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## 5. Clinical Applications of Superimposed High-Frequency Jet Ventilation (SHFJV) in Operative and Interventional Medicine

### 5.1. ENT Surgery

A primary application of SHFJV is in otolaryngologic surgery during micro-surgical procedures involving the larynx and trachea. By eliminating the endotracheal tube (= *tubeless ventilation*), unrestricted access with optimal visualization of the surgical field is achieved [34, 35, 36].

This is particularly advantageous for laser procedures, allowing precise incision control while reducing the risk of iatrogenic mucosal injury. Additionally, controlled reduction of the inspiratory oxygen concentration ( $\text{FiO}_2 \leq 40\%$ ) minimizes the risk of airway inflammation and fire in oxygen-rich conditions [37].

Jet laryngoscopes equipped with integrated measurement lines for  $\text{FiO}_2$ , AW, airway pressure, and end-tidal  $\text{CO}_2$ , provide an added safety margin, especially when modern jet ventilators with laser-safety modes such as the TwinStream/TwinStream EVO are employed [24].

### 5.2. Thoracic Surgery

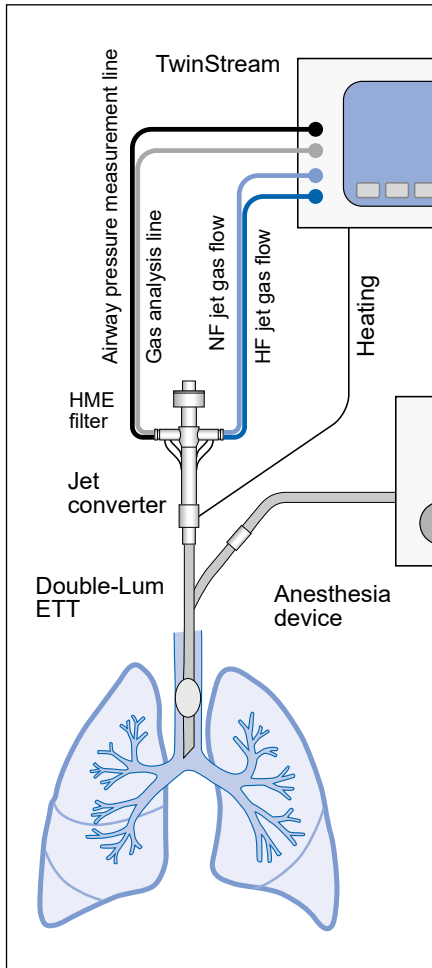
In tracheal surgery, infraglottic HFJV—preferably via a jet ventilation catheter—enables continuous ventilation during resection of stenotic segments or during airway anastomosis creation. Ventilation is applied distal to the airway stenosis (Figs. 4 and 6), with maintenance of an adequately high expiratory gas flow being critical to prevent air trapping and subsequent barotrauma.

The pause pressure measured during high-frequency jet ventilation serves as an important safety parameter and correlates with end-expiratory pressure. Adjustments of ventilation settings in response to rising pause pressures—such as reducing frequency, jet emission pressure, and modifying the i:e ratio—are mandatory to maintain a lung-protective ventilation pattern.

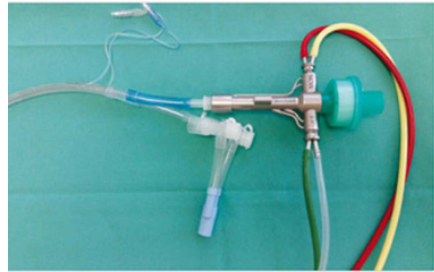
In thoracic surgery, HFJV is used during thoracotomies or video-assisted thoracoscopic surgery (VATS) for one-lung ventilation with a double-lumen tube and jet converter (Figs. 11a/b). Here, jet ventilation is applied solely via the high-frequency unit (= monofrequent jet ventilation). Higher jet frequencies reduce lung vibrations, achieving optimal stabilization of the lung to be operated on while maintaining minimal lung

inflation (= "lung patency" of the lung to be operated on). The non-operative lung is ventilated conventionally.

Fig. 11: Jet Converter in Thoracic Surgery  
a) Functional Principle



b) Connection of the jet converter to the double-lumen tube



### 5.3. Interventional Bronchology

SHFJV is an established ventilation strategy in interventional bronchoscopy. Procedures such as endobronchial ultrasound (EBUS), endobronchial lung volume reduction, electromagnetic navigation bronchoscopy for targeted peripheral lesion biopsy, and bronchial rheoplasty benefit substantially from this ventilation technique [8, 38, 39].

Using SHFJV and the jet bronchoscope, stable oxygenation and sufficient CO<sub>2</sub> elimination can be maintained even during prolonged and technically complex interventions (Figs. 14 and 15).

The pulsed gas flow of SHFJV also facilitates mobilization of bronchial secretions (thixotropic effect), which is clinically advantageous, particularly in COPD patients with dyskinesia.

## 5.4. Cardiology

For all interventional procedures negatively affected by ventilator-induced diaphragmatic motion (e.g., interventions on the heart, liver, or kidney), SHFJV provides “immobilization” of these organs (= optimized respiratory-motion management), resulting in improved procedural quality and reduced intervention duration [40].

## 6. Setting Ventilation Parameters for Operative and Interventional Procedures with SHFJV

Accurate adjustment of ventilation parameters during SHFJV is crucial to achieve effective and lung-protective ventilation.

### 6.1. SHFJV Settings

Parameters for SHFJV

Normal-Frequency Ventilation Unit (NF Unit)

- Normal-Frequency Ventilation Unit (NF Unit)
- Emission pressure ( $P_{NF}$ )
- Ventilation frequency (= low frequency [ $F_{NF}$ ])
- I:E ratio

High-Frequency Ventilation Unit (HF Unit)

- Emission pressure ( $P_{HF}$ )
- Jet frequency (= high frequency [ $F_{HF}$ ])
- i:e ratio

- Oxygen concentration ( $FiO_2$  jet)
- $O_2$  bias flow
- Upper and lower alarm limits

### 6.2. Baseline Settings for SHFJV

NF Unit:

- Emission pressure ( $P_{NF}$ ): automatically set, weight-adapted
- Ventilation frequency ( $F_{NF}$ ): 12–20/min, automatically set, weight-adapted (depending on adult or child)
- I:E ratio (I: $E_{NF}$ ): 1:1 (adult), 1:2 (child)

HF Unit:

- Emission pressure ( $P_{HF}$ ): automatically set, weight-adapted
- Jet frequency ( $F_{HF}$ ): 600/min (= 10 Hz)
- i:e ratio (i: $e_{HF}$ ): 1:1 (adult), 1:2 (child)
- Oxygen concentration ( $FiO_2$  jet): 80 % or adjusted according to  $SaO_2/PaO_2$
- $O_2$  bias flow: off

Alarm Limits:

- Upper alarm limit:
  - Adults: 35 mbar (weight-adapted)
  - Children: 20 mbar
- Lower alarm limit: 2–5 mbar

## 6.3. High-Frequency Jet Ventilation in Laryngeal and Tracheal Airway Stenoses

### 6.3.1. Parameter Settings for Laryngeal Airway Stenoses and Supraglottic HFJV/SHFJV

during supraglottic HFJV/SHFJV using a jet laryngoscope, jet bronchoscope, or jet converter

In laryngeal surgery, bronchoscopy, cardiology, or radiology, the following general parameter settings apply:

- Emission pressure: high
- Jet frequency: high
- Inspiratory time: long
- Expiratory time: short

Both jet gas application and exhalation occur through the airway stenosis (Fig. 4) [21].

Basic Settings for Supraglottic HFJV:

- Patient weight: 50–90 kg
- FiO<sub>2</sub> jet: 80% (adjusted according to SaO<sub>2</sub>/PaO<sub>2</sub>)
- NF Unit:
  - Emission pressure P<sub>NF</sub>: 0.9–1.2 bar
  - Ventilation frequency F<sub>NF</sub>: 12–20/min
  - I:E ratio I:E<sub>NF</sub>: 1:1
- HF Unit:
  - Emission pressure P<sub>HF</sub>: 0.8–1.0 bar
  - Jet frequency F<sub>HF</sub>: 600/min (= 10 Hz)
  - i:e ratio i:e<sub>HF</sub>: 1:1.5
  - O<sub>2</sub> bias flow: off

Fig. 12: Basic settings of the ventilation parameters for supraglottic SHFJV – TwinStream EVO display



- Alarm Limits:
  - Upper alarm limit:
    - Adults 35 mbar (weight-adapted)
    - Children 20 mbar
- Lower alarm limit: 5 mbar

### 6.3.2. Adjustment of Ventilation Parameters in Tracheal Airway Stenoses and Infraglottic High-Frequency Jet Ventilation (HFJV)

using a Jet Ventilation Catheter or Ravussin Cannula

The placement of the jet ventilation catheter is performed translaryngeally through the glottis, whereas the Ravussin cannula is placed transcricoidally (→ post-stenotic jet gas application). Exhalation of the respiratory gas occurs in both cases through the (residual) lumen of the airway stenosis (Fig. 4c/d) [21].

- Jet gas application is performed post-stenotically.
- Jet ventilation is performed exclusively via the high-frequency ventilation unit (HF JET) (Fig. 13).
- Starting from a predefined baseline setting (single-lumen catheter mode), further adjustment of ventilation parameters is performed based on SaO<sub>2</sub> and the level of pause pressure.

General parameter settings for infra-glottic single-frequency HFJV:

- Emission pressure: low
- Jet frequency: low
- Inspiratory time: short
- Expiratory time: long

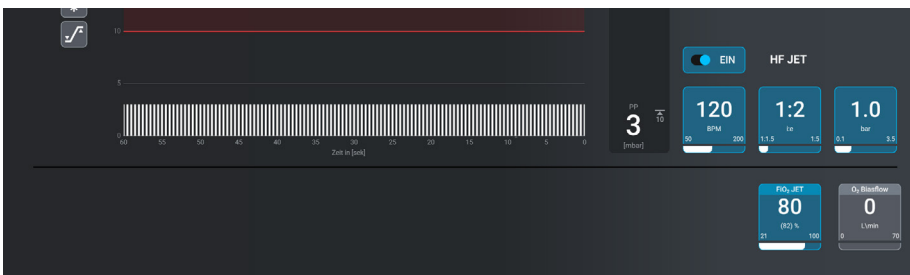
#### Notes:

- Exhalation of respiratory gas occurs through the lumen of the airway stenosis. If the jet ventilation catheter is placed through the stenosis, the catheter can further narrow the airway → risk of barotrauma with tension pneumothorax.
- Infraglottic SHFJV is feasible if the diameter of the airway stenosis is approximately twice the diameter of the jet ventilation catheter → allows adequate gas outflow.
- If the airway stenosis is smaller than twice the diameter of the jet ventilation catheter (e.g., catheter diameter 4 mm / stenosis diameter < 8 mm), infra-glottic HFJV is very limited:
  - Insufficient respiratory gas outflow
  - Risk of complete airway obstruction
  - Risk of barotrauma with tension pneumothorax

The following baseline settings and adaptive adjustments of ventilation parameters have been empirically proven effective in clinical practice:

Parameter	Baseline Setting	Adaptation	
Emission pressure ( $P_{HF}$ )	1.0 bar	→ 0.5 bar	→ 0.1 bar
Ventilation frequency ( $F_{HF}$ )	120/min	→ 100/min	→ 80/min
i:e-ratio ( $i:e_{HF}$ )	1:2	→ 1:3	→ 1:5
$FiO_2$ jet	80%	→ 90%	→ 100% (adjusted to $SaO_2/PaO_2$ )
Pause pressure alarm	15 mbar	→ 10 mbar	→ 5 mbar

Fig. 13: Baseline ventilation parameters for infraglottic monofrequent HFJV – TwinStream EVO display



## 7. Accessories

For the safe and effective application of high-frequency ventilation techniques, device-specific accessories, so-called jet applicators, are required. These must be tailored to the respective technology and clinical application and be mutually compatible (Fig. 14).

### Note:

- When combining medical devices from different manufacturers without a compatibility certificate, the user assumes the obligations of a manufacturer according to the MDR (Medical Device Regulation) and the MPG (Medical Devices Act).

- Combining medical devices contrary to the manufacturer's instructions constitutes use for an unintended purpose. Any change in the intended use of a product already in clinical operation invokes the manufacturer's responsibilities under EU Regulation 2017/745 on medical devices.

Therefore, the TwinStream jet ventilation system was developed such that the jet ventilator and jet accessories could be tested and certified together. This approach transfers the responsibility described above from the user to the manufacturer.