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Ventilation through a 'straw': the final answer in a totally closed upper airway?

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In the rare situation of 'cannot intubate, cannot ventilate' (CICV), even very experienced anaesthetists find it challenging to avert a potentially life-threatening situation. In this situation, all techniques routinely used in daily clinical practice, such as bag mask ventilation, placement of a laryngeal mask, and laryngoscopy, may fail to oxygenate and ventilate the patient. In most instances, the patient already presents with severe hypoxia and is very close to or even has experienced cardiac arrest. The anaesthetist is then forced to take measures that most doctors prefer to avoid. In this life-threatening situation, guidelines throughout the world recommend a surgical cricothyroidotomy or a cannula (needle) cricothyroidotomy as the only remaining options to (re-)oxygenate the patient.[1] The problem with these techniques is lack of specific training and the fact that the techniques are not routinely used. It is possible, therefore, that the anaesthetist opens the 'cric set' for the first time and is confronted with instruments that he or she has never used before in a real emergency.

Occasionally, appropriate equipment might not even be available immediately. Simple 'tricks' using self-made or self-assembled tools could be and often are used, but have mostly been proved to be insufficient or even inherently dangerous. For example, puncture of the cricothyroid ligament with a standard large-bore i.v. cannula with attachment of a self-inflating resuscitation bag using a self-assembled connector (e.g. the cylinder of a 2 ml syringe with a 5 mm tube connector plugged in) has been shown to be ineffective to achieve ventilation and oxygenation.[2] Three-way taps proposed for emergency jet ventilation do not provide sufficient control or release of oxygen flow and pressure to the patient, so in the event of complete upper airway obstruction the intrathoracic pressure can unintentionally increase more than 70 cm H_2O.[3]

Most physicians, especially those working in less 'invasive' specialties like anaesthesiology, have difficulties imagining 'to cut with a blade in someone's throat and slit the trachea open'. Unfortunately, a patient in need of a cricothyroidotomy may often also have abnormal neck anatomy, so that access to the airway might become very difficult with any technique. The combination of a rare event, lack of training and routine, insufficient equipment, challenging anatomy, and reluctance to apply a (very) invasive technique results in a high failure rate of cricothyroidotomy.[4]

Although they are familiar with puncturing techniques and procedures (e.g. placement of central venous lines), most anaesthetists still find the idea of puncturing the trachea more appealing than performing a surgical cricothyroidotomy in the event of a CICV emergency. Additionally, puncturing the cricothyroid ligament and injecting local anaesthetics into the trachea for topical anaesthesia is routinely used in anaesthesia before an awake flexible fibreoptic intubation.[5] In fact, this so-called 'cricothyroid stab' helps to train identification of the anatomical structures and to improve individual performance in routine situations without stress.

Using a standard i.v. cannula for a cricothyroidotomy has clear limitations, because the cannula may kink as a result of the material from which the product is made, such that it may become soft and flexible after insertion. In addition, any manipulation can easily lead to inadvertent dislodging of the cannula. Therefore, the current guideline of the Difficult Airway Society clearly indicates the technical demands for cannula (needle) cricothyroidotomy; a kink-resistant cannula is required along with a dedicated high-pressure ventilation system to overcome the flow resistance of the cannula.[1]

Transtracheal jet ventilation refers to injection of oxygen at high pressure and high velocity through a laryngeally or tracheally placed cannula. There are several devices currently available commercially.

For adequate expiration, a sufficiently patent upper airway is mandatory to avoid critical complications such as barotrauma and haemodynamic deterioration caused by high intrathoracic or intrapulmonary pressures. Passive expiration via the translaryngeal or transtracheal cannula is very limited because of the high flow resistance of the relatively small lumen. In a CICV situation, however, the upper airway might be swollen as a result of desperate attempts to intubate and ventilate the patient. Furthermore, pathology of the upper airway, such as a pharyngeal

tumour mass or swelling because of allergic reaction or angio-oedema, might be responsible for the airway emergency. In such a scenario, active expiration assisted by suction via the translaryngeal or transtracheal cannula is an interesting option to avoid intrathoracic air trapping and pressure build-up while optimizing alveolar gas turnover.

Recently, a purpose-built ejector pump (DE5)[6] has been shown to support expiration efficiently through a small-lumen cannula or catheter by generating negative pressure based on Bernoulli's principle.[7 8] The advancement of this experimental device is the commercially available Ventrain (Dolphys Medical, Eindhoven, The Netherlands), an ergonomically shaped, manually operated, flow-controlled ejector ventilator.[9] Connected to a pressure-compensated flowmeter or flow regulator of a high-pressure oxygen source with the flow properly set according to the demands of the patient, this device allows efficient ventilation through a 'straw' as the one and only airway. However, there are only a few published clinical reports of the device being successfully used in patients.[10 11]

Very little is known about the efficacy of this device in controlled conditions compared with devices already available. In their current experimental work, Paxian and colleagues[12] evaluated the novel Ventrain and one of the most commonly available manual jet ventilators, the Manujet (VBM, Sulz a.N., Germany) in three clinically relevant airway scenarios in pigs. The 'partly obstructed' scenario might represent the situation of CICV with a swollen upper airway after multiple unsuccessful attempts to secure the airway, whereas the 'totally closed' scenario might simulate a situation of massive pharyngeal swelling attributable to angio-oedema. Paxian and colleagues[12] monitored clinically relevant parameters, such as blood gases, airway pressures and haemodynamics. With both devices, the Ventrain and the Manujet, comparable oxygenation could be achieved in 'open' and 'partly obstructed' airway scenarios. In the 'totally closed' scenario, oxygenation was much better using the Ventrain. Compared with the Manujet, ventilation and carbon dioxide elimination were more efficient with the Ventrain, especially in 'partly obstructed' and 'totally closed' upper airways. Use of the Manujet was associated with higher airway pressures in the 'totally closed' scenario.[12]

These results are convincing because they show the principle of an active expiration to help the gas through a small-bore cannula by suctioning. But is it time to discard conventional jet ventilators and always rely on the Ventrain in CICV situations? The idea and working principle behind the Ventrain are very promising and have the potential to change the way we look at ventilation through small-bore cannulae, not only in emergency situations. Nevertheless, there remains one significant limitation, namely the user.

As with any other device, use of the Ventrain requires training and routine use for successful application in emergencies. Like the Manujet, the Ventrain is also a high-pressure device. However, by virtue of a jet nozzle inside the Ventrain, pressure is turned into flow speed of gas. In contrast to the pressure-controlled Manujet, the Ventrain is flow controlled, so the volume insufflated over time can be estimated (e.g. a flow of 6 litres min^{-1} directed to the patient for 1 s equates to an insufflation volume of 100 ml, and a flow of 15 litres min^{-1} for 1 s results in an insufflation volume of 250 ml). Like the Manujet, the Ventrain does not have a pressure-release valve. As a consequence, high intrathoracic pressures can result from incorrect use of this ejector ventilator in the situation of (almost) complete upper airway obstruction, with consequences not only for the lungs, but also for haemodynamics.

The very simple approach of the Ventrain, with a 'design to function' and manual control for ventilation, is a big advantage because it is not a complex device, but it has no warning lights and thus no visual feedback, especially of (high) airway pressure. In very stressful, emergency situations, it might be very challenging for the user to keep calm and watch the chest movements closely to avoid overinflation and potential barotrauma. The authors of the present study show nicely that changes of the inspiratory-to-expiratory ratio during ventilation might cause a significant increase in airway and pulmonary pressures.[12] It is advisable to allow equilibration of intrathoracic pressure with the atmosphere by simultaneously releasing the bypass and the outlet opening of Ventrain intermittently to minimize the risk of an increasing intrathoracic pressure.[13]

Should we now place the Ventrain in every airway cart, in every emergency backpack, or even in every anaesthesia cart? Maybe the time is not yet right. Despite very promising reports, there is very little experience with this device in patients. Current *in vivo* studies and first applications in patients have been undertaken by airway enthusiasts with a high degree of clinical and academic expertise in this field. The experiences of these individuals cannot be transferred directly into broad clinical practice. It is doubtful that there will be a prospective, randomized, controlled study examining different techniques and devices in a CICV situation. It will therefore take some time to generate enough experiences with novel equipment such as the Ventrain to judge its clinical value.

It will be only a matter of time until an inexperienced and stressed anaesthetist will use the Ventrain incorrectly in an emergency situation, resulting in injury or even death of a patient. It is very likely that the novel device will be blamed. Who wants to suggest that it was the physician who used a device inadequately in a CICV situation? But one or two publications documenting negative results without appropriate scientific discussion and careful scrutiny of the cause will create doubt in the mind of anaesthetists and may lead to banning of the use of the device, and a promising new principle with great potential might vanish.

At this point only experienced, well-trained, and enthusiastic anaesthetists should have Ventrain readily available in their workplace and should use it in the correct manner for the right patients. More data and experience is needed to understand fully what ventilation through a 'straw' means for the patient. For the same reason, the manufacturer is invited to develop the device further to make it 'foolproof'. For the benefit of patients in critical situations, it will be necessary to train and educate as many anaesthetists as possible in this novel ventilation technique, not only to avoid inappropriate use, but to allow its incorporation into routine airway management in the future.

Declaration of interest

None declared.

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