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Cervical tracheal resection without intubation

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Abstract

Aim. To present the experience in a new approach for the surgical treatment of cicatricial cervical tracheal stenosis — tracheal resection without using an endotracheal tube.

Methods. The technique includes preliminary metal stent placement instead of bougienage in the stenosis zone; introduction of the supraglottic airway device I-Gel instead of the endotracheal tube and; jet ventilation through the supraglottic airway device. The stent is removed together with the resected trachea. The technique of cervical tracheal resection using the supraglottic airway device was implemented in 22 patients with cicatricial tracheal stenosis.

Results. The resection length ranged from 15 to 45 mm (on average, 27±3 mm). The duration of surgical interventions ranged from 65 to 180 minutes (on average, 109±9 minutes). Preliminary stenting excluded preoperative bougienage of the trachea and facilitated intraoperative assessment of the extent of the stenosis. The absence of an endotracheal tube facilitated the formation of anastomosis of the trachea, eliminated the risk of trauma to the anastomosis during tube removal. There were no complications in the early postoperative period. The length of postoperative hospital stay ranged from10 to 14 days (on average, 12±2 days). No restenosis was detected at long term follow-up.

Conclusion. Performing tracheal resection without intubation allows the surgeon to work comfortably, observing the safety conditions for ensuring airway patency throughout the operation by installing a supraglottic airway device.

Keywords: benign tracheal stenosis, tracheal resection, non-intubated, supraglottic airway device, stenting, dexmedetomidine.

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Introduction. The most favorable method of radical treatment of benign tracheal stenosis is sleeve resection of the stenotic segment with the formation of a tracheotracheal or laryngotracheal anastomosis [1,2]. Such surgery, especially for stenosis in the cervical trachea, being performed by experienced surgeons, is characterized by good immediate- and long-term results. If more than 50% of the length of the entire trachea should be resected, the risk of anastomotic leakage and development of restenosis increases significantly; therefore, many surgeons consider such resections inappropriate.

Particular attention is paid to lung ventilation during surgery. The tightness of the airways in the course of the intervention deteriorated, and achieving adequate gas exchange in the lungs often becomes difficult [3,4].

Traditional anesthetic management of tracheal surgeries. General total intravenous anesthesia is usually used for anesthetic management [5]. The airway patency test is traditionally performed to ensure gas exchange during surgical interventions on the trachea by intubating the trachea with an endotracheal tube (ETT) into one of the main bronchi or leaving it in the tracheal lumen [6], and trachea bougienage is preliminarily required for ETT through the stenosis zone.

After opening the tracheal lumen and sealing deterioration of the airways, the ETT can be inserted into the caudal end of the trachea through the surgical wound (shunt-breathing). It can be installed in the cranial section of the trachea, and a thinner tube (catheter) can be passed through it into the resection area to implement intermittent jet ventilation when the circuit is depressurized. Moreover, the surgeon can perform tracheal resection using the so-called flow apneic oxygenation, when a constant flow of oxygen is fed through the ETT which distal end is installed directly above the resection zone, through the intraluminal catheter after the circuit has been depressurized [7]. In recent years, it is extremely rare to maintain oxygenation

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during tracheal surgery using extracorporeal oxygenation. Each of the methods considered has its advantages and disadvantages.

Advantages and disadvantages of ETT. The main advantage of ETT is good control over the airway condition before tracheal depressurization. After opening the tracheal lumen, the surgeon inserts a sterile reinforced the ETT through the surgical wound into the distal end of the trachea, the tracheal cuff is inflated, and the tube is connected to the ventilation apparatus.

The surgeon has to perform subsequent tasks in the operating wound "around" the tube; the presence of the ETT in the surgical site can disrupt the work of the surgical team and complicate the anastomosis formation. In the most technically difficult stages of surgery, the ETT can sometimes be removed for a short time from the distal trachea; this time usually should not exceed 1–2 min while monitoring the oxygen saturation level (not less than 80%).

Other disadvantages of tracheal intubation during surgeries for cicatricial tracheal stenosis include the need for rough pushing of the ETT through the stenosis zone, which leads inevitably to additional traumatization of the tracheal wall in the site of future anastomosis. Before intubation of the patient, bougienage of the stenosis site with rigid instruments is often required, which also contributes to additional trauma, bleeding, and tears of healthy areas of the mucous membrane. In some cases, especially with "high" stenosis, the correct ETT placement is rather complicated. The inflated ETT cuff exerts pressure on the tracheal wall and affects adversely the blood supply to the mucous membrane, which may affect healing of the anastomosis.

Various instruments can easily be inserted through the ETT into the trachea and bronchi; however, their size is limited by the inner diameter of the tube, which cannot be large in case of tracheal stenosis. In the presence of ETT, the state of the vocal cords cannot be monitored endoscopically. Tracheal extubation with an already imposed tracheal anastomosis can also damage the anastomotic area and create conditions that lead to the development of postoperative complications [8]. Despite the limitations considered, many specialists operating on the trachea agree with the use of just this technique of anesthetic management.

Advantages and disadvantages of jet ventilation. Jet ventilation involves the delivery of a pressurized respiratory mixture into the airways through a thin catheter. Ventilation through the catheter can be implemented with different end volumes of the respiratory mixture, for example, small volumes and frequently (high-frequency jet ventilation), or with large volumes and much less frequently (normal-frequency jet ventilation) [9].

Traditionally, a jet ventilation catheter is passed into the trachea through a preinstalled ETT. This technology provides adequate lung ventilation when the tracheal lumen is opened, and the presence of a catheter with a diameter of no more than 3 mm in the trachea, passed through the diastasis zone between the cranial and caudal ends of the diastasis, should not prevent the surgeon from suturing the ends of the trachea and to form a reliable anastomosis. Moreover, the jet ventilation catheter can be easily removed from the diastasis zone or reinserted, since access to the trachea in the presence of an ETT is not particularly difficult.

The use of jet ventilation of the lungs during tracheal resection traditionally implies the need for its intubation to ensure adequate exhalation until the trachea is depressurized. For this reason, all characteristic disadvantages associated with tracheal intubation, including the stage of ETT extraction, may be realized. If the evacuation of the expired volume, even for a short time, is impaired, barotrauma with the formation of unilateral or bilateral pneumothorax is possible. Hypercapnia often develops while using this method of ventilation, and in patients with impaired lung compliance, achieving oxygenation is generally difficult.

Supraglottic airway device (SAD). SAD offer the advantages of jet ventilation of the lungs and avoid the disadvantages of endotracheal intubation [10]. These devices include laryngeal masks and the I-Gel supraglottic airway. The laryngeal mask design provides an airtight seal around the larynx entrance by means of an inflatable cuff, ensuring a secure air channel during spontaneous or mechanical ventilation under general anesthesia. The I-Gel supraglottic airway with a non-inflatable gel-shaped cuff, mirroring the structure of the laryngopharynx, is an ideological analog of a laryngeal mask. Unlike the designs of many laryngeal masks, the I-Gel does not have a protective perforated diaphragm, which can simplify the passage of the bronchoscope.

SAD is installed into the lower part of the pharynx, and the vocal cords remain intact. The SAD installation procedure is much simpler and less traumatic than that of an ETT. It is relatively easy to manipulate the flexible endoscope, catheter guide, and jet ventilation catheter itself in the distal part of the SAD, in the larynx, and in the lumen of the tracheobronchial tree.

Table 1 presents the comparative characteristics of the use of ETT and SAD in tracheal surgery [11–13].

The use of SAD and refusal of ETT can be safe only in cases when the tracheal lumen in the steno-

Table 1. Comparative characteristics of a supraglottic airway device (SAD) and an endotracheal tube (ETT) during tracheal resection

Factors	SAD	ETT
Provision of ventilation	Provides ventilation regardless of the stenosis area	Impossible to place correctly in case of high stenosis
Cough reflex	Avoids the tracheal reflex	Contributes to it
Impact on the pathological process site	Does not impair the healing of anastomosis	Adverse effect of ETT cuff pressure on blood flow in the trachea
Endoscopic control	Facilitates	Restricts
Intraluminal delivery and control of the tool placement, e.g., placement of a jet ventilation catheter	Facilitated	Limited by ETT diameter
Extubation after surgery	Safer and reduces the risk of prolonged mechanical ventilation	Requires careful monitoring
Provision of exhalation through the stenotic area during jet ventilation	Risk of barotrauma	Determined by ETT diameter

sis site is sufficient for adequate exhalation. This most difficult problem can be solved by the preliminary bougienage of the trachea (the disadvantages of this approach have been discussed above) or by temporary endoprosthetics of the stenosis area.

Endoprosthetics of the tracheal stenosis zone. To ensure adequate exhalation during jet ventilation of the lungs, in our experience, the minimum lumen should not be less than 7 mm with a stenosis of no more than 3–4 cm in length [14]. With a greater degree of stenosis, the risk of lung barotrauma increases, each subsequent jet of air mixture entering the trachea increases the pressure in small-caliber airways, and occurrence of pneumothorax is possible. To prevent such complication, it is advisable to install an endoprosthesis in the stenosis area a few days before the surgery.

The installation of various stents into the trachea should be avoided if there is a possibility to perform radical sleeve resection of the stenotic area with imposition of anastomosis. The presence of a stent itself stimulates the growth of granulation tissue and promotes inflammatory changes in the tracheal wall, which inevitably increases the length of the stenosis [15]. For this reason, indications for stent placement in benign stenoses are almost always associated with the impossibility of immediate radical surgical treatment. Silicone stents are desirable for benign stenosis. Metal-frame stents, although much easier to install, adhere quickly and often cause pressure ulcers of the tracheal wall, and after a few weeks, they are extremely difficult to remove.

Moreover, short-term use of self-expanding metal-frame stents, which is sufficient to prepare the patient for surgical resection and intraoperative anesthesia, appears extremely convenient, completely devoid of the drawbacks characteristic of the long-term use of these endoprostheses. The type of stent has two purposes. First, a sufficient tracheal lumen is provided in the stenosis site, which will minimize the risk of lung barotrauma during surgery. Second, stenting with metal-frame stents as preparation for sleeve tracheal resection with decompensation of its cicatricial stenosis can serve as an alternative to much more traumatic technologies (e.g., bougienage) for temporary restoration of airway patency.

The stent size is selected individually. It is not necessary and even undesirable for the stent to overlap the entire stenotic zone. It is quite sufficient to make the prosthetic appliance to the most narrowed tracheal site, so that the distal and proximal edges of the stent were within the scarred trachea. Metal stents are installed simply and reliably using a flexible bronchoscope, and their migration is practically impossible. The presence of a stent enables restoration of adequate lung ventilation as preparation of the patient for a radical surgery and during the surgical intervention itself until the trachea is transected distal to the stenosis zone. The stent is removed during the surgery along with the resected trachea.

Given the adverse effect of the long-term presence of metal stents in the trachea, the endoprosthesis must be installed no earlier than 3 weeks before the proposed surgical intervention. The stent removed during surgery is not damaged, and if necessary, it can be reused.

Surgery technique. *Interaction between thoracic surgeon, anesthesiologist, and endoscopist.* Interaction of these personnel is extremely important in tracheal surgery, starting with a joint preoperative discussion of the surgery plan, taking into account the individual characteristics of a par-

ticular clinical case. Special aspects such as surgical approach, history of tracheostomy, presence of a functioning tracheostome, severity of concomitant pathology, length of the area resected, distance from the vocal cords to the stenosis proximal border, and others should be analyzed carefully.

The surgeon and anesthesiologist, albeit from different sides, must control adequately the airway patency and ensure adequate gas exchange. The role of the endoscopist is fundamentally important at any stage of the intervention, which includes controlling the position of the SAD and catheter as well as clarifying (if necessary) the resection boundaries. Every member of the surgical team should take into account the peculiarities of their work and tasks during surgery.

Intraoperative difficulties can be associated with an inadequate position of the catheter for jet ventilation, its bending, blood and mucus entering the lower respiratory tract, and unintentional interruption of exhalation. The jet ventilation catheter may be moved cranially at the request of the surgeon and may be above the vocal cords. For its quick reverse movement, it will be justified to suture the catheter tip with a thick thread, so that by pulling it, the surgeon can always bring it out of the larynx into the trachea.

Work of the anesthesia team. The preparatory stage for general anesthesia after the patient's admission to the operating room requires sedative agents. For this purpose, in our opinion, dexmedetomidine is the safest. It can be classified as anesthetic choice of drugs throughout the perioperative period for tracheal interventions [11, 16]. It ensures the preservation of spontaneous ventilation during the installation of SAD, it helps suppress the cough reflex, its insertion is accompanied by additive effects with general anesthetics with mutual dose reduction, possible perioperative reduction when narcotic analgesics are needed, and it suppresses postoperative nausea and vomiting (thereby potentially contributing to additional protection of the anastomosis). In the postoperative period, dexmedetomidine definitely prevents the development of agitation and delirium. Finally, this drug is considered an antihypoxant [17]. At stage 1 of general anesthesia, to achieve the level of moderate sedation according to the American Society of Anesthesiologists (ASA), its combination with propofol and fentanyl is optimal [18].

To install the SAD, drug sedation is intensified to the level of deep sedation according to the ASA by increasing the dose of propofol. We opted for the I-Gel SAD, as its non-inflatable cuff is less prone to accidental injury than the inflatable cuff of a classic laryngeal mask. The choice and size of any SAD depend on the patient's body weight and individual anatomical characteristics. After endoscopic control and correctness of the I-Gel installation, under the control of a flexible endoscope, a guidewire is installed and the catheter itself along it for jet ventilation (Fig. 1).

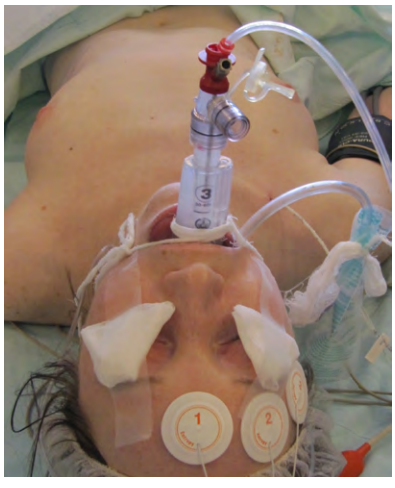

Fig. 1. A jet ventilation catheter is inserted through the supraglottic airway device.

After the anastomosis, endoscopic control of the anastomosis zone and larynx and sanitation of the tracheobronchial tree are performed. The tightness of the tracheal suture is tested by setting the Ppeak within 30 mbar by selecting the required level of positive end expiratory pressure. The absence of air leakage signals the removal of the jet ventilation catheter. The SAD is removed under mild sedation [12].

The I-Gel design enables easy viewing of the laryngeal aperture during endoscopy. If laryngeal edema is detected after the anastomosis, the SAD should be replaced with an ETT, and extubation is moved to the morning of day 1 after surgery [8]. Continued sedation with dexmedetomidine prevents the development of discomfort caused by prolonged tracheal intubation, with full recovery of spontaneous breathing.

Work of the surgical team. The main aspects in the role of the surgeon and his assistants during sleeve resection of the trachea without tracheal intubation may not be recognized, with some exceptions and additions. There is no loss of time to move the ETT; the presence of a stent serves as an additional guideline in assessing the localization and extent of stenosis; it does not interfere, but contributes, to a more precise transection of the trachea, while the stent is removed together with the scarred segment of the trachea (Fig. 2).

After removal of the stenotic area, special attention is paid to the position of the lung jet ventilation catheter; one of the surgeon's assistants is

Table 2. Parameters of partial pressure of oxygen (p_aO_2) and carbon dioxide (p_aCO_2) in the arterial blood at the stages of general anesthesia

Research stage	Values of indicators [M ± m (min; max)]	
	p_aO_2, mm Hg	p_aCO_2, mm Hg
Before surgery	90±5 (73; 109)	39,4±1,9 (32,0; 50,0)
After induction of anesthesia	337±63 (155; 484)	44,3±1,5 (37,0; 51,0)
Start of the jet artificial ventilation of the lungs	263±22 (209; 353)	45,5±2,3 (32,0; 55,0)
Main stage of the surgery	250±26 (146; 318)	67,5±3,9 (45,0; 92,0)
After removal of the supraglottic airway device	166±21 (119; 233)	45,7±1,9 (38,0; 55,0)
Day 1 after surgery	114±11 (78; 179)	40,4±1,1 (34,0; 47,0)

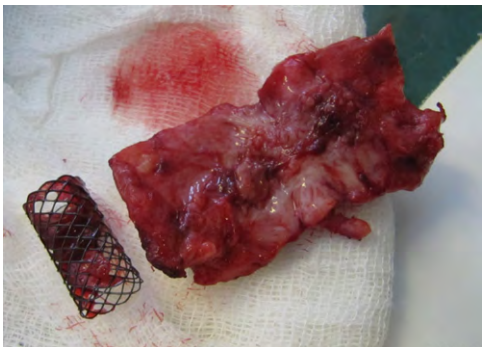

Fig. 2. Resected segment of the cervical trachea and an endoprosthesis.

responsible for fixing the catheter and providing direct sanitation of the distal parts of the tracheobronchial tree.

The primary condition for a successful postoperative period is the quality of the tracheotracheal or laryngotracheal anastomosis [19]. The proposed technique enables the surgeon to work under the most comfortable conditions. The posterior anastomosis wall is usually formed with a continuous suture (PDS 3-0 or 4-0), and the anterior wall is sutured with interrupted Vicril 3-0 sutures, if necessary, under controlled blood oxygen saturation of short-term apnea by pulling the jet ventilation catheter above the anastomotic line. The wound is sutured, leaving drainage in the left paratracheal space, and the chin is sutured to the anterior chest wall with two thick ligatures, which aimed to prevent the head from tilting back within 1 day after surgery. The drain is connected for active aspiration with a pressure of 5 mm Hg and removed the next day after surgery. Sutures fixing the chin are removed on days 7–10 after surgery.

The new approach to resection of the cervical trachea using SAD was implemented in 22 patients with cicatricial post-tracheostomy (14), post-intubation (6), and idiopathic tracheal stenosis (2). A tracheostome was functioning at the time of surgery in 5 (23%) patients. Preliminary stenting of the stenosis zone was required in 8 (36%) patients with decompensated stenosis; an endoprosthesis was installed 7–19 days before surgery. Sleeve tracheal resection with tracheotracheal anastomosis was performed in 13 (59%) patients, that with laryngotracheal anastomosis was performed in 5 (23%) patients, and that with laryngotracheal resection was performed in 4 (18%) patients. Perioperative endoscopic control was performed using a flexible endoscope with an outer diameter of 2.7 mm.

The resection length ranged from 15 to 45 mm (average, 27 ± 3 mm). The duration of surgical interventions was 65–180 min (average, 109 ± 9 min). The anesthesia approach and surgery plan were not changed in any case.

Transcatheter jet ventilation at the main stage of the surgery was accompanied, as a rule, by the development of permissive hypercapnia (Table 2), which is also typical when using other alternative methods of ventilation.

The approach used provided favorable conditions for the surgery. Preliminary endoprosthetics enable avoidance of the preoperative bougienage of the trachea and facilitated the intraoperative search for the length of the zone of its stenosis for subsequent resection. The absence of an ETT facilitated the formation of tracheal anastomosis while eliminating the risk of injury during its removal (which is possible with the conventional technology of tracheal resection).

In all 22 cases, no complications occurred in the early postoperative period. The duration of hospitalization in the postoperative period ranged from 10 to 14 days (average, 12 days). Postoperatively, all patients underwent follow-up bronchological examination every 6 months. With long-term follow-up, restenosis was not detected, and tracheal patency was satisfactory in all cases.

Conclusion. Sleeve resection of the trachea without intubation enables the surgeon to work

under comfortable conditions, observing safety conditions to ensure airway patency with SAD throughout the intervention. The experience of using this technology confirms its safety with the participation of specialists with experience in solving complex clinical situations in thoracic surgery.

Author contributions. A.L.A. developed the methodology, analyzed the results, wrote the manuscript, and performed the procedure on all patients; M.G.K. developed the methodology, analyzed the results, wrote the manuscript, and performed anesthetic management in all patients.

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