Case Report

Near total intrathoracic airway obstruction managed with a Tritube® and flow-controlled ventilation

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Summary

We describe the management of a case of near total airway obstruction in a 79-year-old man who presented with a two-week history of increasing shortness of breath and stridor. Computed tomography imaging revealed a mid-tracheal mass of unknown aetiology with critical airway obstruction. We secured the patient's airway using a Tritube® (Ventinova, Eindhoven, the Netherlands). While this facilitated a secure airway past the lesion, various issues were encountered which complicated the safe conduct of anaesthesia. We conclude that while the Tritube, used in conjunction with a proprietary flow-controlled ventilation system (Evone®, Ventinova Eindhoven, the Netherlands) are useful for critical airway obstruction, they can be problematic and thorough planning is essential.

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Introduction

Surgery for intrathoracic airway obstruction poses several challenges; the most concerning being that emergency surgical front-of-neck access is not an option for salvaging a lost airway.

Patients with a fixed tracheal lesion are typically managed with microlaryngoscopy tubes (MLT) or techniques which provide an optimal tubeless surgical field such as apnoeic oxygenation with high-flow nasal oxygen or high-frequency jet ventilation [1, 2]. In contrast, a foreign body is commonly managed by avoiding positive pressure ventilation, due to the risk of dislodgement and distal air trapping [1], and using inhalational induction with the aim of maintaining spontaneous ventilation [3].

The Tritube is an ultrathin, cuffed tracheal tube which provides an excellent view of the surgical field and allows passage past laryngotracheal obstructions that may inhibit larger tracheal tubes. Passive expiration is inadequate due to the narrow lumen, and thus ventilation is facilitated via the Evone ventilator using flow-controlled ventilation (FCV).

We present a case that presented acutely with near total airway obstruction in which the Tritube and the Evone ventilator were used. We also describe several issues we encountered that necessitated an intra-operative change of technique.

Case report

A 79-year-old male with a body mass index of 31 $kg.m^{-2}$, presented out of hours with a two-week history of worsening shortness of breath and stridor. The patient had undergone debulking of a squamous cell carcinoma of his vocal cord five months prior and had completed radical radiotherapy.

Flexible nasendoscopy showed signs of subglottic soft tissue 'ball valving' within the patient's trachea, but the operator was unable to view the mass. Computed tomography (CT) imaging showed a 17 mm filling defect 40 mm distal to the patient's vocal

cords that was not present on imaging four months prior (Fig. 1a). The report stated this was likely a food bolus with the risk of impending total airway obstruction. However, the patient could not recall choking and was eating well. Furthermore, given the lesion's location, and recent clear imaging, it was felt unlikely to represent the recurrence of malignancy.

Following a multidisciplinary team meeting involving anaesthesia, intensive care and ear, nose and throat (ENT) colleagues, it was agreed that the case should proceed urgently, despite it being 'out of hours', given the imminent risk of total airway obstruction. The patient was pre-oxygenated in an upright position using cautiously up-titrated high-flow nasal oxygen (Optiflow™, Fisher and Paykel Healthcare, Auckland, New Zealand) to a maximum flow of 70 $l.min^{-1}$ over 10 minutes while observing for signs of deterioration (indicating dislodgement of a food bolus). Induction of general anaesthesia was with total intravenous anaesthesia (TIVA) (propofol target effect site concentration 6 $\mu g.ml^{-1}$ and remifentanil 8 $ng.ml^{-1}$ using Marsh and Minto models, respectively) and a 100 mg bolus of rocuronium. Rigid laryngoscopy was performed, revealing a large polypoid lesion arising from the posterior tracheal wall. A Tritube (Fig. 1b) was successfully passed beyond the lesion and ventilation established on the Evone.

The Tritube was then disconnected to remove the rigid laryngoscope; on restarting the ventilator a 'cartridge error' message arose, and ventilation failed (Fig. 1c). As the patient's oxygen saturation was 100%, the cartridge and Tritube were rapidly replaced and ventilation resumed.

Once again, when the Tritube was disconnected to remove the rigid laryngoscope, another 'cartridge error' message arose, and ventilation failed. By this time the patient's peripheral oxygen saturations had fallen to 80% and thus the Ventrain® (Ventinova, Eindhoven, the Netherlands) hand ventilator was used. Oxygenation improved; however, within four to five breaths a loss of radial pulse was identified, attributed to high intrathoracic pressures from air trapping. Upon disconnection and manual chest deflation, the radial pulse immediately returned. A further ventilator cartridge was fitted, a new Tritube inserted and this time the rigid laryngoscope was removed before connecting and commencing ventilation.

Debulking proceeded with significant bleeding from the friable lesion. When almost half of the lesion had been debulked a further issue arose, with high ventilatory pressures and inadequate tidal volumes. There was concern that the Tritube had

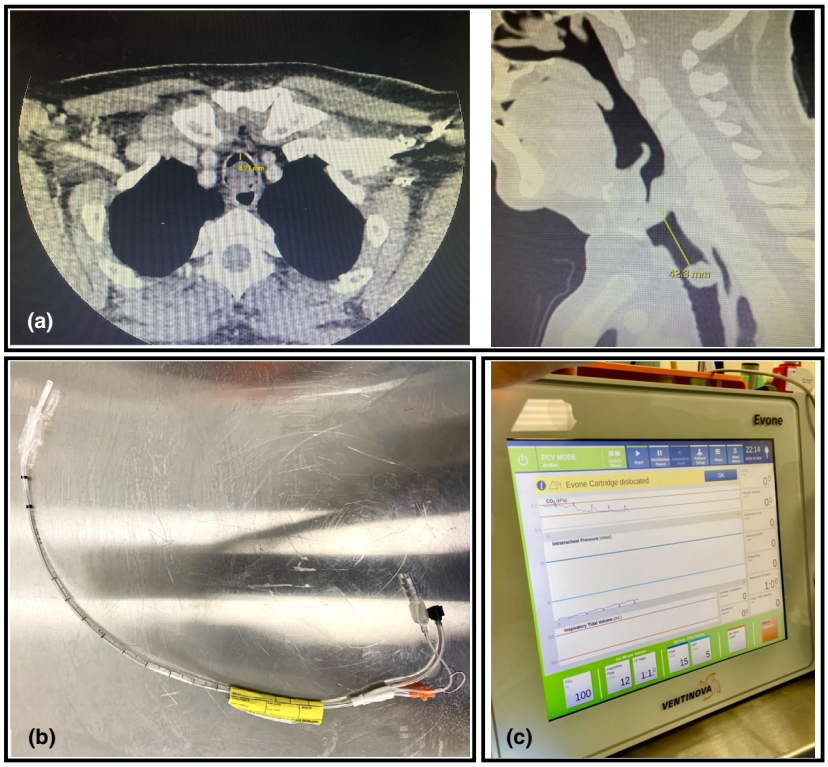

Figure 1 (a) Axial (left) and sagittal (right) computed tomography imaging of the patient's trachea; (b) Tritube; and (c) Evone ventilator showing 'cartridge error' message.

become blocked, so the ports were flushed with air, but without resolution. By now, sufficient mass had been removed to allow the Tritube to be exchanged for an MLT. On removing the Tritube there did not appear to be any obvious cause for the ventilation issue.

At the end of the case, the MLT was exchanged for a standard 8 mm internal diameter cuffed oral tracheal tube. The patient was transferred to intensive care unit postoperatively and his trachea was uneventfully was extubated the following morning. The patient was fully debriefed postoperatively and returned home symptom free shortly thereafter. Review of the histology of the lesion confirmed the diagnosis of sarcomatoid squamous cell carcinoma.

Discussion

The key pre-operative challenge identified was planning a safe anaesthetic out of hours when the aetiology of the mass was unknown. Further critical issues arose intra-operatively.

Multiple anaesthetic techniques and scenarios were considered. If the mass was a food bolus, as per the CT report, the obstruction could be removed rapidly via rigid laryngoscopy and forceps after careful pre-oxygenation. We were concerned that high-flow nasal oxygen might precipitate total airway obstruction, thus we employed very slow titration. However, if there was a fixed lesion, then achieving safe and adequate ventilation would be more challenging. Good pre-oxygenation would be vital which favoured the decision to use high-flow nsasal oxygen. Most elective airway malignancy cases are managed via a MLT with intermittent positive pressure ventilation, or via apnoeic oxygenation with high-flow nasal oxygen or high-frequency jet ventilation, both of which provide an optimal surgical view [1, 2, 4]. In this case, there was concern that oxygenation could not be maintained via apnoeic oxygenation given the distal location of the lesion and the minimal space around it, alongside a patient BMI of 31 $kg.m^{-2}$. Furthermore, the narrow lumen around the mass may have prevented sufficient gas outflow leading to air trapping, high intrathoracic pressures and potential barotrauma. The patient had also recently eaten and therefore a secure airway was essential. Computed tomography imaging measured a maximum of 4.5 mm of remaining space around the mass, too narrow for even the smallest size MLT (external diameter 6.9 mm). Therefore, the Tritube was chosen as Plan A.

The Tritube is an ultrathin, cuffed tracheal tube with an outer diameter of 4.4 mm which provides an excellent view of the surgical field and allows passage past laryngotracheal obstructions that may inhibit larger tracheal tubes [5]. Passive expiration is inadequate due to the narrow lumen, and thus ventilation is facilitated via the Evone ventilator. The Evone uses FCV to facilitate expiration through continuous suction, which maintains a continuous outward flow equal to the inspiratory air flow, down to a predetermined PEEP. Continuous, controlled, positive pressure flow maintains inspiration up to a set peak pressure [5, 6]. This continual expiratory and inspiratory flow ensures no ventilatory pauses and maximal efficiency of ventilation [5]. If the volume of expired gas is reduced compared with that inspired, gas trapping can occur, and therefore intrathoracic pressures are constantly monitored via a third lumen to protect against barotrauma [7].

Induction with TIVA followed rapidly by muscle relaxation was chosen to limit apnoea time due to the patient's BMI and the lack of starvation. An inhalational induction was not used as the patient developed significant airway obstruction on lying flat, which may have portended total airway obstruction before sufficient depth of anaesthesia was achieved [4]. Additionally, we wished to avoid rescue positive pressure ventilation that may have dislodged a mobile obstruction.

The Tritube was thought to be the best device to facilitate a successful outcome. However multiple issues arose after intubation that we believe are important to highlight to potential users. First, ventilation was interrupted via two 'cartridge error' alerts upon disconnection of the Tritube from the ventilator, which only resolved once a new cartridge was inserted; on the second occasion the disruption in ventilation resulted in oxygen desaturation. This error had been reported to the manufacturer previously, who had issued a software update and assured us that the problem would not recur. The Evone had been used since this update without issue, so we felt it reasonable to use this as part of our management plan for this case. When the issue arose again during this case, it was reported to the manufacturer and the Medicines and Healthcare Products Regulatory Agency and the machine has since been withdrawn from use. It is unclear as to why such error messages arose; the case has been since discussed with Ventinova, who, upon further investigation, think the error is either due to supply line pressure variation or failure of the exhaust valve. They have issued a software patch which has yet to be tested in our centre.

The emergency use of the Ventrain also posed a challenge. While there was immediate success in improving oxygenation, a loss of radial pulse occurred after a short period of use, indicating air trapping and high intrathoracic pressures causing transient cardiovascular collapse. While the Tritube has a dedicated lumen for measuring intrathoracic pressures to prevent such an occurrence, there is no way easily to monitor this on the Ventrain itself, nor is there an alarm system or a safety pressure release system which prevents ventilation if the pressure rises beyond a set limit. Managing a rapid desaturation is extremely stressful,

and it is very easy to not allow sufficient time for expiration. As a result, we cannot recommend the use of the Ventrain for oxygenation in circumstances of a completely obstructed airway. A recent study showed that for airway devices with an internal diameter of less than 3 mm, gas trapping increases with rising minute volume and the use of lower tidal volumes (< 200 ml) and rates (< 8 min^{-1}) may be beneficial [8]. Fortunately, the loss of radial pulse was recognised immediately and was remedied via disconnection and manual decompression of the chest. This experience reinforces the importance of continuous blood pressure monitoring in any critical situation, ideally via pre-emptive invasive arterial monitoring.

The final challenge that arose was cessation of ventilation due to Tritube blockage. The narrow lumen of the TriTube makes such a scenario more likely and has been reported previously [7]. An attempt was made to clear the blockage via flushing the ventilation lumen with a hand-syringed bolus of air, and although this was done easily, we were still unable to ventilate, and the device had to be removed.

In summary, we conclude that while the Tritube and Evone ventilator were well positioned to facilitate this challenging case theoretically, their use did come with critical issues which future users must be aware of. These issues were complicated by an inability to easily switch to a backup technique such as hand ventilation or connection of a Mapleson C circuit. Despite these, it is difficult to see how we could have managed the case otherwise. Had the aetiology been certain and the patient been adequately fasted, the case may have been managed successfully with high-frequency jet ventilation. However, the lesion was friable and bled significantly during debulking. Transfer to a cardiothoracic centre for awake extracorporeal membrane oxygenation would also have been an option had the aetiology been certain, the patient more stable and had the Tritube and Evone not been available. If we were to encounter a similar case in the future, we would still use the Tritube with a lower threshold for switching to a MLT if similar problems occurred. We also note the importance of allowing sufficient time for expiration with the Ventrain device.

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Near total intrathoracic airway obstruction managed with a Tritube (R) and flow-controlled ventilation: a reply.

We would like to thank the Editor for the opportunity to respond to the report by Dr Mallam and colleagues. The ultrathin Tritube (R) in combination with both mechanical ventilator Evone (R) and manual ventilator Ventrain (R) (all Ventinova Medical BV, Eindhoven, The Netherlands) were chosen for airway management and ventilation in a patient with acute, near total airway obstruction. The authors describe unexpected complications related to the use of the devices, which we address in this correspondence.

We would like to acknowledge the stressful situation encountered by the authors during this case. Following this case an immediate correspondence was initiated by the hospital's senior airway surgeon and the hospital's senior airway lead. Thanks to a clear and open communication to the manufacturer, appropriate measures were expedited. A field safety notice was filed, and all affected Evone devices were temporarily placed under quarantine. Upon identification of the root cause, a solution was implemented through a software upgrade which addressed the challenges described in this publication. Competent authorities, including the Medicines and Healthcare Products Regulatory Agency were subsequently satisfied with the handling of the problem and the solution provided, and all Evone devices were released from quarantine. To date, no comparable incidences have been reported to the manufacturer. Ventinova is aware of frequent use of Evone and Tritube for various indications in many countries.

Apart from the technical issues related to Evone the authors describe sudden ventilatory problems, which could not directly be linked to an obvious obstruction of Tritube. Based on the description provided, such issues might occur due to an altered positioning of Tritube, such as upon surgical manipulation too close to the carina with the mucous membrane and/or viscous secretions (that are likely with described pathology) causing a valve mechanism occlusion. However, as more data are lacking, the exact reason remains unclear.

Additionally, questions were raised on the suitability of Ventrain as a backup tool for ventilation in obstructed airways. We agree with the authors that proper use of Ventrain and Tritube requires careful monitoring of intra-tracheal pressures, which can be easily done by connecting a manometer to the pressure lumen of the Tritube [1]. Alternatively, in a sealed or (nearly)

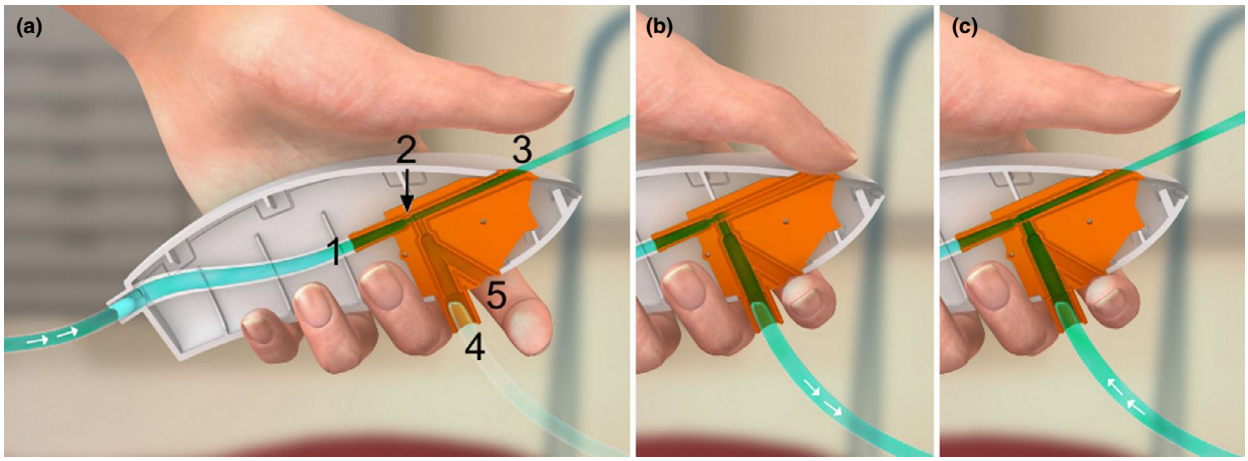

Figure 1 Cross section of Ventrain. 1: Gas inlet connected to oxygen source. 2: Jet nozzle accelerating the velocity of oxygen flow. 3: Exhaust pipe facilitating the exit of gas during expiration and equilibration. 4: Side-port connected to patient. 5: Bypass allowing air to enter the ejector (on/off switch). (a) Equilibration position with open bypass. No clinically-relevant flow to and from the patient (= equilibration with atmosphere). (b) Inspiration position with both exhaust pipe and bypass closed. (c) Expiration position with exhaust pipe open and bypass closed. Used with permission of Ventinova Medical BV, Eindhoven, the Netherlands

obstructed airway, it is recommended to include a sufficiently long equilibration period every five ventilation cycles to avoid excessive positive or negative pressure in the lungs (Fig. 1).

The clinical application of Ventrain, including its potential advantages over alternative techniques, has been described in detail [2]. Several studies have demonstrated that Ventrain is the safest and most efficient device for ventilation in a (near) complete airway obstruction [3–5], and its successful use in emergency situations has been published [6, 7]. However, we would like to emphasise that Ventinova strongly advises users to complete the required training before device use to assure safe application of Ventrain in emergencies.

Finally, we agree with the authors that flow-controlled ventilation using Evone in combination with Tritube represents a valuable solution for managing complex difficult airway cases, as it has been successfully used by others for this purpose [8–10].

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