A new transtracheal catheter for ventilation and resuscitation

Patrick Ravussin MD, James Freeman MD

We describe a new catheter for emergency ventilation of patients difficult to intubate. This catheter can be inserted through the crico-thyroid membrane or the first or second intertracheal ringspace with ease in an almost atraumatic fashion. The outside part of the device, with its dual attachment system, can be connected to conventional resuscitation equipment by its 15 mm male end or to a high-pressure oxygen source by its luer-lock fitting. A double angulation maintains the intratracheal portion of the catheter in the axis of the trachea and the external part in close contact with the larynx. A Velcro band attached to two lateral flanges keeps the catheter in place. The results of transtracheal catheterization of 48 patients by means of this new device are discussed.

Key words
EQUIPMENT: transtracheal catheter; VENTILATION: jet ventilation, high frequency; COMPLICATIONS: difficult intubation.

Difficult intubation in a hypoxic patient is a chilling prospect for any anaesthetist. Over the years anaesthetists and critical care physicians have therefore designed a variety of means to provide oxygenation and ventilation in such instances. In the early fifties Jacoby *et al.*[1,2] punctured, with a 14-gauge needle, the trachea of five patients who were extremely difficult to intubate and in this way insufflated oxygen while the surgeon or the anaesthetist proceeded with a tracheotomy or with intubation. Saunders (1967) ventilated patients down a bronchoscope during bronchoscopy[3] with a high-pressure oxygen source which he opened and closed twenty times a minute. In 1971 Spoerel *et al.*[4] combined transtracheal and high pressure jet ventilation during anaesthesia in elective patients. One year later Jacobs[5,6] stressed the importance of a minimum oxygen flow to correct hypoxemia[7] and attached a high-pressure ventilator to produce adequate alveolar ventilation.

In recent years numerous researchers[8–20] have suggested further methods, based on those outlined above, to rescue hypoxic patients who could not easily be intubated. Klain *et al.*[21–23] developed techniques using high frequency jet ventilation (HFJV) which have enlarged the indications for transtracheal ventilation (Table I).

The solution we present is based on the design of a new device and on the experience gained at the Centre Hospitalier Universitaire Vaudois (CHUV) in the last year.

Methods

Dissatisfied with the custom-made transtracheal needles and catheters available in our centre, we designed and tested our own transtracheal device.* The 13-gauge intratracheal catheter, mounted on a stainless steel needle, is made of radio-opaque Teflon. It is 70 mm long, with an angle 15° in a coronal plan that allows it to be inserted in the axis of the trachea (Carden *et al.*).[8] At the distal end two circular holes, 0.8 mm in diameter, are located 8 mm from the tip. These serve to decrease the Venturi effect and to separate the end of the catheter from the mucosa during high frequency jet ventilation. At the proximal end the catheter is glued to a luer-lock hub located at the centre of a 15 mm ISO male polystyrol connector that constitutes the extra-

From the Department of Anaesthesia, Centre Hospitalier Universitaire Vaudois, Lausanne, Switzerland.

Address correspondence to: Dr. Patrick Ravussin, Department of Anaesthesia, Montreal Neurological Hospital and Institute, 3801 University, Montreal, Quebec, Canada H3A 2B4.

*Now being manufactured by VBM laboratories (Medizintechnick D-7247, Sulz/Neckar, Germany).

TABLE I Indications for transtracheal ventilation

Group I	*Group II*	*Group III*
Unsuccessful intubation related to:	Difficult intubation where a nasal approach is possible:	Airway management where transtracheal ventilation is considered an alternative during:
Foreign body obstructing the airway	Protruding front teeth	Suspension microlaryngoscopy
Large tumour of the airway	Retrognathia and/or presence of an anteriorly placed larynx	Surgery of the trachea
Inflammatory process	Rigid or unstable cervical spine	Laser surgery of the upper airway
Bilateral vocal cord paralysis	Limited mouth opening due to trauma, trismus, etc.	Presence of contra-indications to the use of muscle relaxants
Trauma to face and larynx	Congenital anomalies of the oro-facial region	Endoscopy
Intermaxillary fixation associated with a basal skull fracture		Cardio-pulmonary resuscitation
Failure to achieve intubation in group II patients		

Transtracheal ventilation offers a lifesaving technical advance to group I cases; the technique is a valuable alternative to naso-tracheal intubation in group II cases, and has been used successfully in group III cases.

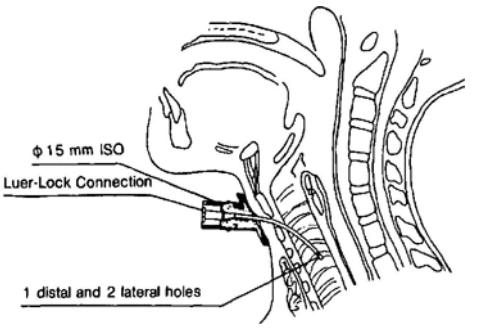

FIGURE 1 The dual angulation of the catheter, as well as the double connection, is outlined; the catheter is positioned through the crico-thyroid membrane.

tracheal portion (Figure 1). This part forms a 45° angle with the catheter, and provides a close fit between the connector and the larynx, to which it is attached by a Velcro band which extends around the neck and is attached to two polyethylene flanges.

The catheter can thus be attached to a high-pressure source (e.g. a HFJV system) with its luer-lock connection, or to a conventional ventilation device such as a resuscitation bag (Figure 2).

Between December 1983 and April 1984 the catheter was used in 48 patients (Table II). A simple approach was used in all cases. Under aseptic conditions, the laryngeal region was infiltrated locally with Xylocaine one per cent if the patient was not yet anaesthetized. The catheter, attached to a 5 ml syringe filled with 1 ml saline, was introduced either through the crico-thyroid membrane or between two adjacent tracheal rings, while continuous negative pressure was exerted with the piston of the syringe. When the tip had entered the trachea, the teflon catheter was advanced to the hilt over the stainless steel needle. During endoscopy the position of the catheter was verified by the

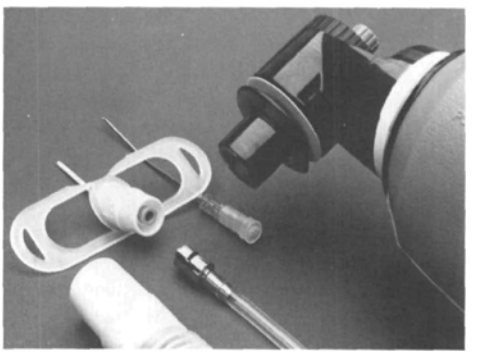

FIGURE 2 The transtracheal catheter with its double connection and the metal guide used for insertion is seen surrounded by alternative ways of ventilation. The lateral flanges allow for fixation to the neck of the patient.

TABLE II Summary of use of transtracheal ventilation in 48 patients

Group A	*Group B*	*Group C*	*Group D*	*Group E*	*Total*
Emergency after unsuccessful attempts at oral intubation	Elective cases; difficult intubation predicted from clinical assessment	Intermaxillary wiring with basal skull fracture	Suspension microlaryngoscopy and laser surgery	Endoscopy	
2 cases*	6 cases†	10 cases	20 cases	10 cases	48 cases

*In both instances the catheter was connected initially to a conventional anaesthetic circuit and intermittent positive pressure ventilation was initiated with 100% oxygen.

†In all cases an apparently mandatory tracheotomy was avoided. Among these six patients, four were first ventilated with IPPV and 100% oxygen with the catheter in place and connected to a conventional anaesthetic circuit.

surgeon; during all procedures tracheal air entry into the syringe was checked twice and lung auscultation performed.

Of 48 patients, 47 were ventilated using a HFJV system with minute volumes of 250 $ml \cdot kg^{-1}$ at ventilator driving pressures of 1–3 bar.[23] The inspiration: expiration ratio was fixed at 1:2 in the presence of a 150 Hz frequency rate; the inhalation gases consisted initially of nitrous oxide and oxygen in equal concentrations. Etomidate (Hypnomidate®), vecuronium bromide (Norcuron®), and fentanyl were used to induce hypnosis, muscular relaxation, and analgesia. Arterial blood gases were measured and the ventilation parameters and the FiO_2 modified, when necessary.

The two patients in group A and four of the six patients in group B were first ventilated with conventional methods at 100 per cent oxygen for as long as was necessary to obtain a high frequency ventilator (one case), to perform an emergency tracheotomy (one case), or to create surgically an escape route for gases insufflated at high pressure (four cases).

Results

In the 48 patients the total anaesthetic time ranged from 10 to 360 minutes. The patients' pulse and blood pressure were routinely monitored and remained within physiological limits. All blood gases were considered normal or better than normal except for eight cases where the $PaCO_2$ was found to be above 45 mmHg in spite of adequate PaO_2 values.

In the six patients who were first manually ventilated with conventional means through the transtracheal catheter, blood gases were measured immediately before the technique was modified. The results are presented in Table III. The values were normalised in each instance either with a HFJV system (five patients) or with IPPV through a tracheal cannula (one patient).

In two additional patients suffering from COPD, $PaCO_2$'s of 60 and 63 mmHg were observed during endoscopy; the situation was corrected rapidly by increasing the minute ventilation of the HFJV.

The tracheal mucosa, observed directly in 36 of the 48 patients, showed no abnormality related to the trauma of puncture or insufflation. The catheter was never repositioned as it appeared to have been correctly inserted in each instance.

One complication was observed when a patient developed severe cervical and mediastinal emphysema caused by accidental displacement of the catheter out of the trachea. Other minor side effects included postsurgical dry coughing in ten patients.

Discussion

This improved transtracheal catheter is an extension of recent trends in resuscitation and ventilation methods applied to patients difficult to intubate. The dual connection, which allows for conventional or jet ventilation, is a most valuable feature. We realize, however, that intermittent positive-pressure ventilation through a 13-gauge catheter is not satisfactory, as $PaCO_2$ levels cannot be controlled (Table III).

A crico-thyroid puncture is the preferred route for the catheter as trauma to vessels or nerves is unlikely at this level.[12] The double angulation of the catheter device allows for optimal positioning in the axis of the trachea. Whenever possible the position should be observed directly. A lower puncture site,

TABLE III Individual values of $PaCO_2$ and PaO_2 in 6 patients

	Initial values Manual transtracheal ventilation		*Later values Transtracheal HFJV (5 cases) and tracheotomy with IPPV (1 case)*	
Patients	$PaCO_2$	PaO_2	$PaCO_2$	PaO_2
1	51	170	36	223
2	112	102	47	184
3	52	130	36	326
4	63	230	44	403
5	83	163	39	368
6	89	122	42	222

All values are expressed in mmHg.
The 6 patients were ventilated initially with conventional methods through the transtracheal catheter system. Patients 1 and 2 belong to group A and patients 3 to 6 are part of group B.

although acceptable, constitutes a more difficult and hazardous route.

The only complication occurred when the catheter was accidentally displaced out of the tracheal lumen. The catheter must be attached tightly to the larynx; the flanges should always be secured around the patient's neck with the Velcro band. Multiple punctures of the tracheal wall should be avoided. Although trauma to the mucosa resulting from high-pressure jet inflation is possible, none was observed in our series, confirming the results of Klain and Smith.[21] An escape route for inflated gases should always be present.

The transtracheal catheter was designed primarily for the emergency treatment of the hypoxic, difficult to intubate patient. However, the catheter also provides a useful alternative to intubation in surgical procedures on the upper airway,[24] as it is less likely to damage the mucosa. Elimination of the endotracheal tube also permits better visualisation of delicate structures during laryngeal surgery. Furthermore the catheter is unlikely to burst into flames during laser surgery.[25] Indications for use of the catheter are outlined in Table I. The list is by no means exhaustive and newer indications will likely arise.

This catheter must obviously be used with caution: no device is guaranteed against human error. A low restriction of the trachea due to a tumour or a foreign object, massive tumoral, inflammatory, or granulomatous tissue at the puncture site, or infection in the area are all reasons for selecting an alternative ventilation technique.

In conclusion, we feel entitled to recommend this new catheter device to all anaesthetists and critical care physicians.

Acknowledgements

We express our gratitude to Professor D. Trop and the personnel of the Montreal Neurological Hospital and Institute for their assistance in writing the manuscript, Professor M. Savary for his help and his advice, R.C. Legrand and M. Thirot for their technical advice, A. Martin for assistance during the early clinical trials, F. Gagneux for typing of the original version of the manuscript.

References

1 *Jacoby JJ, Hamelberg W, Reed JP, Gillespie B, Hitchcock FA.* Simple method of artificial respiration. Am J Physiol 1951; 167: 798–9.
2 *Jacoby JJ, Hamelberg W, Ziegler CH, Flory FA, Jones JR.* Transtracheal resuscitation. JAMA 1956; 162: 625–8.
3 *Sanders RD.* Two ventilating attachments for bronchoscopes. Del Med J 1967; 39: 170–5.
4 *Spoerel WE, Narayanan PS, Singh NP.* Transtracheal ventilation. Br J Anaesth 1971; 43: 932–9.
5 *Jacobs HB.* Emergency percutaneous transtracheal catheter and ventilator. J Trauma 1972; 12: 50–55.
6 *Jacobs HB.* Needle-catheter brings oxygen to the trachea. JAMA 1972; 222: 1231–3.
7 *Nunn JF.* Applied Respiratory Physiology. London: Butterworth & Co, 1969: 146–7.
8 *Carden E, Becker G, Hamood H.* Percutaneous jet ventilation. Ann Otol Rhinol Laryngol 1976; 85: 652–5.
9 *Smith BR, Babinski M, Klain M, Pfaeffle H.* Percutaneous transtracheal ventilation. JACEP 1976; 5: 765–70.
10 *Stinson TW.* A simple connector for transtracheal ventilation. Anesthesiology 1977; 47: 232.
11 *Dunlap LB.* A modified, simple device for the emergency administration of percutaneous transtracheal ventilation. JACEP 1978; 7: 42–6.
12 *Fisher JA.* A "last ditch" airway. Can Anaesth Soc J 1979; 26: 225–30.
13 *Carlton DM, Zide MF.* An easily constructed cricothyroidotomy device for emergency airway management. J Oral Surg 1980; 38: 623–4.

14 *Delisser EA, Muravchick S.* Emergency transtracheal ventilation. Anesthesiology 1981; 55: 606–7.
15 *Hilton PJ.* A simple connector for cricothyroid cannulation. Anaesthesia 1982; 37: 220.
16 *Scuderi PE, McLeskey CH, Comer PB.* Emergency percutaneous transtracheal ventilation during anaesthesia using readily available equipment. Anesth Analg 1982; 61: 867–70.
17 *Gildar JS.* A simple system for transtracheal ventilation. Anesthesiology 1983; 58: 106.
18 *Aye LS.* Percutaneous transtracheal ventilation. Anesth Analg 1983; 62: 619.
19 *Patel R.* Systems for transtracheal ventilation. Anesthesiology 1983; 59: 165.
20 *Pottecher T, Bing J, Cuby C, Fleck G, Coppe B, Otteni JC.* Ventilation translaryngée de sauvetage par aiguille de Tuohy; utilisation en cas d'impossibilité d'intuber et de ventiler un patient curarisé. Ann Fr Anesth Réanim 1984; 3: 54–8.
21 *Klain M, Smith BR.* High frequency percutaneous transtracheal jet ventilation. Crit Care Med 1977; 5: 280–7.
22 *Klain M, Miller J, Kalla R.* Emergency use of high frequency jet ventilation. Crit Care Med 1981; 9: 160.
23 *Klain M.* High frequency ventilators and methods of their use. Presented at Critical Care Medicine 20th Annual Symposium 1982, Las Vegas (Nevada).
24 *Basset JM, Eurin B, Francois M, Hertzog C, Laquerriere MC, Ardoin C.* La ventilation à haute fréquence par voie intercricothyroïdienne dans les endoscopies ORL. Notre expérience de 83 cas. Ann Oto Laryng 1982; 99: 159–66.
25 *Patel KF, Hicks JN.* Prevention of fire hazards associated with use of carbon dioxide lasers. Anesth Analg 1981; 60: 885–8.

Résumé

Un nouveau système de canulation transtrachéale ou transcrico-thyroïdienne est présenté. Les multiples avantages qu'il procure sont a) sa mise en place rapide, b) sa connexion aisée, par son embout ISO 15 mm mâle et/ou par son embout luer-lock femelle scellé en son milieu, à tout circuit d'anesthésie ou de réanimation, c) ses 2 ailettes, permettant une fixation solide autour du cou du patient et d) sa double angulation, assurant une position parallèle à la trachée et un positionnement adéquat contre le larynx du patient.

Un total de 48 patients ayant été ventilés avec succès au moyen de ce cathéter est présenté. Les indications étaient les suivantes: a) patients difficiles à intuber: huit cas b) patients ayant déjà une fixation intermaxillaire associée à une fracture de la base et/ou de la lame criblée: dix cas c) microlaryngoscopies en suspension avec laser: vingt cas d) endoscopies: dix cas.

Vu les excellents résultats obtenus et la facilité d'administrer de l'oxygène par cette voie, on ne peut que souligner l'importance d'avoir rapidement sous la main un cathéter transtrachéal et des connexions adéquates.