Conservative management of flail chest after cardiopulmonary resuscitation by continuous negative extrathoracic pressure

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ABSTRACT

Flail chest after blunt trauma usually requires good pain control and positive pressure support. Continuous negative extrathoracic pressure (CNEP) causes a splinting effect around the anterior chest wall and upper abdomen which increases functional residual capacity and improves lung mechanics. We report an 82-year-old woman with flail chest after cardiopulmonary resuscitation. She underwent mechanical ventilation, with two failed attempts at extubation. She was subsequently ventilated non-invasively using CNEP, allowing early successful extubation. This case illustrates the use of CNEP for weaning and ventilating patients with flail chest after blunt trauma.

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The cornerstones of management of respiratory failure after blunt chest trauma are adequate pain relief and support of the underlying lung.[1] Conservative (non-invasive) techniques using continuous positive airway pressure have been used.[1,2] However, the splinting effect of continuous negative extrathoracic pressure (CNEP) around the anterior chest wall and abdomen increases functional residual capacity and the pulmonary vascular bed. This may help prevent the pulmonary deterioration which is typical in patients with flail chest. The latest generation of cuirass ventilators can be applied easily and comfortably over the anterior chest and abdomen to create CNEP.[3] CNEP is akin to continuous positive airway pressure and can be set at any pressure around the baseline to increase functional residual capacity as required.[4] We document the successful application of this non-invasive form of ventilation in an elderly patient who sustained a large anterior flail chest from cardiopulmonary resuscitation by paramedics.

Clinical record

An 82-year-old woman was admitted to the intensive care unit with respiratory failure secondary to atelectasis and reduced functional residual capacity. This followed an anterior flail chest injury caused by vigorous cardiopulmonary resuscitation by paramedics after a cardiac arrest at her home. On recovery from the arrest, she was fully alert and aware of her condition, and tried to communicate with the attending doctors and nurses by signs while intubated and ventilated. Weaning trials resulted in a rapid shallow breathing pattern. A trial of T-piece weaning resulted in tachypnoea, desaturation and increased $PaCO_2$. Unplanned self-extubation resulted in similar respiratory decompensation, necessitating reintubation.

Thereafter, CNEP was begun using a cuirass ventilator (RTX Respirator, Medivent, London, UK) with a continuous negative pressure of –15 cmH_2O. Endotracheal extubation was successful a few minutes later. Thereafter, oxygen saturation was maintained at over 95% with nasally sampled end tidal CO_2 of 35 mmHg. The patient was able to speak, eat and drink. An additional benefit was that the cough mechanism and analgesia appeared more effective, because of the splinting effect of the CNEP on the anterior flail segment.

Discussion

The paradoxical movement of a flail segment of the chest wall becomes more problematic when it is accentuated by deterioration of pulmonary compliance and causes severe pain.[1] There is a fall in the functional residual capacity of the lung, an increase in airway resistance because of the smaller lung volumes, an increase in pulmonary vascular resistance, and deterioration in ventilation–perfusion ratios, causing hypoxia and further pulmonary vascular spasm. As pulmonary compliance deteriorates because of atelectasis or the development of pneumonic consolidation, intrapleural pressure swings, and the work of breathing increases.[1] The cornerstones of the management of fractured ribs, pulmonary injury and flail chest are good pain relief, prevention of atelectasis, and preservation of functional residual capacity and respiratory function.[1] This can be achieved with precise pain relief, such as thoracic epidural analgesia, and the early application of continuous positive airway pressure, thus reducing the need for intubation and positive pressure supported ventilation.[2]

When CNEP is correctly applied (Figure 1), it is akin to continuous positive airway pressure, and can be set at any pressure around the baseline to increase functional residual capacity as required.[4] CNEP supports functional residual capacity, increases the pulmonary vascular bed, and thereby also reduces afterload of the right ventricle and improves pulmonary circulation. Supplementary oxygen by nasal

Figure 1. Cuirass for applying continuous negative extrathoracic pressure ventilation

Cuirass placement around the anterior chest wall and abdomen allows easy application of continuous negative extrathoracic pressure.

cannula enhances oxygenation in well ventilated lung areas and reduces pulmonary vasospasm. Negative pressure applied extrathoracically to a patient who is already intubated and ventilated may allow a rapid reduction in the requirements for positive pressure support, and physiological improvements in oxygenation and cardiac output.[5] Hartke and Block reported the use of a temporary external chest shell to deliver CNEP to a patient with flail chest undergoing long-term ventilation. This stabilised the patient's anterior thoracic cage, with significant improvement in pulmonary function.[6] CNEP therefore enables weaning from positive pressure support, increasing spontaneously generated tidal volume, and reducing requirement for inspired oxygen.

The cuirass ventilator can also be used to enhance the clearing of airway secretions, by applying it in high-frequency biphasic oscillations followed by larger than normal inspiratory and expiratory excursions. This sequential procedure can be programmed into modern cuirass ventilators and applied at regular intervals as required. In a randomised, crossover comparative study of 20 patients with stabilised bronchiectasis, mechanical high-frequency oscillations were shown to be as effective as conventional chest physiotherapy, theoretically reducing the need for the latter treatment.[7]

Chari and colleagues reported on the use of cuirass ventilation in the resolution of left lower lobe collapse after oesophagectomy.[8] They found, after continuous positive airway pressure and routine interventional physiotherapy via tracheostomy failed to reinflate the lung, that application of the Medivent RTX cuirass ventilator in secretion clearance mode allowed reinflation of the lobe. This was followed by copious production of secretions, complete resolution of the atelectasis and pneumonia, and patient recovery.

An additional benefit of CNEP is that it allows patients to talk, eat and breathe freely around the mandatory negative pressure applied. It may also reduce the incidence of laryngeal injury and ventilator-associated complications. Patients can also then be moved to a step-down or intermediate-care facility, or even home, until they recover.

It is conceivable that, in the near future, small portable machines capable of providing continuous negative pressure will be available in primary care. It is interesting to note that biphasic extrathoracic pressure could theoretically replace both standard chest compression and mechanical ventilation in cardiopulmonary arrest.[9] If this had been used by the paramedics for resuscitating our patient, the flail chest injury might possibly have been avoided.

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