anesthésie à base de sévoflurane, et une cricothyrotomie a ensuite été réalisée à l'aide d'une sonde de cricothyrotomie sans ballonnet Portex<sup>®</sup> Minitrach II (diamètre interne 4 mm). Après retrait du dispositif supraglottique, un bloqueur bronchique Coopdech<sup>®</sup> a été inséré par voie orale ou nasale, et le ballonnet a été gonflé afin de bloquer la trachée immédiatement sous la glotte. Le réglage du ventilateur était d'abord fondé sur l'observation des mouvements du thorax et la tension de dioxyde de carbone télé-expiratoire, puis réajusté en fonction des gaz sanguins artériels. Toutes les interventions ont été réalisées dans un temps moyen de 149 min. Une ventilation efficace a été mise en place chez tous les patients malgré une légère hypercapnie ( $\text{PaCO}_2$  de 58 mmHg au maximum) chez quelques patients. Les niveaux de  $\text{SpO}_2$  ont été maintenus à  $\geq 98\%$ .

**Conclusion** Cette technique permet d'obtenir une ventilation peropératoire efficace et offre un accès endoscopique facile; en outre, elle constitue une bonne contre-mesure contre la complication probable d'œdème laryngé postopératoire. De plus, la trachéostomie traditionnelle et l'intubation prolongée ne sont pas nécessaires. Cette approche constitue un traitement du cancer pharyngé curatif et moins effractif. Certains effets secondaires défavorables, notamment une élocution et une déglutition difficiles, une fermeture possiblement retardée de la stomie ou un résultat cosmétique décevant, peuvent être évités.

Recent advances in gastrointestinal endoscopy enable *en bloc* resection of superficial pharyngeal cancers using a novel technique, namely, endoscopic submucosal dissection (ESD),<sup>1</sup> under general anesthesia.<sup>2</sup> In our institution, when the arytenoids are involved in lesions, surgical tracheostomy is often conducted before the procedure as an endotracheal tube (ETT) might impair endoscopic manipulation. In addition, the tracheostomy tube is beneficial for postoperative airway control in the likely event of potentially life-threatening laryngeal edema.

During recovery, however, the presence of a tracheostomy tube may interfere with patients' speech and swallowing,<sup>3</sup> and possibly lead to delayed closure of the stoma or compromised cosmetic outcome.<sup>4</sup> Our solution to these drawbacks from tracheostomy was to employ a percutaneous small-bore cricothyrotomy tube. Previous model lung studies showed that uncuffed small-bore devices with open upper airways yielded ineffective

ventilation, whereas acceptable ventilation can be achieved by occlusion of the upper airway.<sup>5-7</sup>

Thus, the purpose of this study was to examine the feasibility of controlled ventilation for cricothyrotomy via an uncuffed small-bore tube, together with an orally or nasally inserted subglottic balloon to minimize supraglottic leak.

## Methods

This study was approved by the Institutional Review Board of Showa University Northern Yokohama Hospital in July 2011 (approval number 1106-4). We estimated that a convenience sample of ten procedures was needed for evaluation in this qualitative observational study. Written informed consent was obtained from each patient for participation in the study. Inclusion criteria were patients diagnosed with superficial cancer of the meso- or hypopharynx and scheduled for *en bloc* resection using ESD. Exclusion criteria were cases in which ESD was considered achievable under endotracheal intubation without interference with endoscopic manipulation as well as cases with a low risk of postoperative laryngeal edema judging from the size and location of lesions. Patients with a history of tracheal disease, permanent tracheostomy, body mass index  $> 35 \text{ kg}\cdot\text{m}^{-2}$ , and respiratory compromise were also excluded. No premedication was administered. Standard monitors were applied in the operating room.

With the patient in the supine position, the airway was initially secured with a supraglottic airway (SGA), such as LMA-ProSeal<sup>™</sup> (Intavent-Orthofix, Maidenhead, UK) or i-Gel<sup>™</sup> (Intersurgical, Wokingham, UK), according to the anesthesiologist's preference. A percutaneous cricothyrotomy was then performed by the conducting anesthesiologist using a Portex<sup>®</sup> Minitrach II (MT) (Smiths Medical International Ltd., Hythe, UK) uncuffed tube with a 4-mm internal diameter (ID). The Seldinger technique was used under the guidance of a fiberoptic bronchoscope introduced via the SGA. Thereafter, ventilation was commenced through the MT.

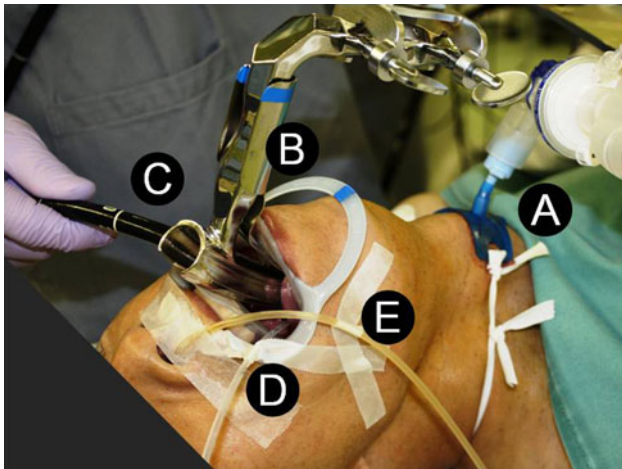
Anesthesia was induced with propofol and fentanyl and maintained with sevoflurane and remifentanyl. Rocuronium was administered mainly to prevent coughing or laryngospasm during manipulation of the fiberoptic bronchoscope and insertion of the MT. In some cases, subsequent rocuronium doses were given intermittently according to the anesthesiologists' judgment.

Following SGA removal, a specially designed surgical laryngoscope<sup>8</sup> (Nagashima Medical Instrumental Co., Ltd., Tokyo, Japan) was used to expose the glottis. Depending on the location of the lesion, a bronchial blocker (BB)

(Coopdech<sup>®</sup> endobronchial blocker with spindle-type cuff, Daiken, Osaka, Japan)<sup>9</sup> was inserted orally or nasally so as not to interfere with the endoscopy. The balloon attached to the angulated tip of the BB was lodged immediately beneath the glottis under direct visualization through the esophagogastroduodeno-scope, directed backwards using axis rotation of the shaft of the BB, and inflated with air to minimize air leak. The proximal part of the BB that protruded from the mouth or nostril was securely taped to the patient's face (Fig. 1).

The procedure commenced after insertion of a radial artery catheter. Arterial blood gas analyses were performed immediately before the procedure (baseline) and every 30 min thereafter. Pressure-controlled ventilation (PCV) without positive end-expiratory pressure was applied. Peak inspiratory pressure and respiratory rate were initially adjusted according to observation of chest motion and end-tidal carbon dioxide tension obtained from a side-stream capnometer, and then, they were readjusted according to baseline blood gas levels. A trial-and-error approach with ventilator resetting and refinement of BB status was used to maintain normocapnia. Inspired oxygen fraction was adjusted to maintain the SpO<sub>2</sub> at  $\geq 98\%$ .

For adequate visualization of the surgical site, carbon dioxide insufflation and irrigating fluids were delivered through the channels of the endoscope. The submucosal layer of the lesion was dissected using endoscopic electrocautery knives. During the procedure, a 10 Fr nasopharyngeal catheter for continuous suctioning was



**Fig. 1** Instrumental setup for therapeutic endoscopy of the pharynx. Instrumental setup for endoscopic submucosal dissection of superficial pharyngeal cancer under controlled ventilation through a Portex<sup>®</sup> Minitrach II (uncuffed cricothyrotomy tube with internal diameter of 4-mm) is shown. A = Minitrach II; B = surgical laryngoscope; C = fiberoptic esophagogastroduodeno-scope for intervention; D = orally inserted Coopdech<sup>®</sup> bronchial blocker for subglottic tracheal occlusion; E = nasopharyngeal catheter (10 Fr) for continuous suctioning

placed in the oropharynx to prevent aspiration. The endoscopic view was displayed on a monitor, allowing the anesthesiologist to assess the status of the BB (e.g., dislodgement, shrinkage, or interference with the endoscope).

All participants were scheduled to return to the ward postoperatively. Repeated palpation of the chest was performed to check for subcutaneous emphysema. Postoperatively, the MT was left *in situ* for transtracheal suctioning and airway control during possible or actual laryngeal edema. Chest *x-ray* studies were performed after the procedures and the radiographs were examined by radiologists.

## Results

Thirteen procedures in 11 consenting patients were screened. Three procedures in two patients were excluded from the study since they were performed under endotracheal intubation after considering the size and location of the lesions. Hence, ten procedures in nine enrolled patients were evaluated in this study. Each patient's characteristics and procedure-related data are listed in the Table.

It was often necessary to adjust the insertion depth of the BB, reposition the balloon, and add air to the balloon in a trial-and-error manner before and during the procedure in order to minimize supraglottic leakage, prevent obstruction of the tip of the cricothyrotomy cannula with the BB, and establish continuous monitoring of capnography.

The time-course of changes in PaCO<sub>2</sub> are shown in Fig. 2. The PaCO<sub>2</sub> values mostly indicated normocapnia or mild hypocapnia, although they exceeded 50 mmHg in two procedures. In one procedure (case 1a), PaCO<sub>2</sub> varied from 48-58 mmHg, but at a second procedure (case 1b) in the same patient undertaken eight months later, mild hypocapnia was maintained. In another procedure (case 3), hypercapnia resolved during the surgical course.

Peak inspiratory pressures and respiratory rates during the procedures varied widely from 18-60 cm H<sub>2</sub>O and from 12-20 breaths·min<sup>-1</sup>, respectively, primarily depending on the amount of the leak that developed. SpO<sub>2</sub> values were maintained at  $\geq 98\%$  in all patients. Intraoperative hemodynamics remained stable and emergence from anesthesia was uneventful. Postoperatively, all patients were successfully returned to ordinary wards.

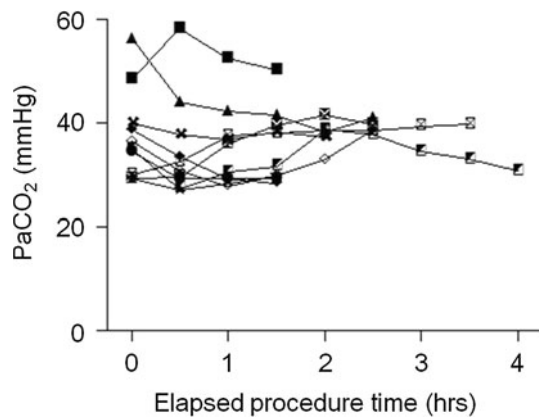
Postoperative chest *x-ray* studies revealed no new infiltrations. No notable anesthesia-related adverse events (e.g., subcutaneous emphysema, pneumothorax, mediastinal emphysema, apparent evidence of regurgitation, bleeding requiring surgical hemostasis, or MT malplacement) were recognized. A representative endoscopic view is shown in Fig. 3. All MTs were removed by the fourth postoperative day.

**Table** Patient and disease characteristics and procedure-related data

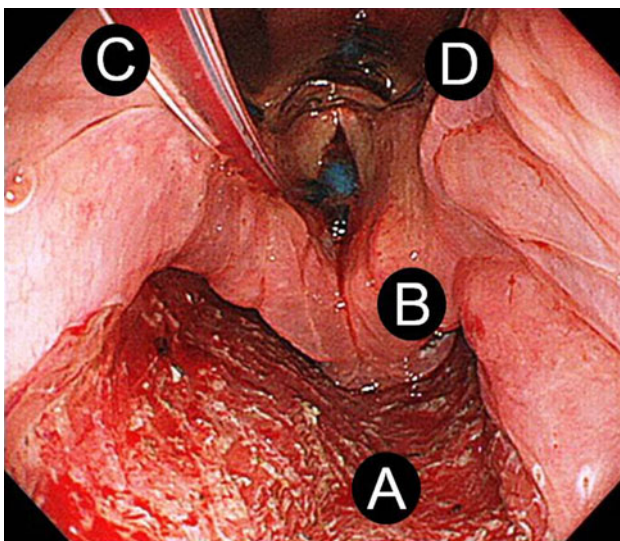
Case no	Age (yr)	Sex (M/F)	ASA class	Weight (kg)	Body mass index ( $\text{kg}\cdot\text{m}^{-2}$ )	FEV <sub>1,0%</sub> (%)	% VC (%)	Procedure time (min)	Maximum PaCO <sub>2</sub> (mmHg)	Location of lesion (Meso/Hypo)	Lesion size (mm)	Staging (UICC-TNM classification)	Previous treatment	Comorbidities/Past history
1a	50	M	II	70	25	66	108	96	58	Meso	8 × 6	IVA	ESD	Chronic hepatitis
1b	51	M	II	70	25	70	111	93	35	Hypo	13 × 8 8 × 6	0	None	Chronic hepatitis
2	67	M	II	61	20	66	104	162	56	Hypo	31 × 27	II	None	HT, OMI Renal dysfunction
3	73	M	I	66	23	74	100	101	39	Hypo	25 × 18	0	None	None
4	58	M	II	60	23	75	111	94	30	Hypo	15 × 15	I	None	HT
5	63	M	II	87	29	59	106	143	40	Meso	32 × 23	II	None	HT, DM Cerebral infarction
6	70	M	II	68	25	79	114	249	39	Hypo	15 × 10	0	None	Esophageal ESD HT, DM, ASO
7	65	M	II	54	20	95	79	155	39	Meso	35 × 27	II	ESD	Esophageal ESD Hyperuricemia
8	64	M	II	68	23	76	100	179	40	Hypo	22 × 11 10 × 10 38 × 23	II	None	Esophagectomy Hyperuricemia Esophageal ESD
9	67	M	II	48	18	99	76	155	39	Meso ~Hypo	63 × 70	III	None	Esophagectomy

The clinical data of the ten cases are listed in the chronological order in which the procedures were performed. One patient underwent pharyngeal ESD twice at an interval of eight months. Data from the patient at the time of both procedures (cases 1a and 1b) are included. Two patients (cases 3 and 6) were also diagnosed as having early stage esophageal cancer, which was treated with esophageal ESD in the same session. One patient (case 3) underwent esophageal ESD under ventilation through an endotracheal tube, following which a MT was inserted for pharyngeal ESD. Another patient (case 6) underwent both esophageal and pharyngeal ESD under ventilation through a MT. In the former case, the duration of only the pharyngeal ESD under ventilation through the MT was adopted as the procedure time, whereas in the latter case, the time for completion of both ESDs was adopted as the procedure time.

ASA = American Society of Anesthesiologists; FEV<sub>1,0%</sub> = forced expiratory volume in 1 second/forced vital capacity; %VC = forced vital capacity (percent of predicted); UICC = Union for International Cancer Control; Meso = mesopharynx; Hypo = hypopharynx; ESD = endoscopic submucosal dissection; HT = hypertension; OMI = old myocardial infarction; DM = diabetes mellitus; ASO = arteriosclerosis obliterans; MT = Portex® Minitrache II



**Fig. 2** Time courses of PaCO<sub>2</sub> during the procedure. Graph showing individual time courses of PaCO<sub>2</sub> during endoscopic submucosal dissection of the pharynx under controlled ventilation through a Portex<sup>®</sup> Minitrach II (uncuffed cricothyrotomy tube with internal diameter of 4-mm) together with an orally or nasally inserted Coopdech<sup>®</sup> bronchial blocker inflated beneath the glottis to minimize air leakage into the oropharynx



**Fig. 3** Endoscopic view of the pharyngolarynx. A representative endoscopic view of the pharyngolarynx is presented immediately after completion of the endoscopic submucosal dissection for superficial pharyngeal cancer. (A) An area of mucosa surrounding the lesion, which was located at the posterior wall of the pharynx, was removed; (B) Swollen aryepiglottic folds; (C) the shaft of the Coopdech<sup>®</sup> bronchial blocker anchored immediately beneath the glottis; (D) the tip of the blade of the surgical laryngoscope used to expose the glottis

## Discussion

We conducted successful airway and anesthetic management in nine patients undergoing pharyngeal ESD. Ventilation was controlled through a MT together with an orally or nasally inserted BB anchored beneath the

glottis to minimize supraglottic leak. Continuous oropharyngeal drainage was applied in tandem using a nasopharyngeal catheter.

The worldwide annual incidences of pharyngeal carcinoma and associated deaths in 2008 were estimated to be 135,000 and 95,000, respectively.<sup>10</sup> This high mortality could be explained partly by the difficulty in early diagnosis. Modern narrow band imaging and magnification endoscopy facilitate detection of early-stage pharyngeal cancer.<sup>11</sup> This can be treated with ESD, as has been described in several case series from Japan. In two different series, tracheal extubation was not performed on the day of the procedure in 61 of 93 (67%) patients and in 22 of 51 (43%) patients.<sup>12,13</sup> In another series, four of 21 (19%) patients underwent a tracheostomy postoperatively.<sup>14</sup> These reports disclosed that invasive or bothersome airway management was employed in patients who underwent a procedure that was supposedly a novel therapeutic option with the benefit of minimal invasiveness.

Cricothyrotomy (cricothyroidotomy), also known as minitracheotomy (minitracheostomy), can be percutaneously performed using a MT or competitive products. The Portex<sup>®</sup> Minitrach II, originally introduced for tracheobronchial suction,<sup>15</sup> is currently recognized as an emergency tool for “can’t intubate can’t ventilate” situations.<sup>16</sup>

In an earlier study regarding lung ventilation through cricothyrotomy using a model lung, PCV via a MT yielded 40% of ventilatory volume of the values using an 8-mm ID ETT. This result was yielded at varying degrees of lung compliance and in the absence of upper airway leak. When a certain degree of leak existed, these values further decreased to 30% of control values using the ETT.<sup>5</sup> In a subsequent study, an uncuffed 6-mm ID Melker<sup>®</sup> tube (Cook, Bloomington, IN, USA) provided effective ventilation irrespective of upper airway resistance, whereas the uncuffed 4-mm ID Quicktrach<sup>®</sup> I (VBM Medizintechnik, Tuttlingen, Germany) performed effectively only with increased upper airway resistance.<sup>6</sup>

Recently, cuffed devices for emergency ventilation have been marketed,<sup>17,18</sup> although none are currently commercially available in Japan. In a more recent study, both cuffed and uncuffed devices varying in ID from 4–6 mm were examined using a model lung to assess whether effective ventilation could be obtained. Effective ventilation was defined as a tidal volume of  $\geq 300$  mL delivered by volume control ventilation in an ordinary setting with normal lung compliance and airway resistance.<sup>7</sup> Reportedly, uncuffed devices, including a 6-mm ID Melker<sup>®</sup>, yielded ineffective ventilation in the presence of a large leak, whereas, not surprisingly, every cuffed device produced satisfactory results irrespective of

the amount of leak. The uncuffed 4-mm ID Quicktrach<sup>®</sup> I was acceptable for controlled ventilation with little to no leakage, allowing spontaneous ventilation without excessive negative inspiratory pressure even with complete obstruction. Our study clinically validated the adequacy of controlled ventilation through a 4-mm ID tube—which is probably the cut-off value for effective ventilation—based on the observed PaCO<sub>2</sub> level in a non-critically ill population. The observed moderate hypercapnia was transient or did not recur at a second procedure. Mere technical refinement of BB positioning to reduce the leakage seemed to improve ventilation.

Even when cuffed devices are available, the MT still provides some benefits. For instance, the cuffed 4-mm ID Quicktrach<sup>®</sup> II (VBM Medizintechnik) is 7.3-mm in maximum outer diameter (OD), whereas the MT has an OD of 5.4 mm.<sup>19</sup> The recently introduced cuffed Melker<sup>®</sup> is 5 mm in ID and has a 7.2-mm maximum OD. Although the differences in OD between these devices and the MT may be small, the smaller OD would be beneficial for the patients' quality of recovery. Additionally, the Quicktrach<sup>®</sup> II can be placed as a cannula over the needle, which reportedly requires less time to perform but is less reliable than the Seldinger technique<sup>17,18,20</sup> employed with the MT and Melker<sup>®</sup> tubes.

The optimal ventilator setting during ventilation through a MT is a real concern, since a marked drop in pressure along the tube is inevitable. Findings from the abovementioned study indirectly suggest that about a threefold higher inspiratory pressure is needed in PCV to obtain adequate ventilation when the MT is utilized instead of a standard ETT.<sup>5</sup> Although placement of a heat and moisture exchanger and an elbow could influence flow resistance,<sup>21</sup> this estimation was in fair agreement with actual adjusted ventilator settings.

Measures to counter the leak associated with use of uncuffed cricothyrotomy and tracheostomy tubes have generated much interest.<sup>22-24</sup> In our experience, once the MT is placed, it is beneficial to use an SGA with occlusion of the 15-mm connector until insertion of the surgical laryngoscope. Simpler methods, including manual occlusion of the patient's nose and mouth and neck flexion without head extension also facilitated ventilation via the MT. Even when uncuffed 4-mm ID devices are the only kits available in emergency situations, upper airway resistance can be increased; therefore, such devices should be considered for use without hesitation.

Our technique occasionally yielded insufficient ventilatory volume, especially in earlier cases in this report; however, this was minimized by refinement of BB status. Another concern with our technique is avoiding a high inspiratory oxygen fraction, since we cannot completely exclude the possibility of igniting the BB

with electrocautery when a massive leak of oxygen-enriched air is present.<sup>25</sup> A leak could also cause work environment pollution when inhalational anesthetics are used. Off-label use of the BB for this purpose remains the responsibility of the clinician. Further clinical experience and multicentre validation is needed to confirm the efficacy and safety of our technique.

In conclusion, the present airway strategy for pharyngeal ESD provided effective ventilation, easy endoscopic access, and postoperative airway patency without the need for tracheostomy or prolonged intubation. Avoidance of adverse outcomes associated with standard tracheostomy, including speech or swallowing disturbances, possible delayed closure of the stoma or compromised cosmetic outcomes are meaningful to establish restorative and less invasive therapy for pharyngeal cancer.

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**Conflicts of interest** None declared.

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