

# Paediatric Intensive Care Unit

## Airway Pressure Release Ventilation UHL Paediatric Intensive Care Guideline

Staff relevant to:	PICU medical and nursing staff
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### What is APRV?

#### Definition:

Airway Pressure Release Ventilation (APRV) is time cycled, pressure limited, inverse ratio mode of ventilation that provides continuous distending airway pressure with intermittent releases. APRV is used mainly as a rescue therapy for the difficult to oxygenate patients with acute respiratory distress syndrome (ARDS).

#### Description:

This mode is similar to pressure control ventilation, but there are two main distinctive features:

1. Extreme inverse ratio ventilation
  - a. High pressure maintained for longer duration, to promote lung recruitment
  - b. Very short expiratory time, which prevents the peak expiratory flow from returning to a zero baseline (this maintains intrinsic PEEP)
2. Constantly active expiratory valve which enables spontaneous breathing anytime in the cycle.

Different names have been coined for the same mode by different manufacturers – for example: APRV(Drager), Bi-Vent (Maquet) ,APRV (Hamilton).  
 We currently use Hamilton ventilators in CICU and Maquet Servo-I in PICU .

**Goals of ARPV :**

- To provide the lung protective ventilation support while minimising alveolar distension and avoiding repeated alveoli collapse and re-expansion.
- To restore FRC through recruitment and to maintain FRC by creating intrinsic PEEP.

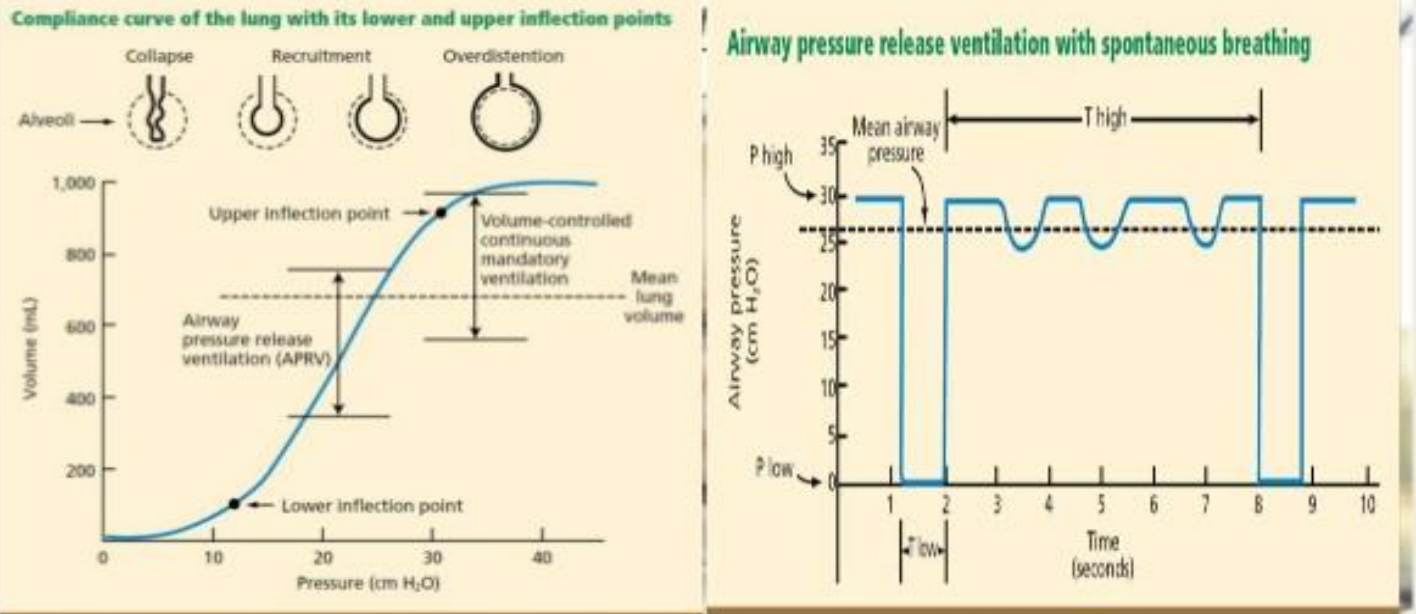


Image: Ventilator graph pressure time graph on APRV with spontaneous breaths (right); left side image is to understand how the pressures compare between conventional and APRV modes for same mean lung volume.

**Terminologies and Initial Settings:**

**Initial setting of ARPV**

Setting up APRV	
<b>P high</b>	Pplat or PIP to target volume 4-8mls/kg bw Typically 20-25 cms H2O Keep P high <30 cms H2O
<b>P low</b>	0-5cmsH2O
<b>Thigh</b>	4-8 secs(start at 4 secs)
<b>T low</b>	0.3-0.6 s
<b>Fio2</b>	Attempt to wean to <60%

### 1. P High:

- Upper pressure level which is maintained during long inspiratory time (similar to PIP). This affects the oxygenation.
- Usually started at a pressure closer to PIP or 3-5cmH<sub>2</sub>O higher than MAP on conventional ventilation.
- After initial stabilization, P High is adjusted to maintain release VTs of 4-8 ml/kg of ideal body weight. Scale down the P High if domes of the diaphragm are visible below the ninth posterior rib and are flattened on chest radiograph or the end-tidal CO<sub>2</sub>-to-arterial blood CO<sub>2</sub> gap widens

### 2. P Low:

- Lower pressure level to which the pressure is reduced during cycling to short expiratory time (similar to PEEP).
- P low is usually set at 0 cm H<sub>2</sub>O. This provides a maximum delta p for unimpeded expiratory gas flow and helps with CO<sub>2</sub> clearance
- Even if it is set at 0 cm H<sub>2</sub>O, the time for this pressure is so short, the end expiratory flow is maintained around 50%-75% of the peak expiratory flow rate (refer to graph on next page). Hence, there is always intrinsic PEEP which avoids collapse of alveoli.
- Some protocols use positive P low of ~5 cm ([Zhou 2017](#)). This may be helpful in cases of severe hypoxemia without increasing P high to dangerous levels and may make APRV more long protective by avoiding wider fluctuations in airway pressure which drives Tidal Volume (TV). However this also reduces TV and may promote hypercarbia

### 3. T High:

T High is the inspiratory time phase for higher pressure (P High). Initial T High is set at about 4.0 seconds. Ideally the T-High should be >9 times the T-Low, so that >90% of the overall time is spent at T-High. Inadequate T high and too frequent releases lead to de recruitment and excessive T-High leads to hypercapnia

### 4. T Low:

- T Low is the release time allowing CO<sub>2</sub> elimination. This is usually set at 0.2 to 0.6 seconds,
- Target an end expiratory flow of 50-75% of peak expiratory flow.
- T Low should be short enough to prevent de recruitment and long enough to obtain a suitable tidal volume. If the tidal volume is inadequate, the T Low is lengthened; if it is too high (>8 ml/kg) the T low is shortened.
- T Low can be as short as 0.2 seconds (closer to 75% of PEFR) in restrictive disease and as long as 1.5 seconds (closer to 25% of the PEFR) in obstructive state.

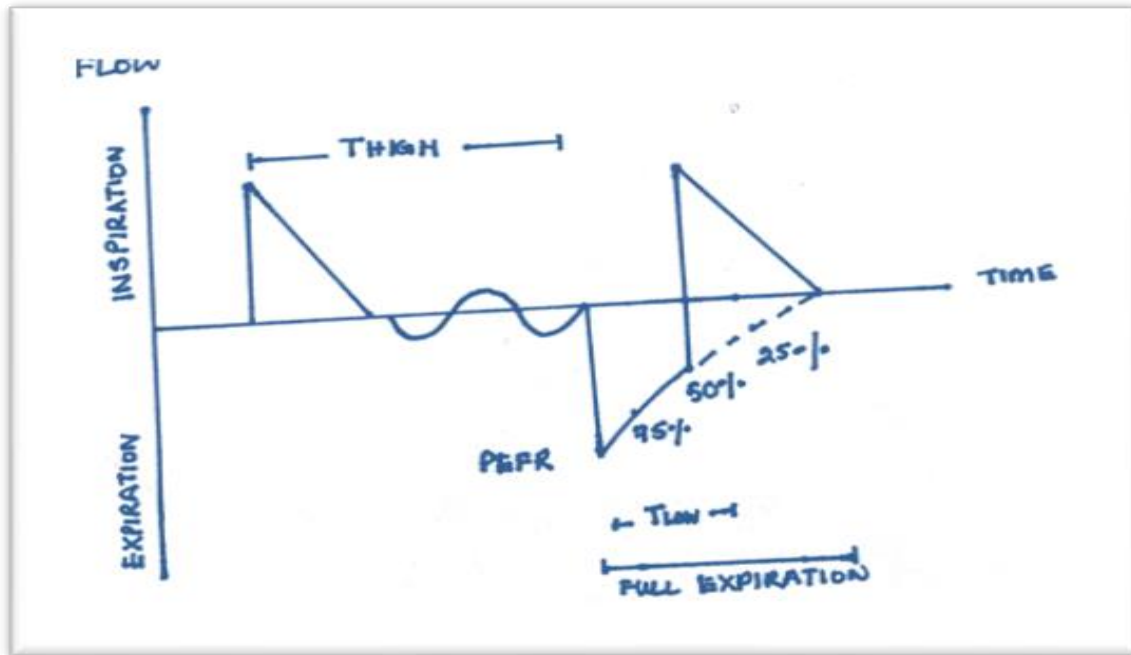


Fig 1: Flow-time graph with APRV and T low titration

**Caution and Considerations:**

1. **Release Frequency:**

When setting T high and T Low, be mindful of Release frequency:

- Release frequency =  $60 / (T \text{ High} + T \text{ Low})$
- Initially a frequency of 10-14 releases/minute is reasonable.
- As the patients wean off support, T High can be increased to reduce the release frequency

2. **Pressure Support(PS) and Automatic Tube Compensation(ATC):**

Unassisted spontaneous breathing on APRV has benefits of better diaphragmatic movements which improves alveolar recruitment in juxtadiaphragmatic regions. At the same time, if there is high ET tube resistance to spontaneous breathing, patient might struggle. So, *if we use Automatic Tube Compensation (ATC) on our ventilator, PS should be kept zero.* Otherwise Pressure support of 3- 5cmH<sub>2</sub>O can be provided.

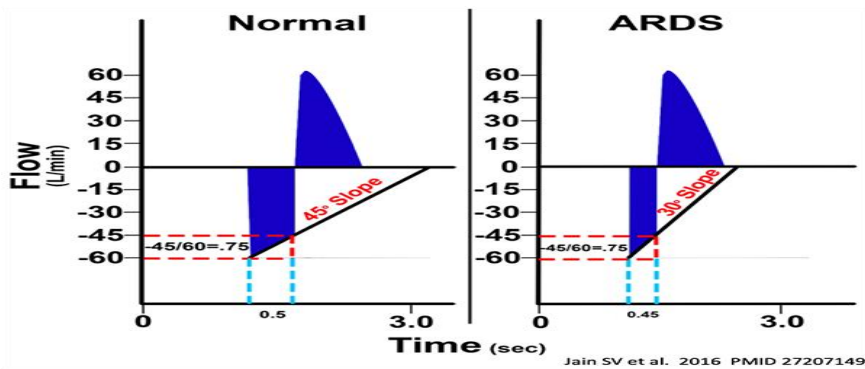
3. **Tidal Volume and Minute Ventilation:**

With very high P High, usually tidal volumes are high; so check and aim to maintain TV at 6-8 ml/kg tidal volumes, not exceeding 9ml/kg; There is also a contribution of spontaneous breathing to minute ventilation, which should be kept in mind.

4. **Sedation and Paralysis:**

Though patient can be paralysed, APRV works its best when spontaneous breathing is allowed. Usually patients are comfortable and tolerate this well with lesser sedation compared to conventional ventilation modes. Ideally approx 10-30% of total minute ventilation should be contributed by spontaneous ventilation (can be more in less severe disease), and sedation can be weaned accordingly.

## 5. Expiratory Flow Deceleration angle:



This can be seen in the flow time graph on the ventilator graphics as shown above. The angle in a normal lung is around 45 degrees (left image); In ARDS due to de-recruitment, this angle is less – steep flow curve (right image) and in over distension or obstruction (bronchospasm or secretions) this angle may be high (flat flow curve).

## 6. Haemodynamic considerations:

APRV is usually well tolerated hemodynamically despite high pressure settings. While initiating on APRV, a few patients may need fluid bolus to maintain cardiac output. But subsequently they manage well, possibly in part due to increased venous return with spontaneous breathing.

## Making Changes on APRV settings:

### 1. CO<sub>2</sub> clearance

As with conventional ventilation permissive hypercapnia should be allowed based on the same principles of ARDS management.

CO<sub>2</sub> clearance is based on the following principles:

1. CO<sub>2</sub> removal is dependent on the difference between P High and P Low (If P Low is zero, as it is most often, higher the P High → higher the CO<sub>2</sub> clearance).
2. Higher the release frequency (by reducing T High), CO<sub>2</sub> clearance is better (caution: too much reduction of T High will negate the purpose of APRV). Additionally increasing T high may improve recruitment and thereby CO<sub>2</sub> removal if lungs are de recruited
3. Increasing T Low (allows more time for exhalation) if the end expiratory flow is > 50% of peak expiratory flow rate (caution: similar to point 2)
4. Allowing and optimizing spontaneous ventilation will also help clear CO<sub>2</sub>.

### Steps to decrease PaCO<sub>2</sub>:

- Increase **P High** by 2 cms H<sub>2</sub>O at a time (monitor Tidal Volume and MAP)
- Decrease **T High** by 0.5-1 s (increases release frequency)
- If possible, increase T Low to allow more time for exhalation ( but risk of de-recruitment )

### Steps to increase PaCO<sub>2</sub>:

- Increase **T High** slowly in increments of 0.5-1 s
- Decrease **P High** by 2 cms H<sub>2</sub>O (Monitor oxygenation and avoid de recruitment)

## 2. Oxygenation: to improve oxygenation

- Increase **P High** by increments of 2cmH<sub>2</sub>O at a time if <30 cms H<sub>2</sub>O
- Increasing **T High** by 0.5-1 s.
- Decrease **T low** to closer to 75% PEFR
- Last resort increase **P low**
- Ovoid over distension

### Weaning from APRV and Extubation:

- Wean FiO<sub>2</sub> first based on sats; only go on to further weaning if FiO<sub>2</sub> < 60%
- Decrease **P High** by 2cmH<sub>2</sub>O slowly until the P High is below 18cmH<sub>2</sub>O
- When **P High** is low, start increasing the T-High by increments of 0.5 – 1 seconds
- This may be done every 4-8 hours as tolerated.
- Once you are on low P High and **T High** increased to ~20-30 seconds-this is very close to being on CPAP (with high CPAP pressure) - you can change to CPAP/PS and wean CPAP slowly towards extubation

### Non Responders or APRV failure:

There may be instances when patient may not be tolerating APRV well or gas exchange may not be optimal, despite changes as mentioned above. Once a child has been given reasonable time (approx 2 hours) on APRV, and gases still not improving, it can be considered as APRV non responder. These may be severe ARDS who are difficult to recruit even by APRV or the lungs are severely consolidated with nothing available to recruit. In such cases, seek senior advice and consider HFOV/ECMO.

### Key message :

**Any ventilation mode is only as good as the person who uses it**, which applies even more so to APRV.

Use APRV in conjunction with these guidelines, only when you feel comfortable with the settings or when you are supported by another expert on APRV.

## 3. Education and Training

None

## 4. Monitoring Compliance

None identified

## 5. Supporting References

1. Zhou Y et al. Early application of airway pressure release ventilation may reduce the duration of mechanical ventilation in acute respiratory distress syndrome. [Intensive Care Medicine 2017](#).
2. Habashi NM. Other approaches to open-lung ventilation: airway pressure release ventilation. [Critical Care Medicine 2005](#)

## **6. Key Words**

PEEP, Tidal volume

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**The Trust recognises the diversity of the local community it serves. Our aim therefore is to provide a safe environment free from discrimination and treat all individuals fairly with dignity and appropriately according to their needs.  
As part of its development, this policy and its impact on equality have been reviewed and no detriment was identified.**

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<b>Details of Changes made during review:</b> <b>New guideline</b>	