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Implementing a care bundle approach reduces ventilator-associated pneumonia and delays ventilator-associated tracheobronchitis in children: differences according to endotracheal or tracheostomy devices

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SUMMARY

Objective: To reduce ventilator-associated infections (VARI) and improve outcomes for children.
Methods: This prospective interventional cohort study was conducted in a paediatric intensive care unit (PICU) over three periods: pre-intervention, early post-intervention, and late post-intervention. These children were on mechanical ventilation (MV) for ≥48 h.
Results: Overall, 312 children (11.9% of whom underwent tracheostomy) and 6187 ventilator-days were assessed. There was a significant reduction in ventilator-associated pneumonia (VAP) among tracheostomized patients (8.16, 3.27, and 0.65 per 1000 tracheostomy ventilation-days before the intervention, after the general bundle implementation, and after the tracheostomy intervention, respectively). The median time from onset of MV to diagnosis of ventilator-associated tracheobronchitis (VAT) increased from 5.5 to 48 days in the late post-intervention period ($p = 0.004$), and was associated with a significant increase in median 28-day ventilator-free days and PICU-free days. Tracheostomy (odds ratio 7.44) and prolonged MV (odds ratio 2.75) were independent variables significantly associated with VARI. A trend towards a reduction in PICU mortality was observed, from 28.4% to 16.6% (relative risk 0.58).
Conclusions: The implementation of a care bundle to prevent VARI in children had a different impact on VAP and VAT, diminishing VAP rates and delaying VAT onset, resulting in reduced healthcare resource use. Tracheostomized children were at increased risk of VARI, but preventive measures had a greater impact on them.

1. Introduction

There has been growing interest in bringing down the rates of ventilator-associated pneumonia (VAP) by applying the successful multi-disciplinary approach for reducing central line-associated bloodstream infections in intensive care units (ICUs).[1,2] However, as noted by Shahin et al.,[3] most studies aimed at achieving a zero VAP rate have excluded high-risk patients such as immunocompromised patients, patients already treated with antibiotics, and patients on prolonged mechanical ventilation – even though the latter are the most resource-intensive recipients of critical care, and their morbidity and mortality rates are high.[4] Ventilator-associated tracheobronchitis (VAT) has also been independently associated with adverse outcomes and has been identified as an important source of PICU morbidity: it may in fact be more prevalent than VAP in children and is likely to be a clinically important nosocomial infection in its own right.[5,6] Muszynski et al. reported successful implementation of a care bundle to prevent VAT in a paediatric ICU (PICU).[7] However, it appears that the simultaneous impact of the implementation of a ventilator care bundle on VAP and VAT rates has not yet been assessed in children, including patients undergoing prolonged mechanical ventilation.

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Furthermore, the role of tracheostomy as a risk factor for VAP or VAT in children has not been assessed either, since tracheostomy for children admitted to the PICU is infrequent, related to previous prolonged mechanical ventilation at home or performed late following PICU admission, usually surgical.[8]

It was hypothesized that VAP and VAT are different. The primary objective of this study was to evaluate whether the implementation of a ventilator care bundle in the PICU could simultaneously reduce the incidence of VAP and VAT in critically ill children, including those on prolonged mechanical ventilation. The primary outcome was the reduction in VAP and VAT rates, taking into account the two airway devices (endotracheal and tracheostomy tubes); the secondary outcome measures were ventilator-free days, PICU-free days, and PICU mortality.

2. Materials and methods

2.1. Study design and setting

A prospective, pre- and post-intervention cohort study was conducted in a 16-bed medical–surgical PICU of a 220-bed tertiary care paediatric hospital, which serves as a referral centre for transplant, burns, haemato-oncological, and immunocompromised children, admitting patients from 1 week to 16 years of age.

The study was divided into three periods: (1) the pre-intervention period (PI), from January 2010 to December 2010; (2) the early post-intervention period (EP), from January 2011 to December 2011; (3) the late post-intervention period (LP), from January 2012 to December 2012.

2.2. Data collection and definitions

All children admitted to the PICU who had received invasive mechanical ventilation (MV) for 48 h or longer were included. There were no exclusion criteria. Cases of VAP or VAT were recorded according to the US Centers for Disease Control and Prevention (CDC) criteria.[9,10] In brief, VAP was defined as the presence of a new or progressive and persistent pulmonary infiltrate, consolidation, or cavitation (or pneumatoceles in those aged ≤1 year) and at least three of the following, in a patient under MV for ≥48 h:[9] (1) temperature >38 °C or <36.5 °C with no other recognized cause; (2) leukocyte count $\geq 12 \times 10^9$/l (15×10^9/l for ≤12 years old) or $<4 \times 10^9$/l ; (3) new onset of purulent tracheal secretions or change in character of sputum, or increased respiratory secretions or increased suctioning requirements; (4) new onset or worsening cough, or dyspnoea, apnoea, or tachypnoea; (5) wheezing, rales, or bronchial breath sounds; (6) worsening gas exchange, increased oxygen requirements, or increased ventilator demand (mandatory point for infants ≤1 year old); and (7) bradycardia (<100 beats/min) or tachycardia (>170 beats/min) (only for infants ≤1 year old). The diagnosis of VAP was considered to be laboratory-confirmed if either bronchoalveolar lavage or endotracheal aspirate cultures presented significant growth ($>10^4$ CFU or $>10^5$ CFU, respectively). VAT was defined on the basis of the absence of clinical and radiographic evidence of pneumonia, the presence of a positive culture obtained by deep tracheal aspirate, and at least two of the following signs in a patient under MV for ≥48 h:[9] fever >38 °C, cough, new or increased purulent tracheal secretions, rhonchi, and wheezing (and/or respiratory distress, apnoea, or bradycardia in infants ≤1 year old). Ventilator-associated respiratory infection (VARI) included VAP and VAT cases, as defined elsewhere.[11] The incidence rates of VAP, VAT, and VARI were expressed as the cases of VAP, VAT, and VARI per 1000 ventilator-days. Tracheostomy and endotracheal VAP, VAT, and VARI incidence rates were also calculated, defined as cases of VAP, VAT, and VARI per 1000 tracheostomy-days on MV (tracheostomy ventilator-days) or endotracheal tube ventilator-days, respectively.

Clinical and demographic information, including the Paediatric Logistic Organ Dysfunction (PELOD) score,[12] duration of MV, length of stay, ventilator- and PICU-free days, and mortality were recorded. Prolonged mechanical ventilation (PMV) was defined as the need for ≥21 consecutive days of MV for ≥6 h per day.[13]

This study was performed as part of the surveillance programme for the prevention and control of nosocomial infections at the authors' centre. The need for individual informed consent is waived for the practice of surveillance, prevention, and infection control activities. The study was conducted in accordance with the principles of the Declaration of Helsinki. Data for each study subject were entered into a research database without patient identifiers for analysis. The study was reviewed and received ethical approval from the institutional review board.

2.3. Ventilator care bundle

A multidisciplinary team was convened to create a ventilator care bundle, which was implemented in January 2011. The ventilator care bundle consisted of five measures: (1) elevation of the patient's head from the bed to at least 30̊; (2) a structured oral care protocol, including oral care with chlorhexidine solution 0.12% every 6 h and tooth brushing with a standard toothpaste every 12 h; (3) use of cuffed endotracheal tubes when not contraindicated; (4) maintenance of tracheal tube/tracheostomy cuff pressure between 20 and 30 cmH_2O; and (5) circuit changes only if the circuit becomes soiled or damaged. In January 2012, a new tracheostomy care protocol was added. Intervals between tracheostomy tube changes increased from weekly to fortnightly, and stoma care and disinfection of the tracheostomy cannula were standardized.

All patients who underwent MV for >24 h received gastrointestinal bleeding prophylaxis. Selective digestive tract decontamination was not performed and patients did not routinely receive prophylactic antibiotics unless as surgical prophylaxis. An early, targeted antibiotic therapy for VAT was prescribed.

2.4. Educational intervention

All healthcare workers in the PICU attended an educational programme consisting of 2-h formal lectures, an educational handout, and an evaluation test before the lectures. Notices were periodically posted in the unit encouraging staff to continue applying the measures and giving feedback on the ventilator-associated infection rates. Surveys evaluating ICU staff knowledge of evidence-based guidelines for the prevention of VAP were administered twice during the study.

2.5. Statistical analysis

Descriptive data were recorded as frequencies and percentages for categorical variables. Continuous variables were expressed as the mean and standard deviation (SD) or median and interquartile range (IQR), depending on whether the data were normally or non-normally distributed. The incidence of overall VAP, VAT, and VARI was calculated as the number of cases of VAP, VAT, and VARI per 1000 ventilator-days, either through tracheostomy or endotracheal tube. The incidence of tracheostomy VAP, VAT, and VARI was calculated as the number of cases of VAP, VAT, and VARI per 1000 tracheostomy ventilator-days. Ventilator-free days and PICU free-days at 28, 60, and 90 days were also calculated. All patients who died in the PICU had zero PICU-free days and zero ventilator-free days. Patients who were discharged on positive pressure ventilation also had zero ventilator-free days. Patients with a