The Role of Biphasic Cuirass Ventilation in Acute Respiratory Failure

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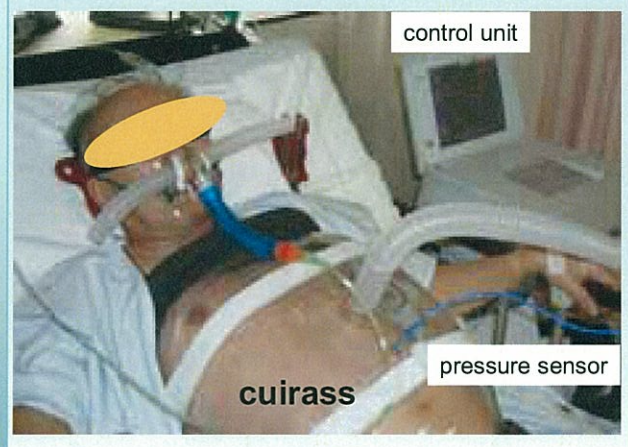
Abstract

Biphasic Cuirass Ventilation (BCV) is a non-invasive extrathoracic ventilator. It supports patient's inspiration by negative pressure as well as expiration by positive pressure. We retrospectively investigated the use of BCV for the patients with acute respiratory failure in the multidisciplinary ICU. From January 2005 to September 2006, 41 cases were ventilated with BCV. The causes for respiratory failure were hypoxemia due to atelectasis (15 cases), pneumonia (10), cardiogenic pulmonary edema (7), acute exacerbation of COPD (3), ALI (1), and miscellaneous (5). 13 patients (7 cardiogenic edema, 5 atelectasis, 1 ALI) recovered without other mechanical supports. 21 patients were received a combined mechanical support with conventional mechanical ventilation or NPPV. For combined therapy high frequency extrathoracic oscillation (600-800 cycles/min) was performed most frequently. An ARDS patient who had a history of sinusitis and a diaphragm nerve palsy suffered from ventilator-associated pneumonia. Bronchoscopic suctioning could not improve airway obstruction, but ipsilateral BCV and postural drainage could recruit the lung. For COPD patients BCV on continuous negative pressure mode helped to avoid intubation probably due to the decreases in WOB and dead space ventilation. BCV would be an alternative or supportive method for acute respiratory failure in the ICU.

Background

The role of BCV in respiratory care for the patients with acute respiratory failure is not clear.

BCV



Methods

- Retrospective investigation from Jan 2005 to Sep 2006.
- The number of patients, causes of respiratory failure, roles of BCV, outcome were investigated.
- Basic operating modes of BCV are;
  1. Continuous negative (CNP); -20-25cmH_2O, 60-120 min, 3-4 sets/day.
  2. Secretion clearance; -25cmH_2O, 600, 700, 800 cycle/min, 8min each, cough (I/E = 4.5/1) +5/-25cmH_2O, 2 min at the end of each vibration, 3 setsx2/day.
  3. Control; +5/-20-25cmH_2O, not synchronized.

Results

Causes of respiratory failure

Atelectasis (postoperative, medical)	15
Pneumonia	10
Acute cardiogenic pulmonary edema	7
Acute exacerbation of COPD	3
Acute lung injury	1
miscellaneous	5
Total	41

History of mechanical ventilation

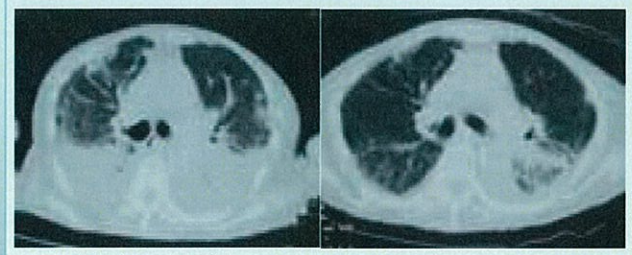
BCV alone;
ACPE 7, atelectasis 5, ALI 1

Combination with positive pressure ventilation;
conventional 23, NPPV 5

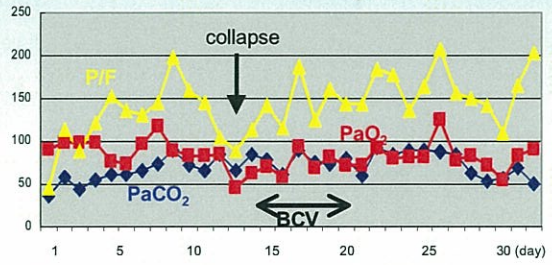
Roles of BCV in various diseases

1. Alveolar recruitment

Case: A 84 year-old woman was diagnosed ARDS caused by aspiration pneumonia. She was placed on APRV (Phigh= 26), then oxygenation was improved. PEEP was gradually decreased to wean, but massive lung collapse developed at 14 cmH_2O on Day 13. Recruitment maneuver (incremental step up of PEEP up to 45 cmH_2O) did not open the lung. We applied BCV and prone position on Day 14 and 15, and BCV alone until Day 20. Lung was successfully reopened by continuous negative pressure (CNP) and high frequency vibration (secretion clearance). Secretion clearance mode is often effective for postoperative segmental atelectasis.



Before BCV | 10 days later with BCV



- BCV worked supportive for lung recruitment.
- Extrathoracic negative pressure seems less hyperinflative to non-dependent lung area.
- Secretion clearance mode is often effective to prevent or treat postoperative atelectasis in patients with increased production of secretion.

2. Treatment of ACPE

Seven patients presented acute respiratory failure due to ACPE were treated with vasodilator, diuretics, and BCV. We could not apply NPPV to those patients because of mask intolerance. Oxygenation was improved in 3 – 7 hours after BCV was initiated.

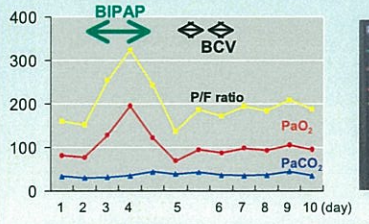
patient	PaO_2 (mmHg)		
	Pre-BCV*	Post-BCV*	%increase
1	96	108	13
2	79	97	23
3	91	112	23
4	95	106	12
5	96	123	28
6	143	172	20
7	68	93	37
Mean (SD)	95 (23)	116 (27)	22 (9)

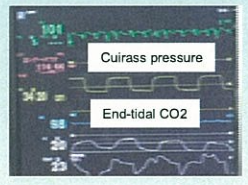
* FiO2 = 0.5 delivered by venturi type face mask.
Cuirass pressure of -20/+5 cmH_2O during inspiratory/expiratory phase was applied.

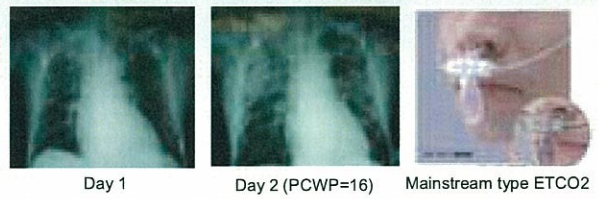
Extrathoracic negative pressure can increase transpulmonary pressure like NPPV does and counteract the elevated hydrostatic pressure. Theoretically, negative pressure would increase left ventricular (LV) wall tension, resulting in impeding LV ejection. Decreasing respiratory work load would be critical in the studied population.

3. Alternative therapy for NPPV; a case of ALI

Case: A 63-year-old man diagnosed pneumonia (bottom, left). Occult AMI was pointed out through further examination. Percutaneous coronary intervention was performed and admitted ICU. On day 2 ALI developed (bottom, center). Although NPPV (IPAP/EPAP=10/8 cm H_2O) increased PaO_2, infiltration unchanged and PaO_2 decreased again to the pretreatment level immediately after the cessation of NPPV. BCV was applied with – 20/+5 cmH_2O for 4 hours on day 5 and 6, then PaO_2 improved and infiltration disappeared.





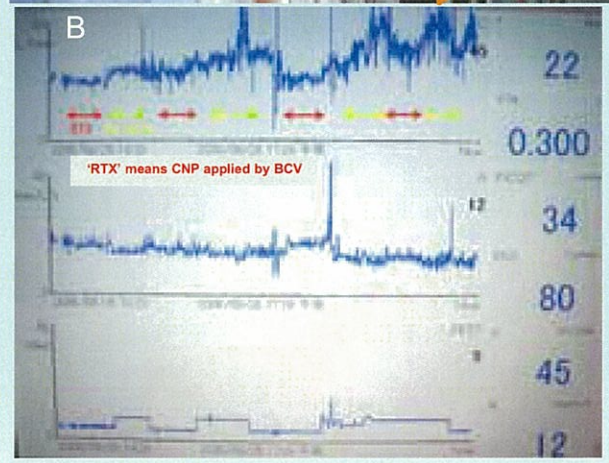


Day 1 | Day 2 (PCWP=16) | Mainstream type ETCO2

- The effect of BCV on oxygenation sustained longer, whereas NPPV was temporarily (top, left).
- We use mainstream type $ETCO_2$ (bottom, right) to get better synchrony of BCV to spontaneous breathing.

4. Improvement of lung compliance after acute exacerbation of chronic respiratory failure

Case: A 73 year-old lady with chronic respiratory failure admitted because of acute exacerbation and CO_2 narcosis ($PaCO_2$=140mHg). Five days later BGA improved but still too early to be weaned because of low lung compliance (23 ml/cmH_2O). We assessed thoracic gas volume need to be increased.



- CNP of – 25cmH_2O in combination with CPAP + ATC increased lung compliance over time and the effect sustained (B, top), resulting in early separation from ventilator.
- PEEP was decreased (5 cmH_2O) during CNP in order to avoid excessive alveolar overdistension. PEEP resumed to the baseline level (10 cmH_2O) after CNP (B, bottom).

Conclusion

The roles of BCV in the ICU were to increase thoracic gas volume and to recruit the lung. BCV would be an alternative or supportive method for acute respiratory failure in the ICU.