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SUMMARY DOCUMENT (1page)

CPAP, Non Invasive Ventilation (NIV) by Mask and Use of NIV systems for intubated patients in the time of Corona patient surge.

David M. Rapoport, MD

Note: this document is my personal opinion – it does not represent the position of any commercial entity.

- CPAP is similar to PEEP and, from early reports, may help improve oxygenation (even without supplemental O2) in patients with ARDS. It is possible it will obviate need for assisted ventilation.
- Ventilation can be accomplished effectively with bilevel NIV by mask.
- Ventilation of intubated patients can be done with bilevel NIV systems if needed.
- Infection control of possible aerosol generation by the system is less than other systems like nasal high flow but may be perceived as an increased risk to health care workers (see attached ref). Dispersion of airborne virus is possibly less than by oxygen cannulas run at high flow rates, and can be mitigated by simple modifications to the home devices:

For both CPAP and Bilevel (NIV) settings

- Use full face (not nasal) masks
- DO NOT use vented masks unless the leak ports are sealed (eg with tape).
- Use exhalation circuits made specifically by manufacturers for NIV hospital use.
- If exhalation circuits are not available, see FULL DOCUMENT for alternatives that can be used to improve safely with minimal or no commercial parts.

Default initial settings

CPAP – use 10 cm H20 with humidity (higher pressures will increase exposure of healthcare workers to exhaled air. Do not use AutoCPAP.

Bilevel (NIV) – start with IPAP 15/EPAP 5 for mild cases, IPAP 20-30/EPAP 5-10 for severe cases. Begin by trying CPAP alone for oxygenation, add IPAP for respiratory support.

Oxygen can be bled into the system, typically at relatively high rates. O2 flow does not translate from nasal O2 by cannula settings. It is diluted by the high flows through the system, and delivered O2 concentration will fall with higher pressures, even while patient may be benefitting. Monitoring O2 sat helps but must be interpreted with this in mind.

Companies that make CPAP and NIV devices widely available in US

Phillips Respironics
ResMed
Fisher and Paykel Healthcare

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FULL DOCUMENT

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Background: CPAP may be used as a form of PEEP. NIV is an effective mode of ventilation and provides ventilatory support. NIV is usually pressure based (not volume). There are, in recent times, anecdotal reports of the use of bilevel devices for intubated patients despite their being designed for mask ventilation. It is important to remember that simple pressure ventilators (eg the original Bird IPPB machine of the 1960s and 70s) were extensively used for both mouthpiece treatments and to ventilate intubated patients in the ICU (they could not be used with masks in those days due to triggering issues, which were overcome by BiLevel devices with a leak port circuit). It is logical to assume that Bilevel ventilators **can be used** to ventilate intubated as well as non-intubated patients. Details for doing this are provided for 3 scenarios, should standard ventilator availability be limited by the expected surge in patients over the next few weeks.

1. FOR INTUBATED PATIENTS
2. FOR NON-INTUBATED HOSPITALIZED PATIENTS WITH MODERATE TO SEVERE RESPIRATORY DISTRESS REQUIRING VENTILATORY ASSISTANCE.
3. FOR HOME USE IF PATIENTS ARE SENT HOME DESPITE NEEDING VENTILATORY ASSISTANCE WHEN HOSPITALIZATION IS NOT POSSIBLE.

DEFAULT PRESSURE SETTINGS for bilevel ventilator

Bilevel settings (IPAP and EPAP) will depend on patient's lung mechanics. The two functions are:

1. Provide CPAP or PEEP for oxygenation (this is the EPAP setting)
2. Provide ventilation (this is the delta between IPAP and EPAP)

Setting a high EPAP limits possible ventilation by mask, so this needs to be as low as possible. Max attainable IPAP is usually 25-30 (depends on machine). Higher pressures than 30-35 will usually leak more than help by mask, but can be delivered via endotracheal tube.

Suggested defaults:

For CPAP alone, set at 10cm. Do not use AutoCPAP setting as this may respond poorly in dyspneic high ventilatory drive patients

For patients with less severely affected lungs use IPAP 15/EPAP 5.

For patients with ARDS use EPAP as low as possible, and IPAP higher by 15-20 up to 25. Start at IPAP 20/EPAP 5.

Assessing success should be by O2 saturation (but may be hard to judge if on supplemental O2). Another sign that is useful is reduction of respiratory rate to <20/min. ABG if available.

Setup circuitry and discussion of clinical issues

Setup Circuit

CPAP and NIV/Bilevel ventilators are built to work with a single tube and a relatively constant intentional leak. Total leak occurs in three parts:

1. Mouth leak if a nose mask is used.
   For infection control one must **AVOID nasal masks.** Nasal masks work well for ventilation during sleep, but mouth leak can be high while awake. Mouth leak both dissipates pressure and increases risk to healthcare personnel. **Full face masks** are better suited to infection control provided they are **NON-VENTED**. Most vented masks (intended for home CPAP use) can be adapted by covering the vent holes with tape (duct tape works well). However, once the mask vents are sealed, you must introduce a leak elsewhere in the circuit to prevent rebreathing. See below.

2. Leak around the mask/face contact
   Attempting to get good mask fit is desirable and recommended, but it is **unlikely that any procedure will reduce mask/face leak to zero over time**. Thus all face mask ventilation carries a small increase in risk of exposure to the healthcare worker. However, I feel larger droplets from the patient are unlikely to get beyond the face as there is not a "jet" of flow.

3. Leak through the intentional leak port.
   If the leak port is in the (vented) facemask itself, it cannot be filtered. Thus a non-vented mask is desirable, and these are routinely available. If a vented mask must be used, the vents must be covered AND A LEAK CREATED ELSEWHERE IN THE CIRCUIT. Flow out this diversion can then be filtered to mitigate the impact of possibile aerosolization of coronavirus. The extent of particle dispersion has been studied for tight fitting masks, and is lower than with other aerosolizing procedures such as bronchoscopy and intubation, but probably not zero (see Hui, ERJ Jan 2019). Since this component of leak can be filtered only with a modified NIV circuit, for the protection of healthcare workers and adjacent patients, standard home circuits should not be used without modification in the hospital or ICU setting. I personally do not feel the benefits of modifying the circuit and adding a filter are justified in the home setting due to complexity and the need to change filters frequently due to condensation, which competes for a negligible change in the risk to people living with the patient.

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CIRCUITS FOR Non Invasive (MASK) Ventilation and for Bilevel Ventilation in INTUBATED PATIENTS. Modifications will reduce risk of aerosol dispersion from the circuit leak (but not reduce leak from around a mask)

OPTIMAL CHOICE is STANDARD "Exhalation Port" circuit, available from
Phillips Respironics, Fisher and Paykel Healthcare and possibly ResMed. These can be used unmodified, are interchangeable across ventilators and will mate with conventional filters for respirators.

Part Numbers to order:

Phillips Resironics	1073228 (contains tube, restrictor, no humidity) – see Phillips parts website (alternative for humidified circuit may exist)
Fisher Paykel Healthcare	RT219 (contains tube, water reservoir, restrictor and connectors for humidified circuit)
ResMed	?

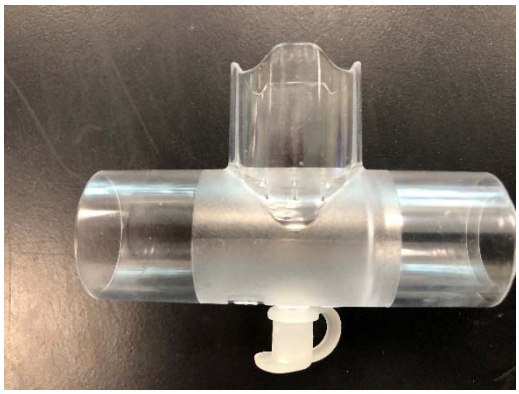
Filters that adapt onto exhalation ports above

Phillips Resironics	C06417
Fisher Paykel Heathcare	RT019 (without insulation) or RT020 (with insulation for high humidity in cold environment)
Resmed	?

ALTERNATIVE (if only standard tubing is available) – MUST combine this with an EXHALATION PORT (flow restrictor). These exhalation ports are sold separately and will fit between most masks and the tubing to the ventilator.

Part Numbers to order

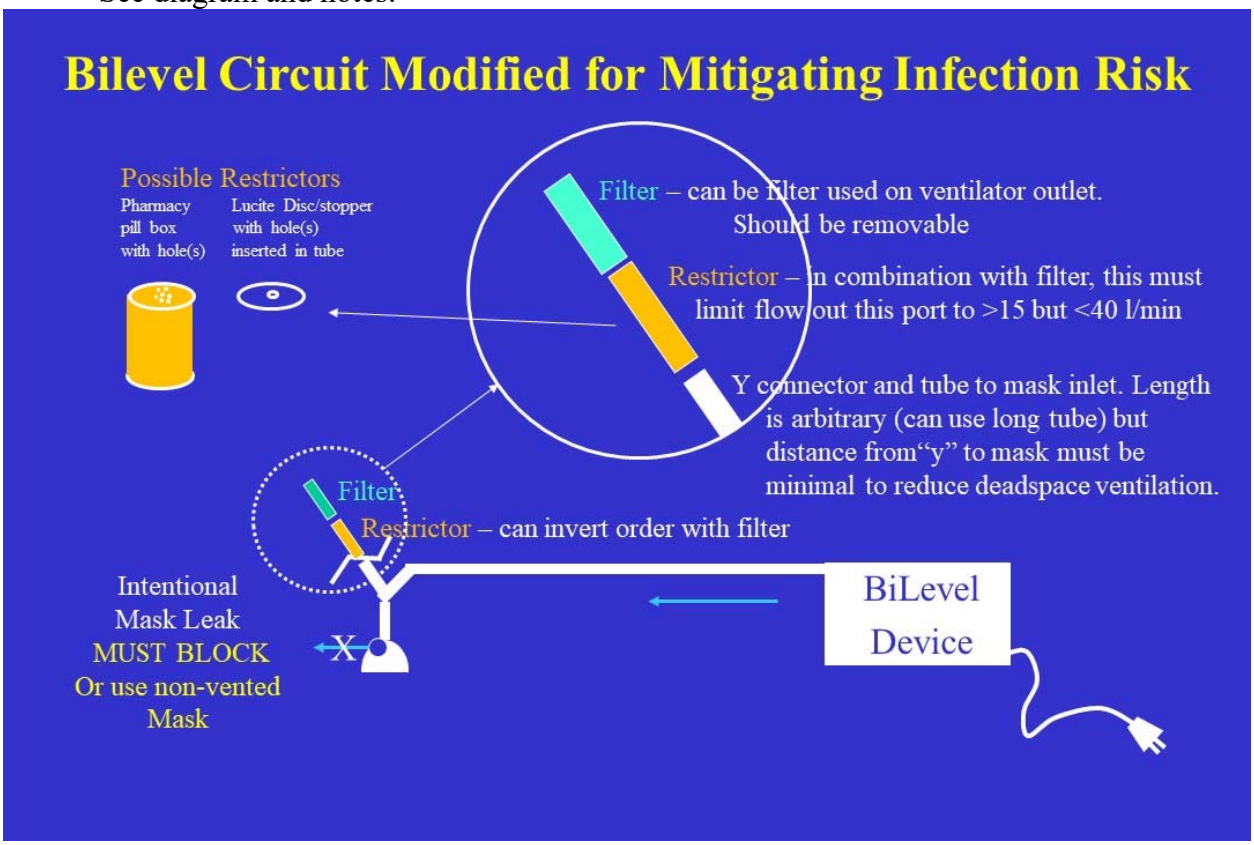
Phillips Respironics	1065775
Fisher Paykel Healthcare	RT017
Resmed	?



LAST RESORT – if you must "jury rig" a system because of lack of a commercial bilevel circuit with an exhalation port, you can do so combining the following:

1. T- or Y- connector to the mask
2. a filter
3. a method of introducing an exhalation port (or resistor containing leak) which should be inserted before (or after) the filter

See diagram and notes:



The addition of a "T" or "Y" tube with an "overflow" port allows filtering of all but the unintentional face leak. As this modified circuit creates deadspace, the Y or T must be connected as close to the mask as feasible; an extension from the diversion point to the filter can be arbitrarily long. However, simply adding a filter on the end of the "overflow" tube will dissipate much of the delivered pressure from the ventilator, unless, it is combined with a restrictor. A combined filter and restrictor resistance in the right range will correct this. To create a resistor if a commercial one (see above) is not available: use a plug with a single 3.5mm (1/8 or 5/32 inch) hole drilled in it OR twenty 0.8 mm holes (these latter can be made these from a standard medication pill box that fits the tubing, with holes punctured/melted into the bottom with a red hot paper clip or 18 gauge needle). This arrangement should provide leak flow of 12 l/min at 3cmH20, and 35 l/min at 25 cm H20, providing adequate ventilation at most bilevel settings without significant CO2 rebreathing. This setup should replicate the typical leak port flows of existing masks or expiratory port circuits directed to a filter. Sterility of this part of the circuit is not a major issue as the flow is unidirectional away from the patient, even if intubated.

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RISK OF AEROSOL TRANSMISSION FROM CPAP and NIV/BiLEVEL Ventilation

Risk of bilevel attached to an endotracheal tube in an intubated patient

Should be identical to risk (low) of a standard ventilator, but ONLY IF AN EXHALTION PORT with filter is used in the circuit.

Risk of mask ventilation in hospital for infecting healthcare personnel.

This is a very speculative area with limited data to rely upon, but logic and some limited bench data suggest that mask NIV and patient exhalate is distributed through existing droplets rather than the ventilator and mask creating new droplets (there is no jet or vortex); as best documented in a 2019 bench study (Hui, ERJ), the area of particle deposition (and thus infectivity) for a vented mask with CPAP is modest (0.30-1 m). Thus the risk of CPAP/NIV should be only a little greater than that of a coronavirus patient breathing spontaneously and less than during cough. Filtering the exhalation port leaves only mask/face leak to spread virus. (NOTE: This is my opinion, and not a scientifically verified fact!). As such, while total isolation and a negative pressure room is a laudable goal, when a large number of cases overwhelm available facilities, standard respiratory precautions (which should be taken with all coronavirus exposure) seem adequate for CPAP and NIV patients. It is not clear what risk would occur to other patients in the same room as one on CPAP/NIV, but avoiding this circumstance with a single room, or, at a minimum, increasing intra-bed distance seems desirable, if possible.

Assessment of risk of infection from CPAP/NIV to other individuals in a home setting

Patients with coronavirus on CPAP/NIV should probably be in a separate room if possible, and certainly in a separate bed, from anyone in the home. Since co-infection is almost certain within the home, I do not believe the added complexity of modifying and filtering the NIV circuit is currently justified in the home. Use of the exhalation port and filter requires changing the filter every few hours due to condensation, and probably is not feasible in the home. In addition, the increased risk of confusion and misuse by the patients for very little reduction of risk to the household caretakers inclines me to recommend against modifying NIV circuits and masks to be used at home.