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High Frequency Jet Ventilation

High frequency jet ventilation (HFJV) is a technology to provide effective ventilation with lower tidal volumes utilized in many surgical and interventional procedures (Table XXX). HFJV has been utilized in patients undergoing pulmonary vein isolation (PVI) to reduce movement of the posterior wall of the left atrium. Utilization has been shown to indeed reduce such movement which results in a reduction in ablation time and total procedure duration improving procedure efficiency. The use of HFJV may allow higher catheter-tissue contact force. Higher force has been demonstrated during apnea compared with ventilation.

Table XXX – Reported uses of High Frequency Jet Ventilation

Pulmonary Vein Isolation
Minimally invasive cardiac surgery
Vocal cord and laryngeal surgery
Tracheal stenosis
Sleeve resection
Transthoracic esophagectomy
Rescue for off-pump single lung transplantation
Airway rescue
Respiratory immobilization during coronary artery CT
Shock wave lithotripsy
Radiofrequency ablation for liver tumor
Bronchopleural fistula
Esophagectomy

HFJV has been demonstrated to be effective in pulmonary vein isolation by producing a more stable posterior left atrial environment facilitating catheter ablation.

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The MGH Thoracic Anesthesia Service utilizes the Monsoon Universal Jet Ventilator (Figure XXX).

There are several key components of the device.

1. The interface has a 9" touch screen display, 6 blue touch tabs on screen that control ventilator setting, 2 green touch tabs that control alarm limits, four outlets (ETCO2, red outlet for pressure monitoring, blue outlet for jet ventilation and aux gas ports,) and an alpha dial.
2. The **alpha-dial** allows one to select among different parameters on the display screen. After depressing a blue or green tab on the touch screen display, use alpha dial to change the numeric value.
3. BLUE TAB; The **FiO_2 tab** allows control of the inspiratory oxygen level. The display screen will display the set FiO_2 only, not the measured FiO_2.
4. BLUE TAB; **DP dial** allows one to adjust the driving pressure. This is not an absolute dial but must be rotated completely several times to affect the desired change.
5. BLUE TAB; **"F"** tab (frequency); allows provider to adust the frequency of respirations.
6. BLUE TAB; **"IT"** tab (inspiratory time); Allows provider to adjust the time for inspiratory phase of respirations.
7. BLUE TAB; **"02"** tab; allows provider to change the FIO2 concentration.
8. BLUE TAB; **"AUX"** tab; allows provider to run gas through auxillary gas port.
9. The **auxillary gas outlet** is utilized in an emergency situation when there in an O2 line failure. The auxillary port utilizes O2 from an "E" cylinder.
10. GREEN TAB; **"PP"** (pause pressure); allows provider to change pause pressure alarm.
11. GREEN TAB; **"PIP"** (peak inspiratory pressure); allows provider to change PIP alarm setting.

12. The alarm reset button removes an alarm display from the display screen once the problem has been solved. **DO NOT IGNORE ALARMS**.
13. The **auto/manual button** allows selection of mode. We always use auto in the EP lab.
14. The **start/stop button** begins or ends the delivery of gas.
15. The display screen will show several bits of information while the ventilator is in normal function.
    a. **FiO_2** - Set inspiratory oxygen level.
    b. **IT (%)** – Percentage of time in inspiration during cycle
    c. **DP (PSI)** – Driving pressure measured in pounds per square inch
    d. **PP (cmH_2O)** pause pressure (or "pre-pressure") set alarm limit, measured in cmH_2O. 'Pause Pressure' is the 'back pressure' or end expiratory pressure measured 10 milliseconds before the next inspiration. If the set limit displayed here is exceeded, the ventilator will stop delivering breaths. This is a critical safety feature to help avoid barotrauma
    e. **PIP** – Peak inspiratory pressure measured by the airway pressure inlet/transducer, it utilized
    f. **MAP** – Mean airway pressure measured by the airway pressure inlet/transducer if utilized
    g. **VTI** – Tidal volume
    h. **MV** – Minute ventilation
    i. **f (CPM)** – frequency; Ventilatory cycles per minute.
    j. **humidity-** based on scale 1-8. (8=100%, 4=50%, 2=25%)

Figure XXX – Display Screen

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Instructions for Setting Up and Initiating HFJV via the Monsoon Universal Jet Ventilator

1. The need for HFJV should be scheduled in MOSAIC.
2. The jet ventilator should be readily available in the EP lab. Anesthesia technicians will assist with setup and turn over. Clinical Engineers are a great resource for troubleshooting problems
3. The oxygen and air supply line should be attached to the power/gas supply column.
4. The power should be connected to the power/gas supply column.
5. The humidity system should be prepared with *sterile water* and connected in the roller pump. The sterile water set up should include 500cc bag of sterile water connected to extension tubing and the humidification tubing. **THIS BAG MUST BE HIGHER THAN THE MACHINE SINCE WATER DELIVERY IS VIA GRAVITY.**
6. Three straight vent adaptors are necessary to connect jet ventilator to ETT (**SEE FIGURE XXX ON NEXT PAGE**)
7. Initial settings
    a. FiO_2 100%
    b. IT (%) 30%
    c. f (CPM) 100
    d. Driving pressure 30
    e. Humidity 100% (level 8)
8. Connect the End-tidal CO_2 monitor to the port **closest** to the patient
9. Connect pressure monitoring line (red port) in the middle port.
10. Connect jet outlet line (blue port) to the port furthest from the patient
11. Start ventilation by pressing the start button.
12. The conventional ventilator should be placed on a standby ventilation mode during HFJV, 1-2 L flow, pop-off valve open. The bag should inflate and deflate with ventilations.

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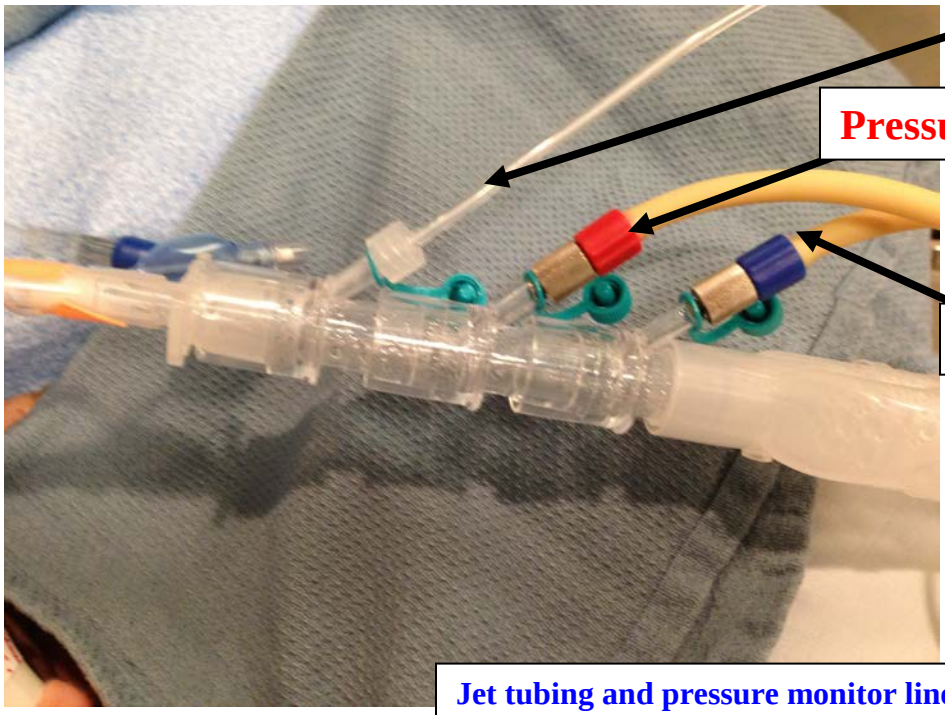
Figure XXX – Humidification System – Bag of water will be connected to system, *not* syringe. The black clip on drip chamber in picture below must be positioned as shown. The clip has infrared sensors that detect water dripping. If chamber is too full or clip is misplaced a "No Water" alarm will appear.

Figure XXX – Order of connectors for HFJV; having the connections with tubing facing up prevents water from collecting in tubing and triggering PIP alarm.



The MGH cardiac Anesthesia Service has established a protocol for the safe use of this mode of ventilation.

1. HFJV will only be utilized on a select group of patients. Patients with obesity, smaller body habitus, COPD, or other significant lung disease will be excluded and will be managed with conventional ventilation.
2. Patients will be intubated with larger endotracheal tubes (8.0 mm) to facilitate air exchange.
3. A radial arterial line will be placed by the cardiac anesthesia team or a small bore femoral line by the EP service.
4. A second peripheral IV may be placed to allow monitoring. An increase in CVP of > 5 cmH_20 indicates an increase in intrathoracic pressure. If a peripheral IV is not possible or desired than the femoral catheter can be used.
5. Conventional ventilation will be utilized for the initial portion of the procedure up to the time of catheter ablation.
6. HFJV will be initiated during the ablation portion of the procedure in an attempt to limit drying of the airway.
7. A baseline arterial blood gas analysis will be obtained prior to initiation of HFJV.
8. HFJV will be initiated at settings listed below (Table XXX).
9. Arterial blood gas analysis (ABG) will be performed after 5-10 minutes of initiating HFJV.
10. ABG will be performed every 30 minutes during ablation and adjustments performed according to the PaO_2 and $PaCO_2$.
11. Active humidification with sterile water will be utilized during the procedure.
12. Airway pressure will be continuously monitored.
13. HFJV may be discontinued at the end of ablation.

Table XXX – Initial HFJV Settings for PVI

Ventilatory rate 100 breaths per minute
Inspiratory time 30% of cycle (I/E = 30%)
FiO_2 100%
Humidity 100% (level 8)
Driving pressure 30 psi

Anesthetic Management

Total intravenous anesthesia (TIVA) is the preferred technique during HFJV. A continuous propofol infusion supplemented by either a continuous infusion of an opioid (remifentanil) or a dose of a longer acting agent (hydromorphone) is preferred. Muscle relaxation is generally necessary. Good communication with interventionalist is essential since the NMB may need to be held at some point in the procedure to avoid injury to the phrenic nerve.

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Alarms, Complications, and Safety Information

There are several potential complications associated with jet ventilation including barotraumas, drying of airway mucosa, loss of ciliary function, bleeding, and even potential airway necrosis.

Do NOT IGNORE ANY ALARMS! Immediately switch to manual conventional ventilation and trouble shoot.

Studies evaluating the benefits of HFJV

The benefits of HFJV have been studies in many settings (Table XXX)

Table XXX – Studies Evaluating HFJV

Parameter	Study / year	Results
HFJV: Utility in left atrial catheter ablation	Goode, 2006	HFJV yields more stable posterior LA environment
HFJV in MIDCAB	Ender 2010	HFVJ feasible PaO_2 higher in HFJV $PaCO_2$ higher during HFJV

Trouble Shooting Problems with HFJV

Problem	Potential Complication	Trouble Shooting
Lack of humidification	Drying of secretions ETT or bronchial occlusion	Check humidity setting and increase
High peak airway pressures	Barotrauma Penumothorax	Disconnect ETT Suction airway Decrease DP Abort HFJV
Elevated $PaCO_2$	Increased PVR	Increase driving pressure
Hypoxemia	Arrhythmias Increased PVR	Increase FiO_2

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