Feico J. J. Halbertsma
Michiel Vaneker
Johannes G. van der Hoeven

Use of recruitment maneuvers during mechanical ventilation in pediatric and neonatal intensive care units in the Netherlands

Accepted: 5 February 2007
Published online: 13 March 2007
© Springer-Verlag 2007

Although the beneficial effects of recruitment maneuvers (RM) during conventional mechanical ventilation (CMV) are unclear and the incidence of adverse effects is unknown [1], RM seem to be widely employed. We investigated the use of RM in all Dutch pediatric ($n = 8$) and neonatal ($n = 10$) intensive care units. RM were defined as any intervention intended to increase the number of alveoli participating in ventilation.

The results of this survey reveal that 8/8 PICUs and 7/10 NICUs perform RM regularly, either manually using a balloon (PICU 100%, NICU 85%) or mechanically by using the ventilator (PICU 100%, NICU 57%). Ventilator RM modes can be divided into isolated PIP elevation (8%), sustained PEEP elevation (25%) and combined elevation (58%). Maximal applied pressures are substantially higher in PICUs than in NICUs: PEEP 28.3 ± 7.5 versus 9.2 ± 1.1 cm H₂O ($p = 0.004$), PIP 46.7 ± 12.1 versus 35.8 ± 4.9 cm H₂O ($p = 0.02$). Reported indications for RM are poor oxygenation (PICU 88%, NICU 85%), atelectasis (PICU 50%, NICU 43%), high FiO₂ (PICU 25%, NICU 43%), and status after PEEP loss (disconnection, endotracheal suctioning)

(PICU 80%, NICU 46%). Manual RM after PEEP loss is mostly done by nursing staff; mechanical recruitment maneuvers are exclusively performed by medical staff. Effects of RM are evaluated by TcSaO₂ (PICU 100%, NICU 100%), PaO₂ (PICU 25%, NICU 28%), pressure–volume loop/minute ventilation measurements (PICU 25%, NICU 28%), and chest X-rays (PICU 25%, NICU 71%). Adverse effects reported are blood pressure decrease and oxygen desaturation (PICU 50%, NICU 28%); no gross barotrauma (pneumothorax, pulmonary emphysema) has been reported.

These data show a diversity corresponding with numerous publications on RM with different strategies and inconsistent results which we recently reviewed extensively [1]. A combined PIP and PEEP elevation, as used by most centers, is theoretically the most effective mode, as recruitment and derecruitment are continuous processes throughout the ventilatory cycle, during which PIP recruits alveoli and PEEP maintains alveolar patency [2]. An isolated PIP increase – e.g. manual RM – carries the risk of alveolar overdistension and increased shear stress forces in non-stabilized alveoli, possibly leading to lung injury. Sustained elevation of PEEP level seems less injurious and increases pulmonary aeration in experimental studies [3]. Only after MV disconnection or endotracheal suctioning is temporary PIP increase rational, as it rapidly recruits collapsed alveoli [4] and repeated derecruitments are harmful [5].

Several studies indicate that in the late phase of respiratory failure RM rarely improve oxygenation. Interestingly, the phase of disease was not reported to influence RM indications.

The maximal reported RM pressures – significantly higher in PICUs than in NICUs – are similar to those applied in clinical studies [1]. The recruitment pressures needed to open alveoli depend on lung condition, being substantially higher in the diseased lung (up to 45 cmH₂O in ARDS) [6] than in healthy lungs, in which 25–30 cmH₂O – and in low-birth-weight infants probably less – is sufficient [7, 8]. Interestingly, use of pressure manometers on balloons varied substantially (PICU 12.5%, NICU 90%). The parameters used to evaluate the effect of RM, TcSaO₂ and PaO₂ reflect well the degree of intrapulmonary shunting caused by non-ventilated alveoli; minute ventilation and chest X-ray in CMV are less suitable.

The encountered adverse effects on hemodynamics are consistent with those reported in the literature [9, 10]. However, despite the absence of reported adverse effects on lung injury, and possible advantages of RM, a critical review of the literature regarding both short-term effects – oxygenation, hemodynamics – and long-term parameters – morbidity and lung injury – does not support the routine use of RM [1]. In a large clinical RM study ($n = 72$) a temporary clinically irrelevant increase in TcSaO₂ (1.7%) was found [11]. The Canadian Open Lung Ventilation pilot study, using thrice-daily sustained elevations of PEEP to 35 cmH₂O, was aborted as there was minimal improvement of oxygenation and serious adverse effects occurred [12].

Although the use of RM during conventional MV is apparently widespread and no marked adverse effects are encountered at the bedside, in our opinion RM should still be considered carefully in view of the lack of evidence.

References

- Halbertsma F, van der Hoeven JG (2005) Lung recruitment during mechanical positive pressure ventilation in the PICU: what can be learned from the literature. *Anaesthesia* 60:779–790
- Halter JM, Steinberg JM, Schiller HJ, DaSilva M, Gatto LA, Landas S, Nieman GF (2003) Positive end-expiratory pressure after a recruitment maneuver prevents both alveolar collapse and recruitment/derecruitment. *Am J Respir Crit Care Med* 167:1620–1626
- Dreyfuss D, Soler P, Basset G, Saumon G (1988) High inflation pressure pulmonary edema. Respective effects of high airway pressure, high tidal volume, and positive end-expiratory pressure. *Am Rev Respir Dis* 137:1159–1164
- Maggiore SM, Lellouche F, Pigeot J, Taille S, Deye N, Durrmeyer X, Richard JC, Mancebo J, Lemaire F, Brochard L (2003) Prevention of endotracheal suctioning-induced alveolar derecruitment in acute lung injury. *Am J Respir Crit Care Med* 167:1215–1224
- Suh GY, Koh Y, Chung MP, An CH, Kim H, Jang WY, Han J, Kwon OJ (2002) Repeated derecruitments accentuate lung injury during mechanical ventilation. *Crit Care Med* 30:1848–1853
- International Consensus Conferences in Intensive Care Medicine (1999) Ventilator-associated lung injury in ARDS. *Am J Respir Crit Care Med* 160:2118–2124
- Tusman G, Bohm SH, Vazquez de Anda GF, do Campo JL, Lachmann B (1999) 'Alveolar recruitment strategy' improves arterial oxygenation during general anaesthesia. *Br J Anaesth* 82:8–13
- Serafini G, Cornara G, Cavalloro F, Mori A, Dore R, Marraro G, Braschi A (1999) Pulmonary atelectasis during paediatric anaesthesia: CT scan evaluation and effect of positive endexpiratory pressure (PEEP). *Paediatr Anaesth* 9:225–228
- Nielsen J, Ostergaard M, Kjaergaard J, Tingleff J, Berthelsen PG, Nygard E, Larsson A (2005) Lung recruitment maneuver depresses central hemodynamics in patients following cardiac surgery. *Intensive Care Med* 31:1189–1194
- Odenstedt H, Lindgren S, Olegard C, Erlandsson K, Lethvall S, Aneman A, Stenqvist O, Lundin S (2005) Slow moderate pressure recruitment maneuver minimizes negative circulatory and lung mechanic side effects: evaluation of recruitment maneuvers using electric impedance tomography. *Intensive Care Med* 31:1706–1714
- Brower RG, Morris A, MacIntyre N, Matthay MA, Hayden D, Thompson T, Clemmer T, Lanken PN, Schoenfeld D, ARDS Clinical Trials Network, National Heart, Lung, Blood Institute, National Institutes of Health (2003) Effects of recruitment maneuvers in patients with acute lung injury and acute respiratory distress syndrome ventilated with high positive end-expiratory pressure. *Crit Care Med* 31:2592–2597
- Meade MO, Guyatt GM, Cook DJ (2002) Physiologic randomized pilot study of a lung recruitment study in acute lung injury. *Am J Respir Crit Care Med* 165:A683

F.J.J. Halbertsma (✉)

Maxima Medical Centre, Department of Neonatal and Pediatric Intensive Care, 5500 MB, 7777, Veldhoven, The Netherlands
e-mail: f.halbertsma@mmc.nl
Tel.: +31-40-8889350
Fax: +31-40-8889340

F.J.J. Halbertsma

University Medical Centre St. Radboud, Department of Pediatric Intensive Care, Nijmegen, The Netherlands

M. Vaneker

University Medical Centre St. Radboud, Department of Anesthesiology, Nijmegen, The Netherlands

J.G. van der Hoeven

University Medical Centre St. Radboud, Department of Intensive Care, Nijmegen, The Netherlands