The occasional acute application of continuous positive airway pressure

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INTRODUCTION

Noninvasive positive pressure ventilation evolved over several decades because of the need to avoid the complications of intubation when respiratory support became necessary. The most useful modalities have been continuous positive airway pressure (CPAP) and biphasic positive airway pressure (BiPAP). The former supports respiration by presenting the airway with a constant pressure on inspiration and expiration. The latter supplies a higher pressure on inspiration than on expiration. BiPAP normally offers an advantage in respiratory failure, but does not in cases of acute cardiogenic pulmonary edema[1] or exacerbations of chronic obstructive pulmonary disease (COPD).[2] These 2 conditions constitute the majority of cases that benefit from noninvasive interventions in rural practice. Since CPAP is equally effective and much easier to set up, it is presently the intervention of choice in small hospitals.

Most rural areas do not have respiratory therapists, and the equipment to deliver these interventions is notoriously difficult to set up, especially when done only occasionally. To achieve optimal results, it is also important to set up CPAP early when there is an indication.[3] For this reason, a simpler way of administering CPAP is required. The Boussignac CPAP system (Vitaid Ltd.) is one solution, requiring only an oxygen source and regulator to supply a single-use valve and mask system.

Objectives of the CPAP intervention include

- reduced in-hospital and postdischarge mortality;
- reduced need for intubation and the attendent complications;
- improvement in clinical parameters and symptoms, allowing improved stabilization for transport, and possibly reduced need for transport;
- improved patient comfort, with reduced need for sedation and analgesia;
- simplified management of some types of respiratory failure in settings in which resources are limited.

INDICATIONS

Evidence from controlled studies is becoming available, although blinding is not possible in these studies because of the nature of the intervention. The following are conditions possibly benefiting from early CPAP, listed in order of level of evidence:

1. Acute COPD exacerbation. Studies are in general agreement that CPAP is a first-line intervention. Two meta-analyses have been published.[4,5]
2. Acute cardiogenic pulmonary edema. Three well-conducted meta-analyses[6–8] had previously established that CPAP reduced both mortality and intubation rate. A recent megatrial[9] has disputed this, although there is agreement that there is early improvement in symptoms and physiologic parameters. CPAP should remain a first-line intervention pending further large trials.
3. Pneumonia. Benefit is only shown in patients with infection associated with COPD and in immunocompromised patients, such as those with pneumocystis or those who have had transplant surgery, for whom intubation should be avoided.
4. Do-not-intubate status. Reversal of deterioration or improvement in

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acute dyspnoea may occur in patients with COPD or pulmonary edema without much risk from the intervention. The wishes of the patient and the course of the disease process must be completely understood by physician and patient.
5. Extubation failure. This might occur after a brief course of intubation for COPD or pulmonary edema in a rural practice. CPAP might ease this transition, but there must always be a fallback plan for reintubation.
6. Asthma. Although there are some reports of benefit, opinions are conflicting, and CPAP is not recommended.
7. Other causes of respiratory failure (acute respiratory distress syndrome, trauma). Little consistent benefit has been reported.

Some of the criteria for respiratory failure must be met, including symptoms, signs and physiologic parameters:

- respiratory distress
- tachypnoea (respiratory rate > 24–30 breaths/min was used in various studies)
- use of accessory muscles or abdominal paradoxical movement
- pH less than 7.35
- partial pressure of carbon dioxide greater than 5.9 kPa (45 mm Hg)
- partial pressure of oxygen less than 12 kPa (90 mm Hg) on maximal concentration fraction of inspired oxygen
- chest radiography may be useful in diagnosis, but is not sensitive enough to aid in decision-making. Changes due to acute pulmonary edema may take many hours to appear

CONTRAINDICATIONS

- medical instability with immediate need for intubation
- respiratory or cardiac arrest
- pneumothorax must always be excluded unless a chest tube is in place
- patient is unable to protect the airway
- vomiting or excessive secretions. The use of morphine is best avoided in pulmonary edema for this reason and others. Use benzodiazepines if sedation is needed
- agitated or uncooperative patient
- unable to achieve mask seal because of facial contour
- recent upper airway or upper abdominal surgery
- hypovolemia
- hypotension with systolic pressure less than 90 mm Hg
- conditions that are preload dependent, such as right ventricular infarction. Like nitroglycerin, CPAP will impair right ventricular filling
- intracranial hemorrhage or increased intracranial pressure
- respiratory muscle fatigue
- patient is younger than 12 years

COMPLICATIONS

- pain or ulcer over the nasal bridge
- mucosal dryness
- fear that the device is limiting the patient's ability to breathe
- eye irritation if the mask seal is not complete
- aspiration or gastric insufflation (rare)
- pneumothorax (very rare)

EQUIPMENT

Traditional ventilators are difficult to set up when used only occasionally. If CPAP is helpful in stabilizing the patient for transport, it is very important not to discontinue the intervention suddenly. Also, a ventilator in a transport setting must be compact

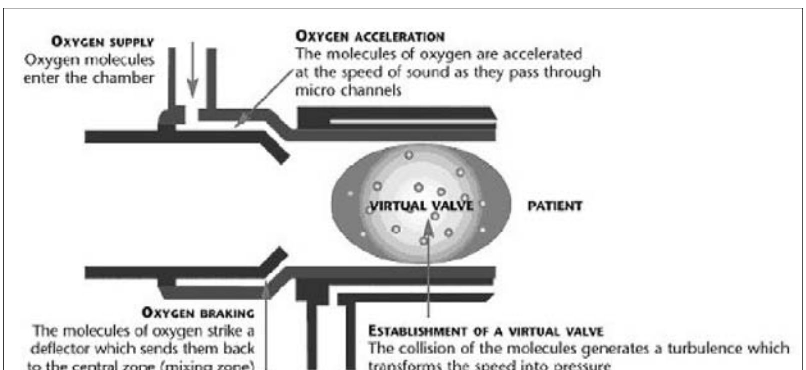

Fig. 1. Structure of the Boussignac valve.

and tends to use a lot of oxygen. A simple, compact option is preferable.

The Boussignac system is a device weighing 6.8 oz and requiring only an oxygen source with a regulator capable of delivering a flow of 25 L/min. It relies on the Bernoulli principle of gas acceleration creating a virtual valve (Fig. 1); therefore suctioning can be done through a port in the mask without loss of pressure or removal of the mask. This device has been deployed in a variety of settings including prehospital,[10] emergency department[11] and coronary care unit,[12] often with beneficial outcomes and minimal training.

The components of the system are as follows:

- sized mask, valve and tubing for connection to oxygen source (Fig. 2)
- oxygen port capable of 25 L/min with flow regulator
- optional pressure manometer (Fig. 3)
- optional nebulizer
- port for optional (but recommended) end-tidal carbon dioxide monitor

Fig. 2. Boussignac valve with attached mask.

Fig. 3. A single-use manometer can be attached in-line between the white end of the valve and the mask.

A 20-mL syringe is needed to inflate the cuff around the mask for optimal fit.

PROCEDURE

1. Select the mask size.
   - child — #3
   - female adult — #4–5
   - male adult — #5–6
2. Inflate the air cuff around the mask using 20–40 mL air. Have a 20-mL syringe available to subsequently facilitate an airtight seal to the patient's face.
3. Connect green tubing to oxygen source (Fig. 4 [1]).

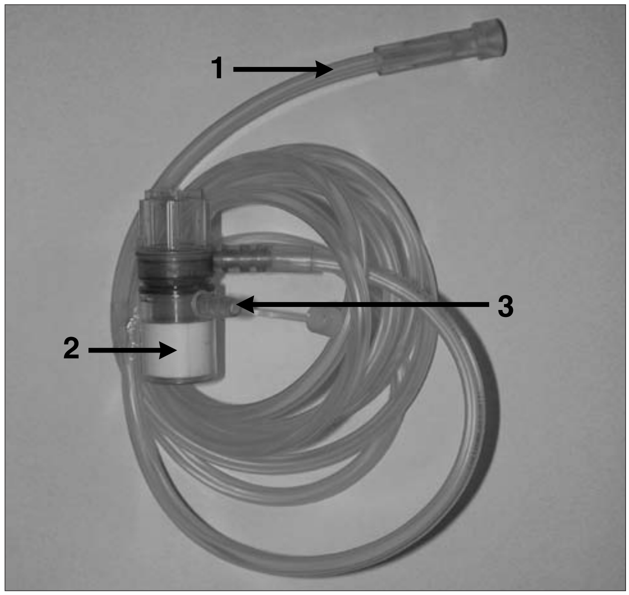

Fig. 4. The Boussignac valve with attached tubing. Green tubing attaches to oxygen regulator (1). Face mask attaches to white end of valve (2). Clear port for end-tidal carbon dioxide sensor (3).

Table 1. Oxygen flow rates to produce continuous positive airway pressure

Flow, L/min	CPAP, cm H_2O
10	2.5–3.0
15	4.5–5.0
20	7.0–8.0
25	8.5–10.0
> 25	> 10.0

CPAP = continuous positive airway pressure.

Table 2. Minutes of oxygen flow by cylinder size, based on 2200–pounds per square inch cylinders

Flow, L/min	D cylinder, EMS portable	E cylinder, EMS portable	M cylinder, EMS ambulances
10	35	61	374
25	14	23	140

EMS = emergency medical services.

4. Connect white end of the valve to the face mask (Fig. 4 [2]).
5. Connect the end-tidal carbon dioxide sensor, if used, to the clear port (Fig. 4 [3]). The transducer can also be slipped under the mask seal if this is preferred.
6. With the patient in the sitting position, hold the mask to the patient's face and begin oxygen at 15 L/min (CPAP of 5 cm H_2O) (Table 1, Table 2). Take time to explain the procedure to the patient.
7. Secure the harness around the head with straps above and below the ears. Check for leaks around

Fig. 5. System in place with head straps. Suction is used without loss of continuous positive airway pressure.

Fig. 6. Nebulizer placed between mask and white valve connection.

Table 3. Boussignac continuous positive airway pressure system. Fraction of inspired oxygen delivery with input of 100% oxygen*

CPAP setting and tidal volume		Ventilatory frequency, respiratory rate/min								
CPAP 5 cm H_2O		10	15	20	25	30	35	40	45	50
Tidal vol., mL	250	100	100	100	100	97	92	84	78	73
	500	100	100	93	83	71	65	60	56	53
	750	100	90	74	61	56	51	X	X	X
	1000	94	72	59	51	48	X	X	X	X
	1250	86	61	51	X	X	X	X	X	X
	1500	73	56	47	X	X	X	X	X	X
CPAP 7.5 cm H_2O		10	15	20	25	30	35	40	45	50
Tidal vol., mL	250	100	100	100	100	100	98	95	92	85
	500	100	100	93	84	75	67	65	61	60
	750	100	91	79	67	60	57	57	X	X
	1000	96	76	66	59	54	X	X	X	X
	1250	87	67	59	54	X	X	X	X	X
	1500	81	62	57	X	X	X	X	X	X
CPAP 10 cm H_2O		10	15	20	25	30	35	40	45	50
Tidal vol., mL	250	100	100	100	100	100	100	95	92	91
	500	100	100	97	90	82	76	72	66	53
	750	100	96	84	79	67	62	X	X	X
	1000	99	85	73	64	60	X	X	X	X
	1250	95	73	64	59	X	X	X	X	X
	1500	89	71	62	X	X	X	X	X	X

Adapted from Templier et al.[13]
CPAP = continuous positive airway pressure.
*Estimation of fraction of inspired oxygen (FiO_2): inspired oxygen concentration falls with increasing minute volume. As dyspnoea subsides and respiratory rate falls, FiO_2 rises. There is a small rise in FiO_2 with increasing levels of CPAP.

the mask and adjust the air seal as necessary.

8. Gradually increase oxygen flow to 25 L/min (CPAP of 10 cm H_2O) as tolerated (Table 1, Table 2).
9. Suction through the large end port of the mask as necessary (Fig. 5).
10. If the manometer is used, place it in-line between the valve and the mask (Fig. 3).
11. If a nebulizer is used, place it in-line between the valve and the mask (Fig. 6). Set the valve oxygen source at 15 L/min and the nebulizer source at 6 L/min.

SUBSEQUENT STEPS

1. Do not remove CPAP without a backup plan in case of deterioration — either resumption of CPAP or intubation.
2. Watch for gastric distention.
3. If nitroglycerine is required, use sublingual rather than spray.
4. Be aware of the actual fraction of inspired oxygen. This will vary with the respiratory rate and oxygen flow (Table 3[13]).
5. Look for results that indicate that the intervention is working:
   - reduced heart rate
   - reduced respiratory rate
   - reduced dyspnoea
   - blood pressure returning to normal (usually tends to be high in cardiogenic pulmonary edema)
   - increasing oxygen saturation
   - decreasing end-tidal carbon dioxide
   - improving mental status
6. If there is no improvement:
   - troubleshoot the equipment
   - check for pneumothorax
   - check for conditions that might reduce preload (hypovolemia, dehydration, nitroglycerine)
   - consider pulmonary embolism. One patient in 4 with a COPD exacerbation severe enough to warrant admission to hospital may have pulmonary embolism[14]
   - consider proceeding to intubation

CONCLUSION

Early deployment of CPAP therapy is important in acute exacerbations of COPD and in acute cardiogenic pulmonary edema, the 2 most common emergent indications for the procedure in rural practice. The single-use Boussignac device simplifies the procedure and facilitates early application, improving the prospect for successful outcomes.

Competing interests: None declared.

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