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# High frequency jet ventilation in reconstructive surgery of trachea

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The autors present use of high frequency jet ventilation (HFJV) in surgical reconstruction of trachea. HFJV has ben used during anaesthesia and surgical reconstruction of trachea and in postoperativ care. Indication of HFJV is based on a specific advantages arising from physical characteristics of jet generator. This technique enables ventilatory support with the use of a thin catheter of a defined size without endotracheal tube. This enables free operating field and improves surgical working conditions. This technique enables to realize longtime controlled ventilation with a deflated cuff in postoperative period. HFJV basically influences the surgical strategy.
**Key words**: HFJV, jet generator, reconstruction of the trachea.

Surgical approach to the tracheal lesions make specific demands upon anaesthesia, postoperativ care, especially upon maintenance of an adequate lung ventilation and toilette of the airways.
Requirements ensuring the ventilation during the surgical procedures on trachea are conventionally met by so-called shunt breating with the help of intubation cannulas for intratracheal and intrabronchial intubation.

One alternative ensuring an effective ventilation during a diagnostic, operative or postoperative treatment of tracheal lesions is a HFJV. Indications for HFJV arise from specific advantages resulting from the construction and physical characteristics of a jet generator.

## PATIENTS AND METHODS

During the period from March 1991 to december 1993 HFJV was used during operative treatment in 11 patients with the lesion of trachea, age range

Table 1. Series of patients

| Tracheal lesion | Number |
|---|---|
| Ruptura tracheae traumatica | 2 |
| Stenosis tracheae post tracheostomiam | 7 |
| Fistula tracheooesophagiale | 2 |

from 10 to 56 (Table 1). The traumatic ruptures of trachea (10 years old boy after a fall from a bike, and 48 years old man after a car accident) were complicated by bilateral pneumothorax and excessive subcutaneous emphysema. Both patients were without any delay treated and a definite suturing of trachea was carried out. Stenoses and fistulas in this series represented the posttracheostomic complications in polytraumatic patients. They were treated electively. All patients were operated in general anaesthesia (dormicum,fentanyl, myorelaxants - SCHJ, arduan, inhalation of $O_2$+ $N_2O$, during HFJV air with $FiO_2$ more than 40%.
Monitoring: ECG, arterial blood pressure invasively, CVP, breathing through auscultation using a stethoscope, which was fixed bilaterally under the back of a patient, $PaCO_2$, $PaO_2$, pH every 20 min., $SpO_2$ continuously.

HFJV was performed by ventilators PARAVENT (Elmed,Prelouc, Czech Republic) and CHIRAJET NCA (Chirana Stara Tura, Slovak Republic).
As far as the construction is concerned, ventilator PARAVENT is pneumatically actuated high frequency jet ventilator with optimal constant frequency 120 c/min, adjustable relative inspiratory time 0.33, 0,55, 0,66, adjustable insufflation pressure (PIN) from 0 to 300 kPa, alarms of nonventilation, hypoventilation and exceeding of limit pressures (PIP) in airways.
PARAVENT PAT is transportable developed for short-term usage (there is no humidification of inhaled gass mixture). In our group of patients it was used for urgent ventilation, during the operation and transport of the patient, for toilette of the airways. Ventilatory parameters: f 120 c/min., Ti 0.55, PIP always less than 2,5 kPa, PIN regulated before the insufflation catheter from 90 to 160 kPa (due to $PaCO_2$), FiO2 always more than 40%.
CHIRAJET NCA is an electronically actuated high frequency ventilator with adjustable frequency from 20 to 600 c/min., adjustable relative inspiratory time, insufflation pressure and fractions of inspirated oxygen. Alarm system is based on continuos measuring of intratracheal pressure. The device equiped with an effective humidifier of inhaled gas mixtures and thus provides conditions for long-time ventilation. In our group it was used in postoperative phase in three patients.
Both above described ventilators have one thing in common: the construction of an injector flow pressure generator. In our patients the HFJV was performed by a set of original jet generators, which enable a safe artificial and supportive ventilation in all age and weight groups of patients via ventilatory protheses. Catheter HFJV while the airways are opened is performed by defined catheter (nozzle) inserted together with a measuring line into the peripheral stupm (cylinder cavity) of trachea. Internal diameter of the catheter accounts 1/10, 1,5/10 of the internal diameter of the trachea (Fig. 1.)The length of the catheter is 20-25 cm.

## RESULTS

The fundamental requirement on every lung ventilation is ensuring an

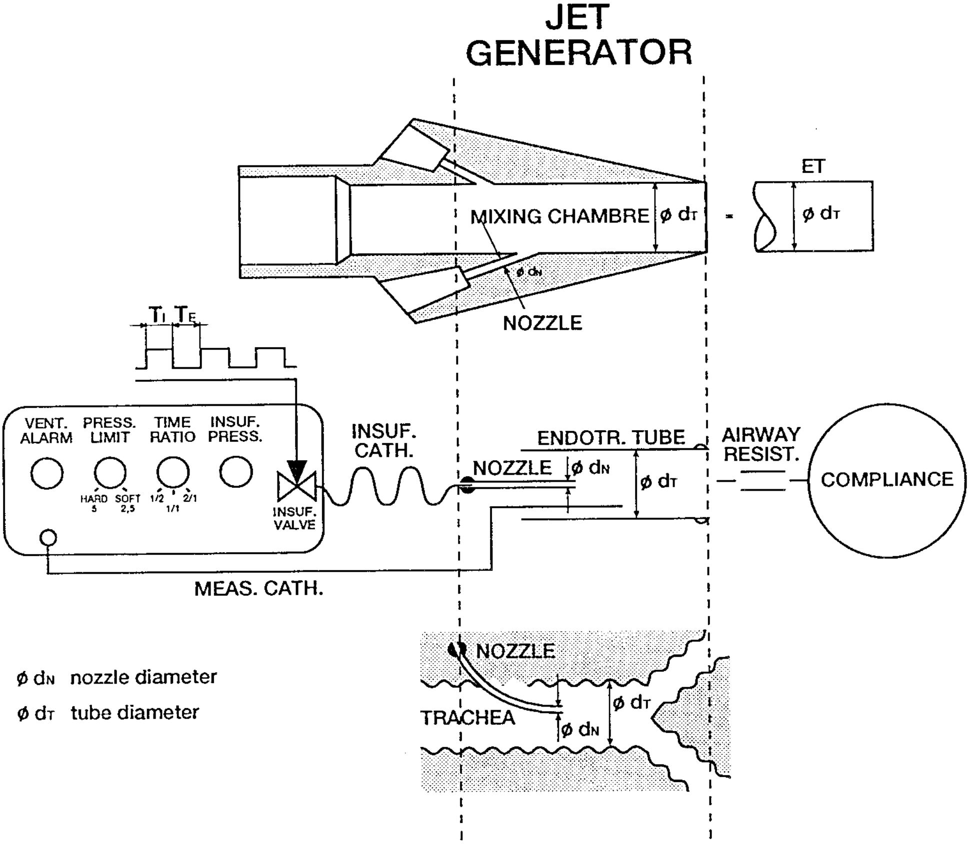


Fig. 1. Scheme of HFJV ventilator

adequate exchange of blood gases together with minimal adverse effects on hemodynamics. The evalution of $PaO_2$, $SaO_2$, $SpO_2$, $PaCO_2$, PIP in all patients during the operative procedure supported by HFJV has shown that:

$PaO_2$ has always been more than 9 kPa (67.5 torr), $SaO_2$, $SpO_2$ more than 90% if $FiO_2$ has been more than 40%. $PaCO_2$ has ranged from 3.5 to 8 kPa (26.5-60 torr), if the initial frequency has been 120 c/min., $T_i$ 0.55, $P_{IN}$ 120 kPa. By changing $P_{IN}$ from 90 to 160 kPa the borders for eucapnia have been stated, eucapnia has ranged from 4.5 to 6.2 kPa (33.7-46 torr).

PIP has been less than 2.5 kPa (25 cm $H_2O$). Regulation of the blood gases has not been dependent on the duration of HFJV during the operative procedure (40-300 min.). Nine patients began with spontaneous ventilation immediately after the operation or within an hour after it. Three patients (2x traumatic rupture of trachea in polytrauma, 1x tracheoesophageal fistula treated in the course of ARDS) needed prolonged postoperative care with continuous artificial lung ventilation. In took two and five days respectively in patients with traumatic rupture of trachea, and 62 days in patient with ARDS.

With respect to the suture of trachea we continued with intubation HFJV without insufflated obturatory sleeve, but with humidification of inhaled gas mixture (CHIRAJET NCA).

## DISCUSSION

This overview presents the possibilities of HFJV in reconstructive surgery of trachea, both preoperative and postoperative by making use of the functions of a jet pressure generator. Practical approach includes catheter, intubation or tracheostomic high-frequency jet ventilation.
HFJV has been recommended as a superior way of ventilating the patient with disrupted major airways, including thouse undergoing tracheal and bronchial surgery (1,3).
This technique seems to satisfy the major requirements of pulmonary ventilation and anaesthesia for these procedures.

1. It provides an adequate gas exchange in the presence of surgically major airways. There is improved gas mixing and accelerated diffusion, which result in good oxygenation and eucapnia (2).

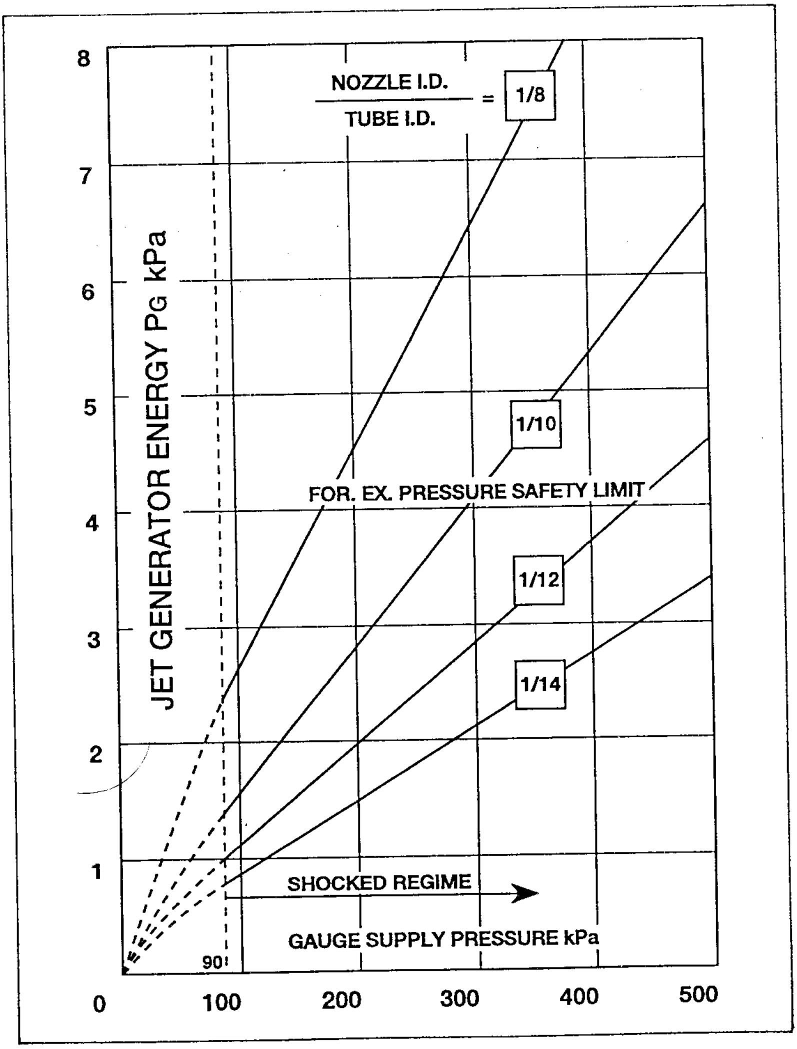


Fig. 2. Theoretical jet generator energy

2. It ensures an unobstructed surgical field with free access to the trachea for airtight anastomosis and repair (1,3,5).

3. It reduces the moution of airways (1).

4. It decreases the danger of aspiration of blood into the airways distal from the resection due to the continuos outflow of gases use of HFJV (1).

However, the use of HFJV requires, that anaesthesia is provided by the intravenous route with an adequate degree of muscle relaxation. Like any other technique, HFJV is not without disadvantages.

The most iimportant is the potential for barotrauma (4,6).

The quality of mechanical ventilation closely depends on technical solution of medical requuirements on maximal safety of the patient.

The fundametal base for the evallution, programming, eventually comparing the HFJV quality is the comparability of the technical equipment for HFJV, and, especially physical characteristics and construction of jet generator.

The jet generator consists of a nozzle set and cylinder cavity, in which the nozzle is placed. From the point of view of prevention of barotrauma in clinical practice the $P_{Gmax}$ is of the greatest importance. This value determines the maximal pressure level, that can be achieved in the system lung-generator with stayed insufflation pressure $P_{IN}$. $P_{Gmax}$ is defined as:

$$P_{Gmax} = 2K_{IN} (d_N / d_G)^2 P_{IN}$$

where Pgmax is maximal generator excess pressure, PIN insuflation excess pressure, $d_N$ nozzle diameter, $d_G$ cylinder cavity diameter, $K_{IN}$ coefficient of flow leakage.

From this relation we can conclude, that the energy of HFJV generetor directly depends on $P_{IN}$ and on ratio $d_N / d_G$ (Fig. 2).

The mentioned theory is from the point of prevention of barotrauma fundamental for the construction of a defined jet generator. The construction is based on a principle, that a nozzle with a defined dN is inserted into a cylinder cavity with known dG (congruent with the diameter of ET cannula, tracheal diameter) (Fig. 1). The above analysed theory enables to define also the construction of "improvized" jet generator during the catheter HF V.

In our case choice of catheter for a 10 y. old child and 48 y. old man with equal $P_{IN}$, f, $FiO_2$ in our overview means the mixed jet volume of $O_2$ and entrained volume of atmospheric air as result of a suitable generator construction.

## CONCLUSION

HFJV and its catheter form respecting the physical characteristics of a jet generatort is an effective and from the point of view of barotrauma defined mode of ventilation on opened major airways. The measurement of pressures in the airways distal from the nozzle of the generator and safety elements thus obtained increase the reliabililty and the possibilities for ventilation programming. Adequate construction solution of HFJV ventilator provides a long term artificial and supportive lung ventilation without insufflated obturatory sleeve of the intubation or tracheostomic cannulas.

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