Abstracts from published studies

Relating primarily to:

I. Negative pressure ventilation:

Negative-pressure ventilation: is there still a role? A. Corrado, M. Gorini; Eur Respir J 2002; 20: 187-197.

Negative-pressure ventilation (NPV) was the primary mode of assisted ventilation for patients with acute respiratory failure until the Copenhagen polio epidemic in the 1950s, when, because there was insufficient equipment, it was necessary to ventilate patients continually by hand *via* an endotracheal tube. Thereafter, positive-pressure ventilation was used routinely. Since it was also observed that patients with obstructive sleep apnoea could be treated noninvasively with positive pressure *via* a nasal mask, noninvasive positive-pressure ventilation (NPPV) has become the most widely used noninvasive mode of ventilation.

However, NPV still has a role in the treatment of certain patients. In particular, it has been used to good effect in patients with severe respiratory acidosis or an impaired level of consciousness, patients that to date have been excluded from all prospective controlled trials of NPPV. NPV may be used in those who cannot tolerate a facial mask because of facial deformity, claustrophobia or excessive airway secretion.

NPV has also been used successfully in small children, and beneficial effects on the cardiopulmonary circulation may be a particular advantage in children undergoing complex cardiac reconstructive surgery.

This review is divided into two parts: the first s concerned with the use of negative-pressure ventilation in the shrt term, and the second with its use in the long term.

Effect of assist negative pressure ventilation by microprocessor based iron lung on breathing effort; M. Gorini, G. Villella, R. Ginanni, A. Augustynen, D. Tozzi, A. Corrado; Thorax 2002; 57: 258 – 262.

Background: The lack of patient triggering capability during negative pressure ventilation (NPV) may contribute to poor patient synchrony and induction of upper airway collapse. This study was undertaken to evaluate the performance of a microprocessor based iron lung capable of thermistor triggering.

Methods: The effects of NPV with thermistor triggering were studied in four normal subjects and six patients with an acute exacerbation of chronic obstructive pulmonary disease (COPD) by measuring: (1) the time delay (TDtr) between the onset of inspiratory airflow and the start of assisted breathing; (2) the pressure-time product (PTPdi) of the diaphragm; and (3) non-triggering inspiratory efforts (NonTrEf). In patients the effects of negative extrathoracic and end expiratory pressure (NEEP) added to NPV were also evaluated.

Results: With increasing trigger sensitivity the mean (SE) TDtr ranged from 0.29 (0.02) s to 0.21 (0.01) s (mean difference 0.08 s, 95% Cl 0.05 to 0.12) in normal subjects and from 0.30 (0.02) s to 0.21 (0.01) s (mean difference 0.09 s, 95% Cl 0.06 to 0.12) in patients with COPD; NonTrEf ranged from 8.2 (1.8)% to 1.2 (0.1)% of the total breaths in normal subjects and from 11.8 (2.2)% to 2.5 (0.4)% in atients with COPD. Compared with spontaneous breathing, PTPdi decreased significantly with NPV both in normal subjects and in patients with COPD. NEEP added t NPV resulted in a significant decrease in dynamic intrinsic PEEP, diaphragm effort exerted in the pre-trigger phase, and NonTrEf.

Conclusions: Microprocessor based iron lung capable of thermistor triggering was able to perform assist NPV with acceptable TDtr, significant unloading of the diaphragm, and a low rate of NonTrEf. NEEP added to NPV improved the synchrony between the patent and the ventilator.

Physiologic Effects of Negative Pressure Ventilation in Acute Exacerbation of Chronic Obstructive Pulmonary Disease; M. Gorini, A. Corrado, G. Villella, R. Ginanni, A. Augustynen, D. Tozzi; Am J Respir Crit Care Med 2001; 163: 1614-1618.

To assess the physiologic effects of continuous negative extrathoracic pressure (CNEP), negative pressure ventilation (NPV), and negative extrathoracic end-expiratory pressure (NEEP) added to NPV in patients with acute exacerbation of chronic obstructive pulmonary disease (COPD), we measured in seven patients ventilatory pattern, arterial blood gases, respiratory mechanics, and pressure-time product of the diaphragm (PTPdi) under four conditions: (1) spontaneous breathing (SB); (2) CNEP (-5 cm H_2O); (3) NPV; (4) NPV plus NEEP. CNEP and NPV were provided by a microprocessor-based iron lung capable of thermistor-triggering. Compared with SB, CNEP improved slightly but significantly $PaCO_2$ and pH, and decreased PTPdi (388 ± 59 versus 302 ± 43 cm $H_2O \cdot s$, respectively, $p < 0.05$) and dynamic intrinsic positive end-expiratory pressure (PEEPi) (4.6 ± 0.5 versus 2.1 ± 0.3 cm H_2O, respectively, $p < 0.001$). NPV increased minute ventilation (V_E), improved arterial blood gases, and decreased PTPdi to 34% of value during SB ($p < 0.001$). NEEP added to NPV further slightly decreased PTPdi and improved patient-ventilator interaction by reducing dynamic PEEPi and nontriggering inspiratory efforts. We conclude that CNEP and NPV, provided by microprocessor-based iron lung, are able to improve ventilatory pattern and arterial blood gases, and to unload inspiratory muscles in patients with acute exacerbation of COPD.

Non-invasive negative and positive pressure ventilation in the treatment of acute on chronic respiratory failure; M. Gorini, R. Ginanni, G. Villella, D. Tozzi, A. Augustynen, A. Corrado; Intensive Care Med 2004; 30: 875-881.

Objective: To investigate in clinical practice te role of non-invasive mechanical ventilation in the treatment of acute respiratory failure on chronic respiratory disorders.

Design: An 18 months prospective cohort study.

Setting: A specialized respiratory intensive care unit in a university-affiliated hospital.

Patients: A total of 258 consecutive patients with acute respiratory failure on chronic respiratory disorders.

Interventions: Criteria for starting non-invasive mechanical ventilation and for endotracheal intubation were predefined. Non-invasive mechanical ventilation was provided by positive pressure (NPPV) ventilators or iron lung (NPV).

Results: The main characteristics of patients (70% with chronic obstructive pulmonary disease) on admission were (mean, SD or median, 25^{th} – 75^{th} centiles): pH 7.29 (0.07), $PaCO_2$ 83 mm Hg (19), PaO_2/FiO_2 198 (77), APACHE II score 19 (15 -24). Among the 258 patients, 200 (77%) were treated exclusively with non-invasive mechanical ventilation (40% with NPV, 23% with NPPV, and 14% with the sequential use of both), and 35 (14%) with invasive ventilation. In patients in whom NPV or NPPV failed, the sequential use of the alternative non-invasive ventilatory technique allowed a significant reduction in the failure of non-invasive mechanical ventilation (from 23.4 to 8.8%, $p = 0.002$, and from 25.3 to 5%, $p = 0.0001$, respectively). In patients as a whole, the hospital mortality (21%) was lower than that estimated by APACHE II score (28%).

Conclusions: Using NPV and NPPV it was possible in clinical practice to avoid endotracheal intubation in the large majority of unselected patients with acute respiratory failure on chrnic respiratory disorders needing ventilatory support. The sequential use of both modalities may increase further the effectiveness of non-invasive mechanical ventilation.

Negative pressure ventilation *versus* conventional mechanical ventilation in the treatment of acute respiratory failure in COPD patients; A. Corrado, M. Gorini, R. Ginanni, C. Pelagatti, G. Villella, U. Buoncristiano, F. Guidi, E. Pagni, A. Peris, E. De Paola; Eur Respir J 1998; 12: 519-525.

This case-control study was aimed to evaluate the effectiveness of negative pressure ventilation (NPV) *versus* conventional mechanical ventilation (CMV) for the treatment of acute respiratory failure (ARF) in patients with chronic obstructive pulmonary disease (COPD) admitted to a respiratory intermediate intensive care unit (RIICU) and four general intensive care units (ICU).

Twenty-six COPD patients in ARF admitted in 1994-95 to RIICU and treated with NPV (cases) were matched according to age (± 5 yrs), sex, causes triggering ARF, Acute Physiology and Chronic Health Evaluation (APACHE) II score (± 5 points), pH (± 0.05) and arterial carbon dioxide tension ($PaCO_2$) on admission with 26 patients admitted to ICU and treated with CMV (controls). The primary end points of the study were inhospital death for both groups and the need for endotracheal intubation for cases. The secondary endpoints were length and complications of mechanical ventilation and length of hospital stay.

The effectiveness of matching was 91%. Mortality rate was 23% for cases and 27% for controls (NS), five cases needed endotracheal intubation, four of whom subsequently died. The duration of ventilation in survivors was significantly lower in cases than in controls, with a median of 16 h (range 2-111) *versus* 96 h (range 12-336) ($p < 0.02$), whereas the length of hospital stay was similar in the two groups, with a median of 12 days (range 2-47) for cases *vs* 12 days (range 3-43) (NS) for controls. No complications were observed in cases, whereas three controls developed infective complications.

These results suggest that negative pressure ventilation is as efficacious as conventional mechanical ventilation for the treatment of acute respiratory failure in patients with chronic obstructive pulmonary disease and that it is associated with a shorter duration of ventilation and a similar length of hospital stay compared with conventional mechanical ventilation.

Clinical Applications of Body Ventilators; N. S. Hill; Chest 1986; 90(6): 897-905.

Interest is increasing in providing ventilatory support in the home for patients with chronic respiratory failure, mainly with the use of positive pressure ventilation via a chronic tracheostomy. However, body ventilators that assist ventilation by applying intermittent negative or positive pressure to the thorax, abdomen, or airway without requiring an artificial airway, can offer distinct advantages for selected patients over systems requiring a permanent airway. These ventilators include the iron lung, portable lung (Portalung), pneumowrap, chest cuirass, pneumobelt, rocking bed, and positive pressure provided via a face or nose mask. They have successfully stabilized or reversed chronic hypercarbia when used intermittently in patients with slowly progressive chronic respiratory failure due to certain neuromuscular diseases and kyphoscoliosis. How they achieve this stabilization has not been clarified, but reversal of chronic respiratory muscle fatigue following periodic rest probably contributes. These ventilators are generally less effective than positive pressure ventilation through a tracheostomy and should be reserved for patients with relatively stable chronic respiratory failure and intact upper airways. However, they have the advantages of simpler operation and less expense, and they allow maintenance of a normal airway.

II. Continuous negative extrathoracic pressure:

Effects of continuous negative extrathoracic pressure versus positive end-expiratory pressure in acute lung injury patients; M. Borelli, A. Benini, T. Denkewitz, C. Acciaro, G. Foti, and A. Pesenti; Crit Care Med 1998; 26: 1025-1031.

Objective: To compare the effects of continuous negative extrathoracic pressure (CNEP) and positive end-expiratory pressure (PEEP) at the same level of transpulmonary pressure.

Design: Prospective analysis.

Setting: Medical intensive care unit of a university hospital.

Patients: Nine consecutive acute lung injury patients. Patients with cardiac failure and patients with chronic lung disease were excluded from the investigation.

Interventions: The patients were sedated and paralyzed while receiving mechanical ventilation and were studied in three different conditions: a) using a PEEP of 0 cm H_2O (zero end-expiratory pressure); b) using a PEEP of 15 cm H_2O; c) using CNEP. CNEP was applied to the thorax and the upper abdomen and its level was chosen to obtain a transpulmonary pressure similar to the one observed at a PEEP of 15 cm H_2O. All patients had an arterial catheter, a pulmonary artery catheter, and a thermistor-tip fiberoptic catheter for thermo-dye-dilution in the femoral artery. These catheters were connected to an integrated monitoring system. We also placed an esophageal catheter in each patient to detect esophageal pressure.

Measurements and Main Results: For each step, we assessed the hemodynamic variations by measuring the intravascular pressures (via a pulmonary artery catheter), transmural pressures (computed by subtracting esophageal pressure from intravascular pressure), and blood volumes (derived from the technique of double indicator). The application of CNEP of -20 ± 0.7 cm H_2O produced a venous admixture and PaO_2/FiO_2 improvement similar to that obtained with a PEEP of 15 cm H_2O. This procedure is associated with a higher cardiac index (5.5 ± 1.5 vs. 4.6 ± L/min/m²; $p < .05$) coupled with lower central venous pressure, pulmonary artery occlusion pressure, and higher transmural pressures and blood volume parameters.

Conclusions: In acute lung injury patients, a CNEP of -20 cm H_2O has the capability to obtain transpulmonary pressure and lung function improvement similar to a PEEP of 15 cm H_2O. CNEP differs from the positive pressure by increasing the venous return and the preload of the heart, and has no negative effects on cardiac performance.

Comparative evaluation of the haemodynamic effects of continuous negative external pressure (CNEP) and positive end-expiratory pressure (PEEP) in mechanically ventilated trauma patients; L. Torelli, G. Zoccali, M. Casarin, F. Dalla Zuanna, E. Lieta, G. Conti; Intensive Care Med (1995) 21: 67-70.

Objective: To compare the haemodynamic effects of identical values of continuous negative external pressure (CNEP) and positive end-expiratory pressure (PEEP) in a group of mechanically ventilated patients.

Setting: General ICU, Vicenza Hospital, Italy.

Patients: 15 consecutive patients, admitted after road accident trauma.

Methods: We compared the haemodynamic effects of ZEEP, 10 cm H_2O of PEEP, and 10 cm H_2O CNEP, applied in random order, in 15 head trauma patients under going controlled mechanical ventilation; 9 had associated thoracic trauma, while 6 did not have lung involvement. CNEP was obtained with a "poncho".

Results: We bserved a significant increase in CI during CNEP, compared with both ZEEP and PEEP 10 cm H_2O. Accordingly the oxygen delivery index significantly increased during CNEP, compared with PEEP 10 cm H_2O. Conversely, Q_s/Q_t decreased with CNEP, if compared with PEEP, both in patients with and without lung damage.

Conclusion: CNEP can significantly increase CI in mechanically ventilated patients in patients with and without associated lung damage.

Adult respiratory distress syndrome: Successful support with continuous negative extrathoracic pressure; A. H. Morris, C. G. Elliott; Crit Care Med 1985; 13(11): 989-90.

We describe the use of continuous negative extrathoracic pressure to treat successfully the adult respiratory distress syndrome in a 19 yr-old woman who resisted the application of positive airway pressure. Arterial hypoxemia was reversed with -26 cm H_20 of extrathoracic pressure, produced by a modified Emerson iron lung. Cerebral and renal functions were maintained, and barotrauma did not occur. The patient required continuous negative extrathoracic pressure for 9 days; 12 days after admission, she was discharged. This case indicates that negative extrathoracic pressure therapy can be an effective and safe alternative to positive airway pressure for the management of selected patients with adult respiratory distress syndrome.