Paediatric Respiratory Reviews 16 (2015) 127–132

Contents lists available at ScienceDirect

Paediatric Respiratory Reviews

Review

Paediatric lung recruitment: a review of the clinical evidence

Jacqui Jauncey-Cooke [a,c,*], Chris E. East [b], Fiona Bogossian [a]

[a] School of Nursing & Midwifery, The University of Queensland, Australia
[b] School of Nursing and Midwifery/Maternity Services, Monash University/Southern Health, Clayton, Victoria and the School of Nursing & Midwifery, The University of Queensland, Australia
[c] Paediatric Critical Care Research Group, PICU, Mater Children's Hospital, Brisbane, Australia

EDUCATIONAL AIMS

The reader will:

- Develop an understanding of the rationale for lung recruitment in mechanically ventilated paediatrics.
- Learn the various means of achieving and measuring lung recruitment.
- Be aware of the limitations of lung recruitment.

ARTICLE INFO

Keywords:
Paediatric
Mechanical ventilation
Lung recruitment
PEEP
Sustained inflation
VILI

SUMMARY

Lung recruitment is used as an adjunct to lung protective ventilation strategies. Lung recruitment is a brief, deliberate elevation of transpulmonary pressures beyond what is achieved during tidal ventilation levels. The aim of lung recruitment is to maximise the number of alveoli participating in gas exchange particularly in distal and dependant regions of the lung. This may improve oxygenation and end expiratory levels. Restoration of end expiratory levels and stabilisation of the alveoli may reduce the incidence of ventilator induced lung injury (VILI). Various methods of lung recruitment have been studied in adult and experimental populations. This review aims to establish the evidence for lung recruitment in the pediatric population.

INTRODUCTION

All mechanically ventilated paediatric patients are at risk of developing ventilator induced lung injury (VILI) and while mechanical ventilation may be lifesaving, a proportion of these children will acquire a degree of lung injury as a direct result of the ventilation strategies employed by the clinician [1]. Mechanical ventilation strategies are continuously evolving but never more so than following the American-European Consensus Conference, ARDSNet lung protective recommendations [2]. These lung protective ventilation strategies (LPVS) were developed post large, multi-site randomised trials in adults [2,3]. Low tidal volumes, adequate PEEP, minimal peak pressures and minimal FiO_2 are now considered standard practice [2,3]. These recommendations have been universally extrapolated to paediatrics, possibly due to the paucity of paediatric data. A retrospective cohort study by Halbertsma and colleagues in paediatrics did demonstrate a correlation between high tidal volume ventilation and a reduced oxygenation ratio (P/F) which is consistent with the findings of the ARDSNet study [4]. Ultimately, irrespective of how gently we treat the paediatric lung, iatrogenic harm still occurs [1].

Lung recruitment is considered an adjunct to LPVS and in part addresses the chronic derecruitment that occurs secondary to low tidal volume ventilation [5,6]. This chronic derecruitment coupled with the acute derecruitment that occurs with each circuit disconnection contributes to the incidence of VILI. This review aims to assess the evidence for lung recruitment in mechanically ventilated paediatrics.

A literature search was undertaken in 2014. Databases searched included Medline, Embase, Lilac, Central register for Cochrane reviews and Cinahl. The search yielded 70 abstracts. Following a review of the abstracts 8 relevant, paediatric papers were

* Corresponding author. Tel.: +61 418335634(moble)/7 3163 1143 2(work).
E-mail addresses: jcqjaun@aol.com, j.jaunceycooke@uqconnect.edu.au, jacqui.jauncey-cooke@mater.org.au (J. Jauncey-Cooke), eastc@unimelb.edu.au (C.E. East), f.bogossian@uq.edu.au (F. Bogossian).

http://dx.doi.org/10.1016/j.prrv.2014.02.003
1526-0542/

Table 1
Paediatric studies of lung recruitment

	Subjects	Method of recruitment	Outcome measures	Results
Boriosi et al. 2011 [15]	Age *yrs* 4.8 (1-14) ALI/ARDS n=21	Established Cdyn Incremental and decremental PEEP via ventilator (Servo-I) in Assist Control/Pressure Control mode using Open Lung Tool (OLT)	PaO_2 $PaCO_2$	-Improved P/F ratio for up to 12 hours post recruitment -Nil adverse events
Boriosi et al. 2012 [16]	Age *yrs* 2.5 (0.5-14) Nested study of ALI patients from their 2011 study n=6	Established Cdyn Incremental and decremental PEEP via ventilator (Servo-I) in Assist Control/Pressure Control mode using Open Lung Tool (OLT)	End expiratory lung (EEL) levels as measured by Computed Tomography (CT) scan Oxygenation	-Increase in EEL post RM 3%-72% median 20% (IQR 6, 47) -Reduction in PIP post RM by -14% (IQR -18, -12) -Improved P/F ratios
Duff et al. 2007 [17]	Age *months* 16 (11days to 14 years) Lung disease status: from healthy lungs through to ARDS n=32	SI of 30-40cmH_2O for 15-20secs post circuit interruption, suctioning, hypoxia or routinely every 12hours	Oxygenation as measured by P/F or S/F ratios Haemodynamic markers Safety	-Improved oxygenation post recruitment for up to 4 hours -Safe in children -Spikes in ICP in some children
Halbertsma et al. 2010 [66]	Age *months* 0.5-4.5 n= 7	Single recruitment manoeuvre – incremental increases in PIP and PEEP until transcutaneous SaO2 98%. Max PEEP 30cmH2O Max PIP 45cmH2O	Translocation of pulmonary cytokines Oxygenation Lung kinetics	-Plasma levels of cytokines increased post recruitment -No increase in$TcSaO_2$ noted in 5/7 patients -haemodynamic compromise in 2/7 patients
Tusman 2003 [14]	Age *months* 6-72 Children undergoing scheduled cranial MRI n=24	Manual SI to 40cmH_2O + PEEP of 15cmH_2O for 10 breaths Compared to 5 cm H2O of PEEP alone and zero PEEP	% of atelectic regions as measured by MRI	- Children in the recruitment group had significantly less atelectic regions compared to those managed with PEEP alone or zero PEEP
Marcus et al. 2002 [13]	Age < 24 *months* Children undergoing scheduled general anaesthesia n=20	Timed re-expansion inspiratory manoeuvre = 30cmH2O CPAP for 10 seconds	Dynamic compliance Airway resistance	-TRIM maneuver resulted in improved dynamic compliance -Airway resistance changes insignificant
Morrow et al. 2007 [36]	Age *yrs* <1 n=48	SI up to 30cmH2O for 30 seconds using an anaesthetic bagging circuit post ETT suctioning	Dynamic compliance Oxygenation	Nil difference between experimental and control groups in terms of oxygen saturations or dynamic compliance
Wolf et al. 2012 [18]	Age *yrs* 9.9 ± 4.2 ALI n=10	Sustained inflation to 40cmH2O for 40 secs using CPAP mode followed by a stepwise RM, escalating plateau pressures by 5cmH2O every 15mins	Regional atelectasis, lung compliance and regional overdistension as measured by EIT	-small decrease in reversible atelectasis post SI RM -physiological lung recruitment achieved in responders during the stepwise manoeuvre -lung overdistension proximally

identified. The paediatric literature is referred to in the first instance. In the absence of paediatric literature, adult and experimental literature is considered.

WHAT IS LUNG RECRUITMENT?

Lung recruitment is a deliberate strategy to increase transpulmonary pressure; to maximise the number of alveoli participating in gas exchange [7]. The aim of lung recruitment is to recruit all recruitable alveoli and minimize atelectic regions of the lung. It can be achieved by either a sustained inflation (SI) or by briefly increasing positive end-expiratory pressure (PEEP). These methods aim to overcome alveolar threshold opening pressures and/or overcome alveolar threshold closing pressures. Table 1 lists the current evidence of lung recruitment in paediatrics.

WHOSE LUNGS DO YOU RECRUIT?

The process of lung recruitment is applicable to mechanically ventilated children and those undergoing general anaesthesia. Studies have been undertaken in both of these populations. Children, because of developmental differences may benefit most from lung recruitment; physiologically immature lungs differ significantly from adult lungs. At term, neonatal lungs possess only 25% of their alveolar potential with a rapid increase in number in the first two years of life and the interalveolar connections of Kohn's pores are absent [8,9]. Diaphragmatic muscle fibre fatigue is rapidly acquired as only 25% of muscle fibres are the fatigue resistant Type I – slow twitch fibres, compared to 50% at 8 months of age [9]. Additionally, the diaphragmatic angle is almost horizontal rendering it less efficient in terms of contractility and oxidative capacity [9]. By approximately two years of age, chest wall and lung compliance is similar to adults however, older infants and children continue to have a significantly smaller airway radius in proportion to their weight, less elastic retraction force, and a lower relaxation volume [10–12]. These factors all combine to predispose infants and children to atelectasis and hence an increased risk of VILI. Subsequently these populations show potential to benefit most from lung recruitment. In terms of lung disease severity, which patients do you recruit? Using clinically