High Frequency Jet Ventilator Management Guidelines

Process Map: Preventative Lung Strategy *(rev. 12.21.2021)*

Indications for intubated neonates:

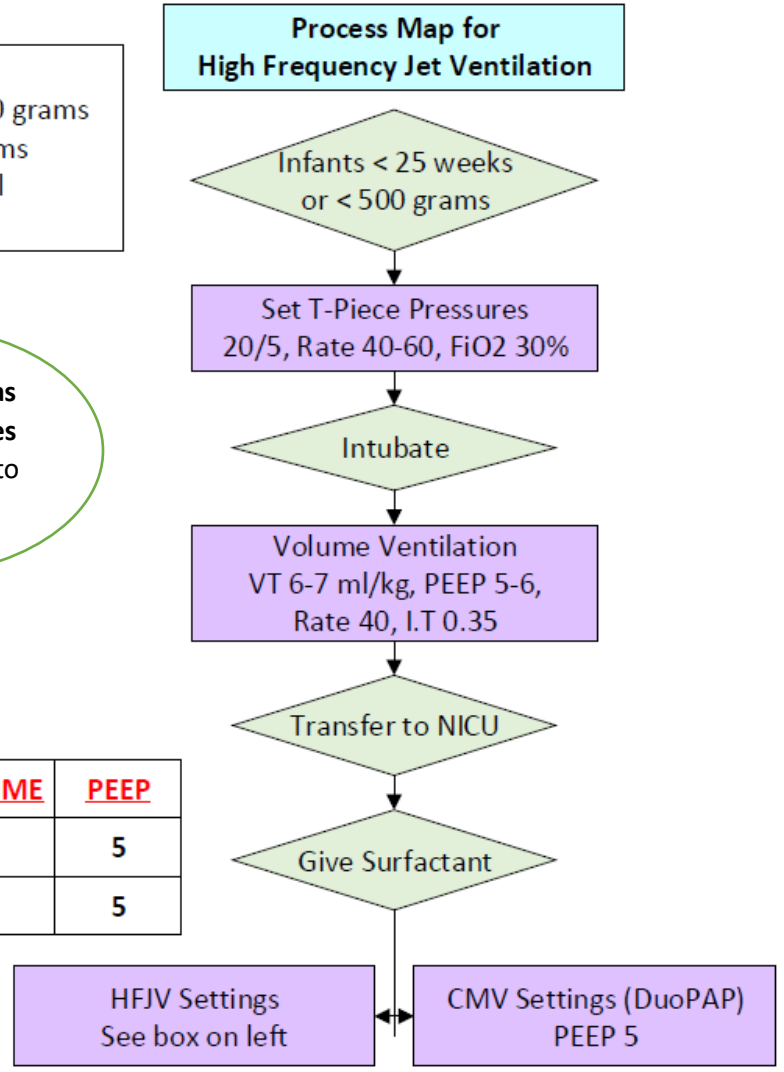
- Preventative Lung Protection Strategy in infants < 25 weeks or < 500 grams
- **Strongly** consider jet ventilation for infants < 26 weeks or < 750 grams
- Rescue therapy for Air Leak Syndrome such as Pulmonary Interstitial Emphysema, pneumothorax, lung hyperinflation & air trapping

Ensure adequate chest wall **wiggle/vibrations**

Check a blood gas within **30 minutes** after converting to the Jet

Obtain a CXR 45-60 minutes after converting to the Jet

PATIENT POPULATION	JET RATE	JET PIP	JET INSPIRATORY TIME	PEEP
22 - 23 weeks GA	300 bpm	24 - 26	0.02 seconds	5
24 - 25 weeks GA	360 bpm	22 - 24	0.02 seconds	5



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Jet Rate:

1. ELBW infants < 27 weeks gestation – start with a Jet rate of 300 or 360 bpm. The reason to start on a lower Jet rate in this population is to prolong the I:E ratio to decrease the risk of developing pulmonary interstitial emphysema (PIE) from inadvertent air trapping.

Initial Jet Rate for First Intention Use for RDS:

< 24 weeks GA or < 600 grams:	300 bpm (I:E of 1:9)
24 – 26 weeks GA or 600 – 1000 grams:	360 bpm (I:E of 1:7)
≥ 27 weeks GA or ≥ 1000 grams:	420 bpm (I:E of 1:6)

   a. If PIE develops, decrease the Jet rate further and turn off the Sigh Breaths. Most infants improve on a rate of 300 bpm. If needed the rate can be lower (280/260/240) with 240 being the lowest Jet rate. At rates from 240 – 300 changes can be made by 20 bpm for fine tuning. Lower rates can also be used to decrease alveolar ventilation to avoid hypocarbia.
   b. *It is important to note that while optimal PEEP is extremely important in these infants, the use of excessive PEEP beyond optimal can result in PIE and/or pneumothorax. PIE results when respiratory and terminal bronchioles become overdistended with resultant tearing of the alveolar ducts, allowing air to escape into the interstitial tissues resulting in the classic "soap bubble" appearance of the CXR. An effective method to treat PIE is to allow the alveoli to partially collapse in order for the epithelial cells to come back into contact with one another and heal the leak. This may require decreasing the PEEP to decrease overdistension along with decreasing the Jet rate to minimize air trapping while remain of HFJV. You should expect an increase in the FiO2 as well as the pCO_2 and may need to transiently tolerate the higher oxygen requirement and relative hypercapnia until the PIE has begun to heal.

2. *For worsening late RDS or early BPD, when there are significant issues with pCO_2 retention and the chest radiograph is diffusely hazy (poor aeration between the ribs) despite adequate expansion (inflation, 9 ribs), then consider increasing the Jet rate to improve alveolar recruitment.
   a. Adequate expansion in this population is usually 9 ribs; it may be less for those infants with pulmonary hypoplasia from Preterm Prolonged Ruptured of Membranes.
   b. Increasing the Jet rate will increase the mean airway pressure (MAP) and will help recruit atelectatic alveoli. A higher rate leads to a decrease in expiratory time (shorter 1:E ratio) with the I-time constant at 0.02 seconds, so you will need to monitor for potential air trapping (especially if the infant is on high levels of PEEP).

Jet Rate Continued:

3. *Generally, ELBW infants can ventilate on the lower initial rate of 300-360 bpm for the first 5-7 days of life, though this is not always the case.

4. Avoiding overdistension in the ELBW population is critical. Once infants develop mechanical injury from overdistension, treating their lung disease becomes more complex as they are at an increased risk of air trapping leading to cystic BPD.

5. Increased oxygen needs and pCO_2 retention may mean that the infant needs more Jet rate, more PIP, more PEEP or all the above. Increasing the Jet rate to 420/480/540 is not routinely done in the first few weeks of life in the ELBW population unless needed and is used more in infants who are developing early BPD or have established dense BPD.

6. *Higher Jet rates are utilized more frequently after the first 2-3 weeks of life:
   a. When the infant's chest radiograph is adequately expanded at 9 ribs but is hazy bilaterally and the infant has increased oxygen needs and pCO_2 retention, then increasing the Jet rate can help with pCO_2 elimination.
   b. Increasing the Jet rate will also increase mean airway pressure by decreasing expiratory time, which can help to improve oxygenation. MAP = (PIP-PEEP) [Ti/(Ti+Te)] + PEEP
   c. Increasing the PEEP will also lead to improve alveolar recruitment, however if the level of PEEP is excessive the lungs can become hyperinflated leading to increased pulmonary vascular resistance. Alveolar over distension can also lead to a decrease in passive elastic recoil worsening ventilation as well as oxygenation.
   d. If you use appropriate Jet rates 360-420 (maybe 480 in some), you can operate at a lower PEEP level.

7. *Sometimes, with an increase in the Jet rate, infants can improve both ventilation and oxygenation, as the increase in rate leads to an increase in MAP without using excessively high levels of PEEP.
   a. Of note, high PEEP (not optimal PEEP) and high Jet rates together can result in air trapping. **To minimize inadvertent air trapping, which can be detected when the PEEP measured by the Jet exceeds the PEEP set on the conventional ventilator by > 1.5-2 cm H_2O. Always monitor both PEEP values.**

Sigh Breaths:

1. Conventional IMV breaths used as a recruitment tool for "wandering" atelectasis, but the purpose of HFJV is to minimize volutrauma, so add sigh breaths in a controlled manner.

2. *In general, sigh breaths are not usually started during the first week of life, as sigh breaths may increase the risk of PIE in ELBW infants.
   a. If you notice PIE on your infant's CXR when on sigh breaths, it is important to remove all sigh breaths to help heal the PIE.

3. When you do add sign breaths, avoid large tidal volumes to minimize volutrauma, but use enough PIP to get above the critical airway opening pressure of the area of atelectasis.

Initial Sigh Breaths Settings

Rate: 4

Conventional PIP set: 6-10 cmH20 above the PEEP

I.T: 0.4

4. Start with a small number of sigh breaths to treat wandering atelectasis: rate of 4, although some infants may require more depending on their degree of lung disease.

5. Once infants require sigh breaths, most should remain on the sighs until extubation due to wandering atelectasis from changes in positioning leading to atelectasis from overly compliant chest walls.

6. If the infant is overdistended on CXR, you may need to wean both the sigh breaths PIP, and the PEEP.

7. Sigh breath rate can be increased from 4 up to as high as 12 if the main issue is severe desaturation spells (saturations < 80% for prolonged periods requiring nursing intervention) from alveolar hypoventilation (unresponsive to increase in caffeine) which occurs when the infant slows their spontaneous respirations to < 20 BPM.

Jet PIP:

1. The PIP on the Jet is not equivalent to the same level of PIP delivered by the conventional ventilator in terms of the risk of lung injury due to the minimal tidal volume delivered from the very brief inspiratory time (0.02 seconds). Therefore, using a higher PIP on an ELBW infant, will not result in the same high degree of volutrauma that is associated with high PIPs (> 30) during conventional ventilation. The highest PIP on the Jet is 50 cm H_2O. The lowest that is used is around 14 cm H_2O.

2. Increasing the PIP as needed to increase the tidal volume to help with pCO_2 retention and wean the PIP for low levels of pCO_2.

3. If your infant has PIE, you will need to decrease the Jet rate, as you do this, the pCO_2 may increase so you can compensate for this by increasing the PIP. Infants with severe PIE may require rates of 240-280 and a PIP often > 30 to maintain appropriate pCO_2 values.

4. *In the first week of life, pCO_2 goals for these infants are generally 40-55 (50-60 if significant PIE develops). Typically, adjusting the PIP is the primary mechanism used to maintain these goals on your baseline Jet rate of 300 or 360 bpm.

5. *After the first week of life, allow for more permissive hypercapnia with a pCO_2 goal of 45-60 to continue to reduce the risk of ventilator associated lung injury from volutrauma.

6. Minimize prolonged periods of severely abnormal levels of pCO_2 in the ELBW infants, as prolonged pCO_2 levels > 65 are associated with an increased risk of intraventricular hemorrhages and prolonged pCO_2 levels < 30 are associated with an increased risk of periventricular leukomalacia and IVH.

The PIP-PEEP is the delta P which generates the delivered tidal volume.

1-2 cm H_2O change in PIP changes pCO_2 roughly by ± 2-4 mmHg

3-4 cm H_2O change in PIP changes pCO_2 roughly by ± 5-9 mmHg

5-6 cm H_2O changes in PIP changes pCO_2 roughly by ± 10-14 mmHg

Jet PEEP: Optimal PEEP minimizes lung damage from both atelectrauma and overdistension.

1. For ELBW infants, start the PEEP at 5/6 cm H_2O and aim for 9 rib expansion to balance overdistension versus atelectasis to minimize the risk for lung damage.

2. Increase PEEP as needed to improve oxygenation if requiring high FiO_2, and if your pCO_2 is within the acceptable range, also increase the PIP by the same amount to maintain your delta P (the effective tidal volume).

3. *The use of higher Jet rates and sigh breaths can minimize the need to use a PEEP level of > 8-9 cm H_2O for alveolar recruitment. When adjusting PEEP always follow the chest radiograph to avoid hyperinflation and overdistension as well as using enough PEEP to maintain adequate FRC.

Jet Inspiratory Time

1. ***Always use 0.02 seconds (20 milliseconds) for the inspiratory time** (range 20-34 milliseconds). The I.T. should never be increased above 0.02 seconds without Neonatal staff approval. Any increase in I.T. will greatly increase the risk of air trapping and pneumothorax.

Management Strategy Table

		Oxygenation		
		Inadequate or Poor (Increase FiO_2)	**Adequate or Good**	**Too Good (Decrease FiO_2)**
Ventilation	**Over Ventilated** **CO_2 is too Low**	Increase PEEP while keeping PIP constant. This increases MAP while decreasing ΔP to prevent hypocarbia.	Decrease ΔP by decreasing PIP and consider increasing PEEP if needed to keep the MAP constant to prevent atelectasis. If over inflated just decrease PIP to decrease TV.	Decrease PIP until CO_2 is acceptable. If still over inflated decrease PIP and PEEP by the same amount.
	Appropriate Ventilation **CO_2 is Adequate**	Increase both PIP and PEEP by the same amount to keep ΔP unchanged while increasing the MAP.	**No Changes**	Decrease PEEP and PIP by the same amount to decrease MAP to avoid over inflation. This keeps ΔP unchanged.
	Under Ventilated **CO_2 is too High**	Increase both MAP and ΔP by increasing PIP until CO_2 is acceptable. If oxygenation is still poor increase both PIP and PEEP by the same amount to keep ΔP constant while increasing MAP.	Increase ΔP by Increasing PIP.	Increase ΔP by decreasing PEEP to avoid over inflation until CO_2 is acceptable. If still over inflated decrease both PIP and PEEP by the same amount to decrease MAP.

Management Initiation for Air leak Syndrome: Pneumothorax, PIE

Conversion Tables

Converting from Conventional Vent to the Jet Vent

High Frequency Jet Settings (HFJV)		Conventional Vent (Hamilton) during HFJV (DuoPAP mode)	
PIP	Match conventional vent PIP	**PEEP**	Maintain conventional vent PEEP
Rate	360 bpm	**Rate**	* No Sigh Breaths
I.T	0.02	**I.T**	0.1

* Please note: The RT will set the Hamilton Vent in these settings to avoid Apnea Alarm activation.

Rate 3, (PEEP = PIP), I.T 0.1

These settings allow for **zero** sigh breaths

Converting from High Frequency Oscillator Vent to the Jet Vent

High Frequency Jet Settings (HFJV)		Conventional Vent (Hamilton) during HFJV (DuoPAP mode)	
PIP	Use HFOV Amplitude as starting PIP	**PEEP**	** HFOV MAP - 3
Rate	360 bpm	**Rate**	* No Sigh Breaths
I.T	0.02	**I.T**	0.1

** Please note: It is very important to keep MAP consistent during conversion to the Jet vent to avoid excessive atelectasis. This can be very patient specific. The MAP must be adjusted based on the clinical scenario.

2.0 ETT's with Jet Ventilation: Key Reminders

1. DO NOT CUT THE 2.0 ETT
2. Keep the ETT midline and upright to avoid hitting the side of the trachea which can affect ventilation.
3. Higher PIP's may be necessary to overcome the resistance and dead space of the ETT diameter.
4. For 22-week GA infants, use tape instead of the "bone" for ETT securement.
   *When infant is 14-21 days of life, consider upsizing to a 2.5 ETT.

Weaning

1. **Decrease Jet PIP** by decreasing minute ventilation slowly by lowering PIP as blood gases allows. If hyperventilation is occurring, then it should be weaned faster.
2. Once **Jet PIP is 18** and **PEEP 5-6** cmH20, **begin weaning Jet Rate in increments of 60 bpm to a goal of 240-360.**
3. Maintain optimal MAP by **adjusting PEEP as necessary to maintain a MAP** sufficient to achieve adequate oxygenation. Don't wean PEEP until FiO2 in < 0.40

Extubation Criteria

Jet PIP: < 20

Jet Rate: 240-300

Jet MAP 7-8 cmH20 & FiO2: < 0.30

Extubate to NIPPV or Bubble CPAP with PEEP equivalent to Jet MAP

Reference:

1. Stacy Kern, MD, Jonathan Klein, MD, Medical Director University of Iowa NICU, Tom George, MD, Director of Neonatology Children's Minnesota.
2. Timothy G. Elgin, Amy H. Stanford, Jonathan M. Klein, First intention high frequency jet ventilation for periviable infants. Co-pediatrics.com vol 34, 2022