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Case Report

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Successful removal of a large intratracheal tumor using the injection-time-controllable manual jet ventilator via translaryngeal approach -a case report-

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Background: Removal of intratracheal tumors is challenging due to the difficulty in securing a patent airway before surgery. We report a case of successful removal using jet ventilation with an injection-time-controllable manual jet ventilator.
Case: A 3.3 cm-long intratracheal mass was located 5 cm below the vocal cords and obstructing 70%–80% of the trachea. Following induction, a rigid telescope under suspension laryngoscopy was used to guide the careful insertion of a hard and long catheter (inner diameter: 1.8 mm; outer diameter: 3 mm; length: 50 cm) beyond the tumor, enabling jet ventilation. The soft, lobulated mass was gradually excised using long forceps under endoscopic visualization. Anesthesia was maintained using total intravenous anesthesia. The operation lasted for 1 h and 45 min.
Conclusions: This device ensured oxygenation and ventilation during the endoscopic removal of a large intratracheal tumor. This approach highlights its utility in managing challenging airway obstructions.

Keywords: Airway obstruction; Anesthesia, intravenous; High-frequency jet ventilation; Laryngoscopy; Tracheal neoplasms; Tracheal stenosis.

Managing a patient with an intratracheal tumor is challenging for anesthesiologists due to the difficulty in securing a patent airway before the commencement of surgery. The main concern during anesthesia is maintaining adequate ventilation and oxygenation. Various anesthetic techniques have been employed for the removal of intratracheal tumors during tracheal resection and reconstruction, including endotracheal intubation with mechanical ventilation; native airway or laryngeal mask airway with spontaneous ventilation; jet ventilation (e.g., high-frequency jet ventilation [HFJV] or manual jet ventilation; regional, neuraxial, or local anesthesia; and extracorporeal life support (e.g., extracorporeal membrane oxygenation [ECMO] or cardiopulmonary bypass) [1].

Meanwhile, for intratracheal tumors that do not require tracheal resection and reconstruction, rigid bronchoscopy or suspension laryngoscopy has been considered as potential methods for removing intratracheal tumors. Various anesthetic techniques can be used during rigid bronchoscopy, including apneic oxygenation, spontaneous assisted ventilation, controlled ventilation, and jet ventilation [2]. Apneic oxygenation is suitable only for brief procedures because of the risk of respiratory acidosis. Spontaneous assisted ventilation involves titrating intravenous agents to induce hypnosis while preserving spontaneous ventilation. While this method ensures continuous ventilation and oxygenation throughout the procedure, it carries risks such as hypoxemia, laryngospasm, and bucking. Controlled ventilation can be achieved by connecting an anesthetic circuit to the side port of a rigid bronchoscope. Jet ventilation using either high-frequency or manual jet ventilators provides an immobile surgical field by paralyzing the patient and ensuring uninterrupted ventilation during the procedure; however, it is associated with risks of barotrauma and hypercapnia. Except for controlled ventilation, these methods can also be applied during suspension laryngoscopy.

We present the case of a 59-year-old man with a 3.3 cm-long intratracheal tumor extending from 5 cm below the vocal cords to 5 cm above the carina, obstructing 70%–80% of the tracheal lumen. As the patient was not a candidate for tracheal resection, the surgical plan involved debulking the tumor using a suspension laryngoscope with the aid of a telescope for visualization. A jet catheter was advanced through the vocal cords and positioned beyond the tumor mass to enable manual jet ventilation via an injection-time-controllable manual jet ventilator [3] (Fig. 1), while the patient was maintained on total intravenous anesthesia (TIVA).

Case Report

A 59-year-old man, weighing 67 kg and 165 cm tall, presented with a slightly noisy sound during expiration persisting for several months. Although he did not experience significant breathing difficulties, he reported mild exertional dyspnea. A chest computed tomography scan revealed a 3.3 cm-long lobulated, sessile, and enhancing mass located 5 cm below the vocal cords (approximately 2.4 cm below the cricoid cartilage), extending 5 cm above the carina (Fig. 2A). The mass was attached to the posterior and right lateral wall of the intrathoracic trachea and occupied 70%–80% of the lumen (Fig. 2B). A preoperative fiberoptic bronchoscopic examination conducted by the otorhinolaryngology department confirmed that the oral cavity, oropharynx, and vocal cords were intact. However, they did not verify the shape of the mass. Excision biopsy and tumor removal under general anesthesia were planned. This report was approved by the Yonsei University Severance Hospital Institutional Review Board, Seoul, Korea (4-2024-1319). We did not obtain written consent from the patient regarding their agreement for publication.

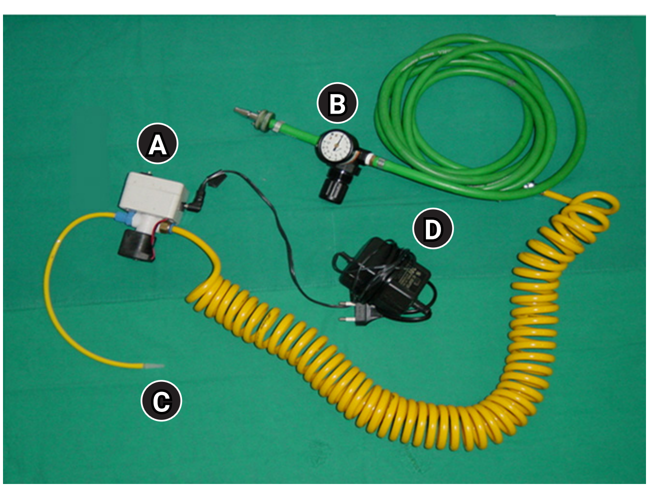

Fig. 1. An injection-time-controllable manual jet ventilator. (A) The time controller. The manual toggle switch was modified by replacing it with a solenoid valve triggered by an adjustable timer circuit to control the injection time. The duty cycle was set to deliver bursts of gas injection lasting for 0.5, 0.75, and 1 s. (B) The pressure regulator. (C) The part that connects the jet catheter. (D) A DC adapter for the time controller. DC: direct current.

Intraoperative monitoring included an electrocardiogram, automatic blood pressure cuff, pulse oximeter, and bispectral index sensor monitor (BIS™ sensor; Covidien). Neuromuscular blockade was assessed using a peripheral nerve stimulator (Innervator 252®; Fisher and Paykel Healthcare).

The initial SpO_2 was 98% on room air, and all other vital signs were within normal ranges (blood pressure: 116/74 mmHg; heart rate: 77 beats/min; respiratory rate: 13 breaths/min). As the mass was located approximately 2.4 cm below the cricoid cartilage, transtracheal jet ventilation using an angiocatheter was deemed unfeasible. Therefore, translaryngeal jet ventilation using a long catheter was planned.

With a ring-support under the head, the patient was placed in a reverse Trendelenburg position of approximately 15° to facilitate ventilation prior to induction of anesthesia. A face mask was securely fitted to the patient, and manual mask ventilation was tested in accordance with the patient's breathing. Mask ventilation was possible without any problems. However, anticipating potential ventilation difficulty or ventilatory failure after induction, ECMO equipment was prepared, and a thoracic surgeon and the ECMO team were kept on standby in the operating room.

Following an intravenous injection of 0.1 mg glycopyrrolate, preoxygenation with 100% oxygen was performed using four deep breaths, and TIVA was initiated with propofol and remifentanil. Following the loss of consciousness, face mask ventilation remained unproblematic.

Subsequently, after the administration of 100 mg succinylcholine, a hard and long polyvinyl chloride catheter (inner diameter [ID]: 1.8 mm, outer diameter: 3 mm, length: 50 cm) was blindly inserted under direct laryngoscopy through the glottic opening, directed toward the anterior portion of the trachea to a depth of 27 cm from the teeth. The catheter was then secured to the left cheek with adhesive tape, and jet ventilation was initiated using

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Fig. 2. Chest computed tomography scan illustrate the presence of a tracheal tumor (white arrows). (A) Lobulated, sessile mass, approximately 3.3 cm-long located 2.4 cm below the cricoid cartilage extending to 5 cm above the carina. (B) The tracheal tumor was attached to the posterior and right lateral wall of the intrathoracic trachea, where the mass occupied 70%–80% of the lumen. Rt: right.

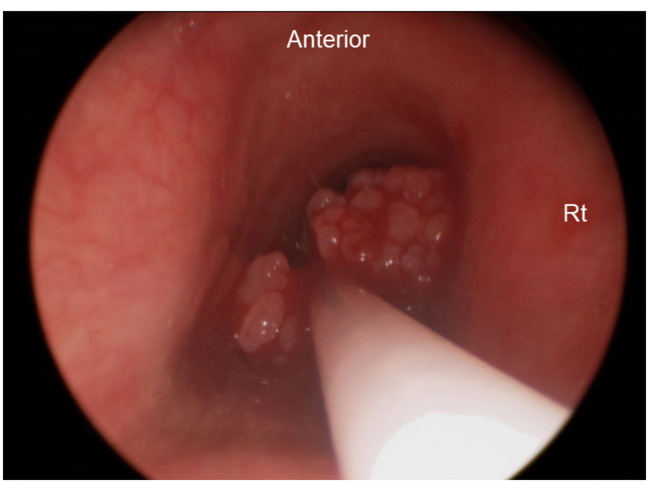

Fig. 3. A jet catheter (inner diameter: 1.8 mm, outer diameter: 3 mm, length: 50 cm) was inserted between the intratracheal tumor and the tracheal wall and placed in the distal trachea. A polypoid, lobulated, and sessile mass was attached to the posterior and right lateral wall of the intrathoracic trachea. Rt: right.

an injection-time-controllable manual jet ventilator, allowing injection times of 1, 0.75, or 0.5 s. A driving gas pressure of approximately 2100 cmH_2O (30 psi) and an injection time of 0.5 s was applied several times, and ventilation efficacy was assessed by observing chest wall movement. The chest wall expanded well during insufflation; however, the sinking of the chest wall during expiration was slightly delayed. Shortly after administering 30 mg rocuronium, the otorhinolaryngology surgeon inserted a suspension laryngoscope and the catheter's location was identified using a rigid telescope connected to a video monitoring system. The catheter was withdrawn until the tip was visualized and then reinserted through the space between the tracheal wall and the mass, advancing it toward the carina under video guidance (Fig. 3). After this adjustment, smooth downward chest wall movement during exhalation was observed. Once effective chest wall movement during both insufflation and expiration was confirmed, the injection time was increased to 1 s and maintained until the end of operation. The catheter was secured to the left cheek using adhesive tape. Neuromuscular blockade was maintained with intermittent bolus injections of rocuronium, with 20 mg administered three times, resulting in a total of 90 mg administered during the operation.

As the mass was soft and lobulated, it was excised bit by bit using straight and curved long forceps under rigid telescope guidance via a suspension laryngoscope connected to a video monitoring system. Although the target respiratory rate was approximately 12 breaths/min, insufflation was frequently paused to minimize interruptions during extraction. The patient's SpO_2 level was closely monitored, and whenever the SpO_2 dropped to 95%, the operation was halted and jet ventilation was resumed until the SpO_2 returned to 100%. The operation then resumed, and the process was repeated until the mass was completely removed. After the operation, jet ventilation was stopped, and the jet catheter was removed. A conventional endotracheal tube (ID: 7.0 mm) was inserted using a direct curved laryngoscope and mechanical ventilation was initiated. End-tidal CO_2, measured immediately after the initiation of mechanical ventilation, was 80 mmHg but normalized shortly with continued mechanical ventilation. Neuromuscular blockade was reversed with 1 mg of neostigmine and 0.2 mg of glycopyrrolate. Reversal of the neuromuscular blockade was confirmed by observing four twitch responses after train-of-four stimulation, and extubation was performed once the patient regained consciousness. The operation lasted for 1 h and 45 min and the duration of jet ventilation was 1 h and 50 min. The patient was discharged uneventfully one day after surgery. Pathological examination revealed squamous papilloma with high-grade dysplasia.

Discussion

Due to the size of the intratracheal mass and the length of the affected segment, ECMO was initially considered. However, since the patient did not experience dyspnea, the otorhinolaryngology surgeon opted against tracheal resection. Instead, the surgeon preferred to remove the mass using a rigid telescope under suspension laryngoscopy. Following the discussion, manual jet ventilation was selected as the anesthetic technique. The mass was successfully removed using jet ventilation with a long catheter that bypassed the obstruction via a translaryngeal approach.

In our department, we developed a manual jet ventilator equipped with a timer, allowing control of the injection time (1, 0.75, and 0.5 s) [3]. This device has proven to be safe and easy to operate, and capable of delivering a constant volume per injection. At an injection time of 1 s and a driving pressure of 2100 cmH_2O, it delivers approximately 740 ml through a 14 G cannula [3]. After setting the injection time to a specific value, the device was activated to inject a precise volume by pressing the trigger button with the thumb. The injection automatically ceased once the set time had elapsed. As in conventional jet ventilation, adequate ventilation was assessed by observing chest wall movement during both insufflation and expiration. This device has been used safely in emergencies, as well as during elective operations requiring prolonged duration.

When using a conventional jet ventilator, maintaining anesthesia during long elective procedures can be challenging and tiresome for anesthesiologists, as it can not consistently deliver a constant tidal volume with each injection. Consequently, anesthesiologists must closely monitor chest wall movements during each breathing cycle. Due to these limitations, conventional jet ventilators are typically recommended for rescue and temporary maneuver to oxygenate the patient while a more secure and permanent airway is being established as soon as possible.

The injection-time-controllable jet ventilator differs from conventional jet ventilators in its ability to deliver a consistent tidal volume. This feature makes it more comfortable and convenient to use, particularly during extended operations. Because the mass was large, soft, and lobulated, it could not be removed in a single attempt. Therefore, it was gradually excised using both straight and curved long forceps, a process that requires a considerable amount of time. Our injection-time-controllable manual jet ventilator was greatly beneficial, as it eliminated concerns about volutrauma and facilitated the surgical process by allowing intermittent pauses during jet ventilation.

Initially, the catheter was blindly inserted into the anterior portion of the trachea because the mass was not visible during direct laryngoscopy. Immediately after catheter insertion, chest wall expansion was observed during the injection; however, during exhalation, a slight delay was seen in the sinking of the chest wall. To ensure accurate placement, it might be advantageous to use a telescopic video monitoring system immediately after induction to guide catheter insertion and confirms its correct positioning while the suspension laryngoscope is in place. Alternatively, using a fiberoptic bronchoscope during catheter insertion could also facilitate proper placement.

We did not anticipate ventilation difficulties after anesthesia induction because the patient did not have dyspnea, and demonstrated no breathing difficulties during manual face mask ventilation prior to induction of anesthesia. However, it was uncertain whether ventilation efficiency remains consistent after anesthesia induction. Administering a small amount of inhalational anesthetic while maintaining spontaneous respiration may provide a safer approach to confirm whether positive pressure ventilation is possible after loss of consciousness. A slow inhalation induction can help determine whether ventilation with positive pressure is feasible. If ventilation difficulties arise during this process, the patient can be awakened. This approach has been reported as an acceptable option and has been well tolerated by the patient [4]. If there is any doubt about the possibility of manual ventilation after loss of consciousness, attempting this method before initiating TIVA may be beneficial.

Zhu et al. [5] reported five successful cases of bronchoscopic removal of intratracheal tumors using HFJV with a driving pressure of 1530–2039 cmH_2O (0.15–0.2 MPa), an inspiratory to expiratory time ratio of 1:2–1:3, and a respiratory rate of 60–100 cycles/min. In these cases, a 10 Fr endobronchial suction catheter (Shiley™; Medtronic) was passed beyond the tracheal tumor. One concern with HFJV is its potential to cause barotrauma. Barotrauma may occur if exhalation is inadequate, resulting in a rapid pressure build-up in the lungs due to the high respiration rate. A key advantage of manual jet ventilation is its ability to control the respiratory rate by allowing complete chest wall deflation, even in

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cases of severe obstruction. If expiration is somewhat delayed but ventilation is still feasible, manual jet ventilation can be maintained. If not, Ventrain® (Ventinova Medical) [6] can be considered as an alternative option.

During jet ventilation, expiration is entirely passive and occurs through the spontaneous recoil of the chest and lungs. Therefore, a partially open airway that permits adequate passive expiratory flow is essential for jet ventilation. Generally, if the ID of the trachea is 4 mm or greater, sufficient expiration can be achieved [7]. We found no reports on the use of conventional manual jet ventilation during intratracheal tumor removal with rigid bronchoscopy or suspension laryngoscopy. This omission is likely due to concerns about the difficulty of maintaining a consistent tidal volume during prolonged surgical procedures.

In this case, intermittent interruptions of jet ventilation during the procedures led to hypercarbia, with a $PaCO_2$ of 80 mmHg observed immediately after the initiation of mechanical ventilation. Brief permissive hypercapnia, with $PaCO_2$ levels of up to 100 mmHg, has been reported to be well tolerated in healthy patients without significant adverse effects [8,9]. However, marked hypercarbia ($PaCO_2$ > 100 mmHg) may restrict the safe use of jet ventilation [10]. Assessing ventilatory adequacy through conventional capnography can be difficult during jet ventilation; careful clinical observation is essential. Instead, continuous monitoring using an arterial line or through transcutaneous CO_2 measurement would be beneficial in preventing hypercarbia.

The jet catheter used in this case had an ID of 1.8 mm and a length of 50 cm, while the 14 G angiocatheter had an ID of 1.6 mm and a length of 4.5 cm. We were interested in evaluating the impact of the length of the jet catheter on the delivered volume. To investigate this, we conducted measurements using a human trachea-lung model with a lung compliance of 60 ml/cmH_2O and resistance of 5 cmH_2O/L/s (SmartLung2000; IMT Analytics AG) (Supplementary Fig. 1). With a driving gas pressure of 2100 cmH_2O and an injection duration of 1 s, the delivered volumes were approximately 780 ml and 720 ml for the 14 G catheter (length: 4.5 cm) and the 1.8 mm ID long jet catheter (length: 50 cm), respectively (n = 4 each).

During the inspiratory phase, the Venturi principle generates a small suction effect that is quickly counteracted by upward gas flow through the larynx as pressure increases in the trachea after injection [5,11,12]. This phenomenon displaces blood or debris away from the larynx during the injection. Placing the catheter near the carina beyond the mass causes blood to be expelled towards the vocal cords rather than being sucked in. Immediately after the injection, we observed that some blood resulting from pinching the mass was pushed upward towards the vocal cords during the injection. However, when the jet catheter is positioned proximal to the mass, it is important to note that some blood or debris can be displaced into the trachea following injection.

A conventional jet ventilator is recommended for temporary use to oxygenate a patient while a secure and permanent airway is established as quickly as possible. However, this case demonstrated that a manual jet ventilator, equipped with a time-controllable function, is a safe and effective device for prolonged elective operations.

Funding

None.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

Data Availability

The datasets generated or analyzed during this study are available from the corresponding author on reasonable request.

Author Contributions

Darhae Eum (Data curation; Writing – original draft)
Hyun Joo Joo Kim (Data curation; Writing – review & editing)
Wyun Kon Park (Conceptualization; Data curation; Writing – review & editing)

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Supplementary Material

Supplementary Fig. 1.Trachea-lung model. A trachea-lung model consists of corrugated anesthetic breathing system tubing (inner diameter [ID]: 2 cm, length: 22 cm) connected to a test lung (SmartLung2000; IMT Analytics AG) with a static compliance of 60 ml/cmH2O and a resistance of 5 cmH2O/L/s. The proximal end of the trachea was closed with a rubber stopper to simulate complete airway obstruction. A polyvinyl chloride tubing (ID: 1 mm, outer diameter: 2.4 mm) was inserted into the connection site between the respirometer and the test lung that was connected to a pressure gauge (Smiths Medical ASD Inc.) to measure the pressure. The insufflation catheters were inserted through the wall of the short hollow tube and secured in place.

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