TRACHEOSTOMY UNDER JET-VENTILATION

- An Alternative Approach to Ventilating Patients Undergoing Surgically Created or Percutaneous Dilational Tracheostomy -

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Summary

In a prospective observational study we compared the results of 297 elective tracheostomies under jet-ventilation with regard to its complication rate and practicability. Of those, 156 patients underwent surgically created tracheostomy (SCT) and 141 patients percutaneous dilational tracheostomy (PDT).

Initially, in 159 patients jet-ventilation was performed using a jet-cannula inserted intratracheally through the cricothyroid membrane. In the remaining 138 patients the jet-ventilator was connected to the endoscopic instrument channel (2,2 mm ID, 4,9 mm OD, 600 mm Length) and ventilation via the fiberoptic bronchoscope (FB-15x, Pentax Europe GmbH, Hamburg) was applied manually. With jet-ventilation, oxygenation was maintained throughout the procedure as long as the tracheal puncture was successful und jet-cannula fixed in place. The bronchoscope-guided gas stream, when compared to jet-cannula inserted

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intratracheally, offered more space for tracheostomy and safety for the patient. The permanent danger of mishappenings and dislocation involved with the jet-cannula could be avoided, since the bronchoscope was operating on under direct visualization. Under these circumstances, PDT is an acceptable approach to inserting a tracheostomy tube under jet-ventilation via bronchoscope, particularly for the management of difficult airway in critically ill patients.

Keywords: Surgical tracheostomy – Percutaneous dilational tracheostomy – Jet Ventilation – Bronchoscopy – Intensive Care.

Introduction

Since 1996 we have carried out surgically created (SCT) and percutaneous dilational (PDT) tracheostomies under jet-ventilation at our ICU Department. In 2005 we presented the jet-ventilation using a teflon cannula placed through the cricothyroid membrane in the tracheal lumen during tracheostomy in a video available on DVD[1]. During PDT we used to control the tracheal puncture with the aid of a bronchoscope. Taking advantage of the knowledge accumulated over the years, the jet ventilation was subsequently no longer performed via puncture of the cricothyroid membrane, but through the instrument channel of the endoscope.

Jet ventilation using a fiberoptic bronchoscope has been already demonstrated experimentally and clinically in adults[2,3] and has also been reported in a child[4]. For tracheostomy, it has been published only as case reports[5,6]. However, we are not aware of a study describing the complications of the method using a bronchoscope as a tool for jet ventilation in a group of patients in the context of a tracheostomy. This form of jet-ventilation through the endoscopic instrument channel could be an alternative ventilation method for both elective and emergency tracheostomies, particularly under difficult circumstances since endoscopic intubation is the method of choice for the management of difficult airway and in “cannot ventilate, cannot intubate”-situations.

The aim of this study was to compare the results of two methods of jet-ventilation delivered either through cricothyroid jet-cannula or instrument channel of the bronchoscope, with regard to complication rates and practicability in critically ill patients undergoing tracheostomy by several techniques.

Methods and Materials

The study was approved by our Institutional Human Investigation Committee. After explanation and written informed consent obtained from the patient or a legal guardian authorized by the court, 297 patients underwent either SCT or PDT. Tracheostomy was necessary to supply prolonged ventilatory support or airway protection in cases of cerebral damage, sepsis, polytrauma and difficult weaning from mechanical ventilation.

All patients were already intubated and had been provided with a central venous catheter and an arterial cannula. For anesthesia during tracheostomy we used propofol 1.5-3.0 mg/kg/h (= 10-20 ml/h) in combination with Remifentanil 0.05-0.175 μg/kg/min (= 3-10.5 μg/kg/h) or ketamine S 0.5-1 mg/kg KG/h and nondepolarizing muscle relaxants. After positioning of the patient with the head tilted back, the skin was disinfected and 1% lidocaine with an adrenaline supplement to prevent bleeding, was injected in a rhomboid pattern under the skin.

Initially, in 159 patients jet-ventilation was performed through a cannula with a jet-ventilation device (MANUJET® III, VBM Medizintechnik GmbH, Sulz am Neckar, Germany). After extubation, the jet-cannula was inserted into the tracheal lumen through the cricothyroid membrane with the head tilted back. The correct position of the cannula in the tracheal lumen was ensured by air aspiration. After the jet-cannula was connected to the jet-ventilator, the patient was ventilated manually with a jet-pressure of 30-50 Psi.

In the remaining 138 patients the bronchoscope was inserted into the endotracheal tube that had already been placed. The tube was pulled back over the endoscope serving as an endotracheal track until the tip of the tube was positioned in the oropharynx, thus facilitating passive exhalation and minimizing gas trapping during manual jet-ventilation. The jet-ventilator was connected to the endoscopic instrument channel (2,2 mm ID, 4,9 mm OD, 600 mm Length) and infraglottic ventilation via the translaryngeal fiberoptic bronchoscope (FB-15x, PENTAX Europe GmbH, Hamburg) with a jet-pressure of 30-50 Psi was applied manually. Ventilation was performed at a rate of 15-20/min, with visual inspection of the chest and abdomen for expansion.

For videoendoscopic control of the tracheotomy the equipment of Karl Storz GmbH & Co, Tuttlingen Germany was used. The blood pressure parameters and oxygenation were continually monitored by arterial cannulation and pulse oxymetry. The ECG was recorded. Blood sampling for blood gas analysis under jet ventilation was done every 5-10 minutes.

The surgically created tracheostomy (SCT) was performed in 156 patients by passing a curved clamp underneath the thyroid isthmus and removing it from the surface of the trachea. Then a strong suture material was ligated to both sides of the thyroid isthmus, which was completely dissected. The bronchoscope was lying intratracheally, with its distal tip above the carina, and the trachea was opened by a horizontal incision with the scalpel to the lower edge of the second tracheal ring (Fig. 1).

Fig. 1
Surgically created tracheostomy (SCT) under jet-ventilation via endoscope

For the Percutaneous dilational tracheostomy (PDT) in 141 patients, a small skin incision was made 1 to 2 cm distal to the cricoid cartilage. The tracheal puncture was performed under endoscopic control between the first and second or preferably the second and third tracheal cartilage, in order to avoid damaging the annular cartilage during dilation. The correct cannula position was ensured by the aspiration of air in an applied syringe filed with saline solution. A Seldinger J-wire was threaded in via the teflon cannula. A "first-step dilator", known as pre-dilator, was inserted over the wire. This enabled gentle and atraumatic initial expansion of the stoma.

The tracheostoma was positioned in 8 patients by Ciaglia multi-dilation technique[7] and in 73 patients by Ciaglia Blue Rhino One-Step-Dilation method requiring just one single dilation step using a conical-shaped Blue Rhino dilator (CBR)[8,9]. Dilators were inserted and removed, and the jet-ventilation was interrupted during insertion (Fig. 2).

Fig. 2 Percutaneous dilational tracheostomy using blue rhino dilator under jet-ventilation via endoscope.

32 patients underwent a blunt dilation of the trachea in one step using Griggs spreading method (GWDF)[10,11] and 10 patients were tracheotomized according to the technique of Frova and Quintel as one-step-dilation method using a screw-in dilator (Percu-Twist®)[12], while maintaining jet-ventilation under endoscopic control (Fig. 3).

Fig. 3 Percutaneous dilational tracheostomy using a screw-in dilator method (Percu-Twist®) under jet-ventilation via endoscope.

The remaining 18 patients underwent a Fantoni translaryngeal tracheostomy (TLT)[13]. This method involves the dilation of the trachea and the neck tissue from inside to outside (Fig. 4). The Seldinger J-wire fed out of the mouth had to be cut at a marked point with scissors. The tracheal cannula, conical-shaped at one end, was threaded onto the Seldinger J-wire and secured by a firm knot at the wire end. After its

Fig. 4 Fantoni translaryngeal tracheostomy with the Seldinger J-wire out of the mouth under jet-ventilation via endoscope.

lubrication with generous amounts of Xylocaine® gel the tracheal cannula passed the pharynx and larynx to then penetrate the anterior wall of the trachea and neck soft tissue with its pointed end by pulling at the wire's neck end under digital counter-compression, while jet-ventilation was stopped.

The rate of complications in all 297 tracheostomized patients was assessed in either group SCT and PDT, and the practicability of the procedures in terms of operating time, possibility of bedside performance, manpower and the subjective scale of technical difficulties encountered were evaluated (1 = minor, 2 = intermediate/moderate, 3 = major/serious or severe). Complications are regarded as serious or not, depending on whether there is any associated morbidity. Consequently, any desaturation is regarded as intermediate, and if associated with cyanosis or bleeding then this is a serious life threatening event. We also consider bleeding to have taken place only when blood loss was estimated to be more than 20 ml; blood loss requiring surgical intervention or life threatening blood loss is regarded as an intermediate or a major event. Posterior tracheal wall injury and tension pneumothorax are always serious events.

Values are given as mean (± SD). Complication rates and practicability parameters in the two groups (SCT, PDT) were compared by using Mann-Whitney U tests, chi-square test or Fisher's exact test when appropriate. Modifications of the physiologic variables (blood pressure and blood gases) were compared by using a non-parametric Wilcoxon test. A p value of $<.05$ was deemed significant.

Results

Between 1996 and 2007 we tracheostomized a total of 297 patients, 153 men and 144 women, with an average age of 67 years (ranging between 28-95 years). Of those, 156 patients underwent a SCT and 141 patients a PDT (Table 1).

Table 1

Complication rates and practicability of two methods of jet-ventilation delivered throughout tracheostomy by several techniques.

Technique of tracheostomy and jet-ventilation		SCT total	SCT via jet-cannula	SCT via endoscopic channel	PDT total	PDT via jet-cannula	PDT via endoscopic channel
Patients included		156	97	59	141	62	79
Complications	Bleeding	11	9	2	7	5	2
	Pneumothorax			0	4	3	1
	Others	38	31	7	18	16	2
Practicability	Operating time (min) (mean/SD)	47±9	53±12	38±6	16±8	20±4	8±6
	Bedside performance	42	0	42	130	54	76
	Manpower			5			3
	Scale of technical difficulties	2-3	3	2	1-2	2	1

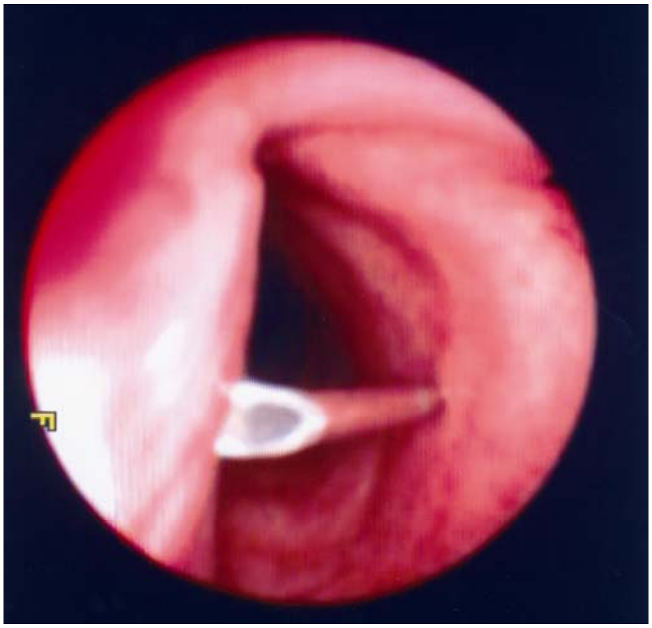
In the ICU, 47 (15.8%) out of 297 patients died as a result of their basic illness. Of the remaining 250 patients, 11 patients were successfully decannulated in the ICU, 8 of whom had undergone the SCT and 3 the PDT. The 250 patients could be transferred-with or without tracheal cannula – to a rehabilitation clinic or nursing institution after a medium of 14 days.

The complication rates are shown in Table 1. In 18 patients (6.1%), bleeding that required surgical intervention occurred. This concerned 11 patients after SCT und 7 cases after PDT (SCT versus PDT: $p<.05$). In 15 patients, subcutaneous and pretracheal vessels were the main source of bleeding. However one day after PDT, two patients showed repeatedly severe hemorrhage that was stopped by open revision of the tracheostoma under intubation at bedside. In another 34-year old male patient with short neck, large goiter, congestion of cervical vessels and severe obesity, with an extremely thick pretracheal layer of tissue (body weight more than 200 kg), a life threatening hemorrhage that occurred one week after SCT and was stopped by revision of the tracheostoma by ligatures and sutures of the isthmus under intubation at bedside.

In addition, there were 4 incidences of pneumothorax occurring under PDT and jet-ventilation via jet-cannula or bronchoscope (PDT with jet-cannula versus bronchoscope: $p < .05$). In one patient, a left side tension pneumothorax with a critical drop in SaO_2 occurred during a Fantoni puncture. This 61-year old patient with sepsis required immediate relief by thoracic drainage and a surgical tracheostomy was carried out instead. The other 3 cases were COPD patients with pneumonia and multiple infarction syndrome.

The remaining complications in 56 patients include stoma infections, loss of airway without hypoxia, paratracheal dislocations and tracheal mucosa lesions that may occur during tracheal puncture with a teflon cannula in patients undergoing PDTs and might be responsible for developing subcutaneous and particularly mediastinal emphysema and pneumothorax caused additionally by the jet-stream and air-trapping (Fig. 5).

Fig. 5
Tracheal mucosa lesions during tracheal puncture with a teflon cannula in patients undergoing PDTs



Clinically relevant tracheal stenosis was not observed while exchanging tracheal cannula, one week after surgery. Also decannulated patients did not show any signs of clinically relevant tracheal stenosis.

The initial blood gas values of low PO_2 at 77.4 ± 9.32 mmHg in spite of adequate saturation by FiO_2 0,4, were probably due to the predominantly elderly and polymorbid patients. At the second blood sampling 5 minutes under jet-ventilation, PO_2 was 86.1 ± 8.8 mmHg ($p < .05$), while PCO_2 had risen from 38.9 ± 3.32 mmHg to 48.2 ± 10.3 mmHg ($p < .05$). Oxygen saturation did not drop below 95%. The values of the third blood sampling 15 minutes under jet-ventilation displayed only minor changes compared to the second sampling.

Circulatory parameters remained stable during surgery. Except for a minor increase in heart rate, the electrocardiograms did not display any changes in comparison with the initial ECGs.

With jet ventilation, oxygenation was maintained throughout the procedure as long as the tracheal puncture was successful and the jet-cannula fixed in place. However, the jet-cannula interfered with the surgical field particularly in obese patients or patients with short neck or stiffness of cervical spine. Attention should therefore be paid to the cannula during surgery. If the jet-ventilation was done through the bronchoscopic instrument channel instead of a jet-cannula, jet ventilation enabled continuous ventilation, offered an optimal amount of space and could help to restore oxygenation by difficult airways during tracheostomy. The permanent danger of mishappenings and dislocation involved with the jet-cannula could be avoided, since under jet-ventilation the bronchoscope was moving for- and backward under direct visualization. This prevented an unintentional dislocation from the glottic opening. Fantoni's technique offered under jet ventilation via endoscope further advantages: the tracheal cannula was rotated in the tracheal lumen towards the bifurcation under direct visualization, the bronchoscope did not have to be pulled back before rotating the cannula in the trachea, thus preventing the danger arising from an inability to rotate or damaging the tracheal wall during rotation.

The operating time for completion of tracheostomy was significantly reduced by PDT as compared to SCT ($p < .05$). An operating room was rarely required since PDT was performed mostly as a bedside procedure. Five persons were required to perform the SCT under jet-ventilation. Apart from the surgical team (surgeon, assistant and nurse for instrumentation), two people were also needed for other tasks. An anesthesiologist was in charge of the jet-ventilation and had to operate the bronchoscope while fixing it to the angle of the mouth. The second person acted as a stand-by for non-sterile tasks. However, much less personnel were required for the PDT: surgeon, anesthesiologist and stand-by.

Between the two methods of jet-ventilation, delivered either through cricothyroid jet-cannula or instrument channel of bronchoscope in critically ill patients undergoing tracheostomy by several techniques, significant differences were shown in complication rates and practicability variables, except manpower (Table 1).

Discussion

Jet-ventilation has been a technically ambitious ventilation technique, which involves needle puncture of the cricothyroid membrane as an additional invasive measure. It has been, however, an alternative ventilation method for patients with difficult airway access and in “cannot ventilate, cannot intubate”-situations[14,15,16]. So far it was unclear whether jet-ventilation during tracheostomy could have advantages or did bear additional risks.

In our study, 297 patients underwent SCT and PDT under jet ventilation with or without puncture of the cricothyroid membrane. Even though the success rate of tracheal puncture with a teflon cannula is very high, in the hand of the inexperienced there is a considerable danger of complications that include bleeding, puncture of the large vessels, perforation of the esophagus and injury of the larynx. Further complications are caused by the jet-stream and air-trapping, such as subcutaneous and particularly mediastinal emphysema and pneumothorax. In fact, pneumothorax occurred only in the PDT group receiving jet-ventilation mainly by puncturing cricothyroid membrane with jet-cannula.

With jet ventilation, oxygenation was maintained throughout the procedure as long as the tracheal puncture was successful and the jet-cannula fixed in place. However, the jet-cannula interfered with the surgical field particularly in obese patients or patients with short neck or cervical spine stiffness. Attention should therefore be paid to the cannula during surgery. If the jet-ventilation was done through the bronchoscopic instrument channel instead of a jet-cannula, jet ventilation enabled continuous ventilation, offered an optimal amount of space and could help to restore oxygenation by difficult airways during tracheostomy. The permanent danger of mishappenings and dislocation involved with the jet-cannula could be avoided, since under jet-ventilation the bronchoscope was moving for- and backward under direct visualization. This prevented an unintentional dislocation from the glottic opening. In addition to the direct visualization of the trachea during needle puncture in case of PDT, the bronchoscope acted as stylet and thus the tracheal tube might be railroaded over the endoscope should difficulty occur, and satisfactory oxygenation was provided by jet ventilation via the instrument channel.

In the PDT group with 79 patients, high-pressurized oxygen was delivered into the airways in short impulses (jet) through the bronchoscopic instrument channel instead of the transtracheal jet-cannula. The endotracheal gas track was held under visualization in the tracheal lumen, thus decreasing the danger of dislocation. Compared with the teflon cannula, jet-ventilation under bronchoscopic guidance offered a certain amount of safety due to visual control. Further advantages were also offered by Fantoni's technique. Fantoni's TLT was performed by holding the tip of the bronchoscope inside the glottic opening while inserting the tracheal cannula under view. The tracheal cannula was rotated in the tracheal lumen towards the bifurcation under direct visualization. The bronchoscope did not have to be pulled back before rotating the cannula in the trachea, thus preventing the danger arising from an inability to rotate or damaging the tracheal wall during rotation. This approach appears to be justified, since after puncture of the cricothyroid membrane the endotracheal tube is recommended to be replaced by a thinner tracheal tube contained in the set, with a diameter comparable to our bronchoscope. Instead, the bronchoscope ought to be left in the glottis, and ventilation continued under fiberoptic control. The short impulses during jet ventilation did not jeopardize the gas exchange. Thus, the bronchoscope-guided gas-stream offered more space for tracheostomy and safety for the patient. However, specialized knowledge was required to provide safe ventilation.

The rate of bleeding requiring surgical interventions seems to be significant higher in SCT as compared to PDT. Most of them were regarded as intermediate bleeding events and rarely clinically relevant. In two patients, open revision of the tracheostoma under intubation at bedside was required the day after PDT. Furthermore, there was a life threatening blood loss or blood loss requiring complete surgical exploration following SCT in one young patient with short neck, large goiter, congestion of the cervical vessels and severe obesity, with an extremely thick pretracheal layer of tissue (body weight more than 200 kg). The hemorrhage was stopped by revision of the tracheostoma by ligatures and sutures of the isthmus under intubation at bedside.

At our ICU Department, the SCT is still the method of choice in patients with difficult airway passages, short neck, large struma, excessive obesity or non identifiable tracheal course. Difficulties with anatomical landmarks and a short fat neck make PDT a more hazardous procedure than in a patient with a long, thin neck and clearly palpable laryngeal structures. The increased distance from skin to trachea may also add problems; with too short a tracheostomy tube becoming displaced, necessitating the use of a long-stemmed or adjustable flange tracheostomy tube. In these patients, however, a SCT bears considerable technical risks, which can be minimized if the procedure is done by surgically experienced staff. Since the rate of hemorrhages in our study exceeded that published by other authors[17,18,19], we decided to discontinue the anti-coagulative heparinisation with non-fractionated and fractionated preparations 12 hours before the scheduled intervention. In addition, preoperative threshold values of coagulation parameters were set at INR 1.5, PTT <50 sec and thrombocyte count >50.000/µl t further minimize the risk of bleeding.

Our data give the overall complication rates of approximately 31% for SCT and 20% for PDT, using a number of different tracheostomy techniques. However in the PDT group, they do not, however, quote the rates for each individual PDT technique. The incidence of complications is too low for meaningful statistical analysis of the different PDT techniques used in our study. Based on personal experience, no PDT technique has proved clearly superior to another in critically ill patients. Nevertheless, we prefer to use Ciaglia Blue Rhino One-Step-Dilation method for PDT. We therefore feel that our results are completely in accordance with the existing literature. Our study has proven that, as has been shown in the literature, PDT under jet-ventilation via bronchoscope is a safe, fast and easily performed intervention on a par with surgically created tracheostomies and bearing an acceptable complication rate[22,23,24,25].

The operating time for completion of the PDT is reported to range from 5-23 minutes[20] and is in the PDT group significantly reduced as compared to SCT ($p < .05$). No operating room is required if PDT is performed as a bedside procedure, which is usually the case in our study. In addition, the number of staff required is not more than needed to perform PDT under ventilation with normal endotracheal intubation at our Department. As a consequence, percutaneous dilational techniques have lately become the method of choice for tracheostomies in intensive care patients and are performed by intensive care practitioners of various medical subspecialties. In order to decrease the complications inherent in the technique, it is vital to ensure proper patient selection, the necessity for tracheal puncture and dilation under bronchoscopic control, as well as leaving the methods in experienced hands only[21,26,27]. A high complication rate often indicates insufficient experience and lack of familiarity with the technique concerned, particularly during the learning phase[28]. In this context, prospective clinical trials must be conducted before a definitive evaluation of tracheostomy under jet-ventilation via bronchoscope as an alternative approach to ventilation via endotracheal tube with regard to complication rates and practicability in critically ill patients can be made. So far, we could then propose under which conditions jet ventilation via bronchoscope should be used instead of normal endotracheal intubation and ventilation.

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