



## Iatrogenic pneumothorax in mechanically ventilated children: Incidence, risk factors and other outcomes



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### ARTICLE INFO

#### Article history:

Received 12 October 2014

Received in revised form

9 January 2015

Accepted 10 January 2015

Available online 11 February 2015

#### Keywords:

Children

Iatrogenic pneumothorax

Mechanical ventilation

Pediatric intensive care unit

Quality improvement

### ABSTRACT

**Objectives:** Determine prevalence, risk factors and outcomes of iatrogenic pneumothoraces (IPs) in a pediatric intensive care unit (PICU).

**Methods:** Patients with IP (cases) and patients without IP (controls) were retrieved from a 5-year prospective cohort of 645 PICU patients who received mechanical ventilation (MV).

**Results:** Twenty cases and eighty controls were assessed. The overall prevalence of IP was 3%. Eleven IPs were procedure-related IP and 9 MV related. Performance of thoracic invasive procedures (odds ratio 11) was the significant IP predictor in the logistic regression analysis. IP incidence was higher within 12 hours. There were no differences between the groups concerning duration of MV, length of PICU and hospital stays. IP patients had a significantly higher mortality rate ( $p = 0.005$ ).

**Conclusions:** Performance of thoracic invasive procedures was strongly associated with IPs events in mechanically ventilated children. Many of these events may potentially be preventable with the implementation of quality improvement programs.

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### Introduction

Iatrogenic pneumothorax (IP) is a potentially life-threatening event as well as one of the main iatrogenic complications in intensive care unit (ICU) patients.<sup>1,2</sup> This event occurs predominantly as a complication of barotrauma related to mechanical ventilation or as a post-procedural event (e.g., after central venous catheter insertion, thoracentesis, or surgery) and, it has been associated to increases in ICU length of stay, resource use, and mortality.<sup>1,3–5</sup> Nevertheless, there are only a few studies in adult population describing the outcome and prognostic factors

associated with iatrogenic pneumothorax in ICU patients<sup>1,4,5</sup> and the available pediatric studies are limited to merely report the overall incidence of IP in children.<sup>3,6–8</sup> In addition, most studies of IP in adults were retrospective cohort and focused on a single category of IP.<sup>1</sup> Of note, there is a lack of pediatric studies addressing IP in a case-controlled approach or assessing its incidence and circumstances, or the outcomes after IP on mechanically ventilated children.

The aim of this study was to identify the prevalence and risk factors associated with the IP in critically ill children receiving mechanical ventilation. Secondly, we assessed the outcome of this event. We hypothesized that a high number of IP in PICU patients may be preventable, thus, identifying modifiable risk factors for complications is especially important to take preventive actions to minimize the incidence of these events.

### Methods

#### Study design

This was a matched case–control study comprising a five years period (from January 2009 through December 2013). This study was performed in an eight-bed PICU within a tertiary university–

**Abbreviations:** CVC, central venous catheter; IP, iatrogenic pneumothorax; MV, mechanical ventilation; PICU, pediatric intensive care unit; VAP, ventilator-associated pneumonia.

**Author contribution:** PSL da Silva – conception and design, analysis and interpretation of data, drafting of the manuscript, revision and final approval of the manuscript submitted. VE Aguiar – analysis and interpretation of data, drafting of the manuscript, revision and final approval of the manuscript submitted. MCM Fonseca – conception and design, analysis and interpretation of data, drafting of the manuscript, revision and final approval of the manuscript submitted.

**Conflict of interest:** The authors report no conflicts of interest.

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affiliated hospital. The Institutional Review Board approved the study and waived the need of informed consent.

Although we had no formal mechanical ventilation protocol for patients with Acute Lung Injury (ALI)/Acute Respiratory Distress Syndrome (ARDS), it is our institutional practice to use pressure-limited modes of ventilation, with a target peak inspiratory pressure (PIP) <35 cm H<sub>2</sub>O, ventilator rate (VR) < 35 bpm, and to allow permissive hypercapnia. We sought to adjust positive end expiratory pressure (PEEP) and FiO<sub>2</sub> to maintain SpO<sub>2</sub> between 88 and 95% or PaO<sub>2</sub> >60 mm Hg. Of note, we did not perform real-time ultrasound (US) guidance for central venous catheter (CVC) placement.

#### Human subjects

##### Inclusion criteria

All mechanically ventilated children, aged from 30 days to 16 years old from January 2009 to December 2013, were eligible for this study.

##### Exclusion criteria

Patients were excluded if (1) the pneumothorax was established before PICU admission and, (2) children had undergone any thoracic surgery.

##### Patient cases

Cases were defined as all consecutive patients who developed IPs while on mechanical ventilation during the study period. All patients were screened daily for IP throughout their PICU stay. The following criteria were necessary in order to diagnose pneumothorax: evidence of pneumothorax on chest radiographs; and air drained by thoracentesis or chest tube thoracostomy.

Pneumothorax was considered CVC-related (IP-CVC) when it occurred within 24 h after the insertion of a CVC either in the subclavian or jugular vein.<sup>9</sup> Also, it was considered procedure-related (IP-procedure) if it occurred within 8 h after the patient had undergone thoracentesis (IP-thoracentesis) or other procedures; otherwise, the cause of pneumothorax was considered to be barotrauma due to mechanical ventilation (IP-MV).<sup>4</sup> For the purpose of the study we defined invasive thoracic procedures as being thoracentesis, central venous catheter placement (jugular/subclavian vein), bronchoscopy, pericardiocentesis, and tracheostomy.

##### Patient controls

Controls were selected among the pool of patients on mechanical ventilation during the study period who did not experience IP during the study period. These patients were randomly selected using a random number generator algorithm in the proportion of 4 controls to 1 case. Control patients were matched according to three criteria: a) diagnosis category; b) patient age; and c) severity of illness as defined by PRISM II. Age was matched  $\pm 3$  months if the case patient's age was  $\leq 12$  months and  $\pm 12$  months if the case patient's age was  $> 12$  months. For their severity of illness patients were matched using PRISM II score  $\pm 3$ .

##### Data collection

The selection of cases and controls were made anonymously and the investigators were unaware of patients' outcomes. Data were registered in a structured data sheet and afterward the primary investigator transcribed them, with double entry, to a designed computer database. All attending physicians had more than 5 years of experience caring for critically ill children.

The following data were collected: patient characteristics at admission, admission diagnosis category; severity of illness at admission (Pediatric Risk of Mortality II<sup>10</sup> score and Pediatric Logistic Organ Dysfunction score<sup>11</sup>), the latest arterial oxygen tension/fractional inspired oxygen ratio (PaO<sub>2</sub>/FiO<sub>2</sub>) at admission, thoracic procedures performed before the occurrence of pneumothorax; total duration of mechanical ventilation, length of PICU and hospital stay, occurrence of ventilator associated-pneumonia (VAP), and death. VAP was defined in accordance with criteria established by the Centers for Disease Control (CDC) and Prevention and the National Nosocomial Infections Surveillance System (NNISS).<sup>12</sup>

#### Study variables and outcomes

The primary outcome variable for the analysis was the incidence of iatrogenic pneumothorax in mechanically ventilated children. The incidence of iatrogenic pneumothorax was calculated by dividing the number of iatrogenic pneumothorax (numerator) by the number of children on mechanical ventilation. We also assessed the risk factors for IP occurrence. Secondary measures included time on mechanical ventilation, length of PICU and hospital stay and mortality.

#### Statistical analysis

The sample size was not derived from statistical calculation but intended to include the largest possible proportion of patients who were exposed to the IP events (controls) and all those patients presenting IPs (case) during the planned study duration of 5 years. Therefore, in order to increase the precision and the statistical power<sup>13</sup> the random number generator algorithm used the proportion of 4 controls to 1 case, as the increase in precision is marginal when ratio of controls to cases is increased beyond 4:1.

Standard descriptive statistics were constructed using frequencies and proportions for categorical data elements and medians with interquartile ranges (IQR) for continuous variables. Categorical variables were compared using a chi-square analysis or Fisher's exact test when appropriate. Continuous data were compared using either a Student's *t*-test for normally distributed data or a Mann–Whitney *U* test for non-normally distributed data. A multivariate binary logistic regression model consisted of those variables that were considered clinically relevant for IP occurrence. Results were summarized by estimating odds ratios (OR) and respective 95% confidence intervals (CI). Statistical significance was determined a priori as a *p* value <0.05 (two-tailed). All statistics were performed using the commercially available software SPSS 16.0 for Windows (SPSS®, Chicago, IL, USA).

#### Results

During the study, there were 1515 PICU admissions. Of these, a total of 645 (42.5%) patients were mechanically ventilated (7951 ventilator days). Among these, 20 patients had pneumothorax while receiving mechanical ventilation (3% incidence rate). Invasive thoracic procedures were the most frequent IP cause affecting 11 (55%) patients. IP-CVC occurred in 9 patients, whereas IP-thoracentesis occurred in 2 patients, with a median time from VM to IP of 4.5 days, with a median time from MV initiation to the episode of IP due to procedures of 5 h (IQR, 3–7 h). IP was secondary to barotrauma during invasive ventilation (IP-MV) in 9 patients, with a median time from MV initiation to IP of 12 h [IQR, 5–15 h]. Seven of these patients had diagnosis of acute lung injury/

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