

Care Measures and Health Outcomes in a Pediatric Intensive Care Unit in Brazil

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Abstract

Introduction: In low- and middle-income countries, including Brazil, conditions that favor mortality in the PICU remain significant. Compared to developed countries, there is a shortage of skilled human resources, lower availability of technological resources, greater difficulty of access and a higher incidence of infections, including both those acquired prior to admission and those resulting from treatment and hospitalization (*i.e.*, healthcare-associated infections (HAIs)). HAIs in the PICU include ventilator-associated pneumonia and catheter-related bloodstream infections. Actions for the prevention of HAIs can minimize the occurrence of negative outcomes. **Materials and Methods:** This is an epidemiological study comparing admissions at the PICU of a high-complexity hospital in South Brazil over two three-year periods: 2012-2014 (before the measures were adopted) and 2015-2017 (after the measures). The care measures were adopted mainly at the beginning of 2015 and consisted of expansion of physical therapy care, adoption of care protocols, acquisition of new materials and equipment (transparent dressings for central catheters, high-tech mechanical ventilators and multiparametric monitors) and multidisciplinary team training. The frequency of the outcomes mortality, length of PICU stay, diagnosis of catheter-related bloodstream infection, need for and duration of ventilatory support and diagnosis of ventilator-associated pneumonia were compared between the two trienniums using logistic regression with adjustment for age in months and need of vasoactive drugs. **Results:** A total of 1140 admissions were analyzed (470 in the first triennium and 670 in the second), representing an increase in the admission rate of 42.6% after the adoption of the measures. After adjustments, significant reductions in the frequency of mortality (adjusted OR [adjOR] = 0.54; CI 95%: 0.34 - 0.84), length of PICU stay > 7 days (adjOR = 0.75; CI 95%: 0.57 - 0.97) and duration of ventilatory support > 7 days (adjOR = 0.54; CI 95%: 0.39 - 0.74) were observed. **Conclusion:** The results indicate

the benefits of care measures for children admitted to the PICU in terms of a reduction in adverse events and expansion of access.

Keywords

Pediatric Intensive Care Units, Outcomes Assessment, In-Hospital Mortality, Hospital Stay, Mechanical Ventilation, Catheter-Related Infections

1. Introduction

Pediatric intensive care units (PICUs) in Brazil were first regulated in the 1970s, shortly after the advent of units for the treatment of adults. Approximately 8% of the 452,755 hospital beds in the country are intended for patients in need of intensive care, and 10% of these intensive care beds are intended for the treatment of children between 0 and 14 years of age [1]. In the private sector, which consists of users with healthcare insurance and those who pay for their own treatment, there are 4.84 beds per 10,000 beneficiaries. For users of the Unified Health System (Sistema Único de Saúde—SUS), there are 1.04 beds per 10,000 inhabitants [1]. Therefore, there is greater difficulty accessing public hospital beds designated for intensive care, and it is important to improve care and access to those in need of public assistance.

Since the 1990s, there has been a reduction in mortality rates in Brazilian ICUs, both general and pediatric, due mainly to the acquisition of technologies and the improvement of human resources [2]. Despite the reduced mortality, there is still heterogeneity in the advances among the different macroregions of the country and between the public and private sectors. For example, the Southeast region has a concentration of 53.4% of all the available intensive care beds, while the North region has only 5% of the nation's beds [3]. This results in inequalities in access, the severity of patients at admission, the length of hospital stay, and the probability of survival for children admitted to the PICU [4] [5].

In low- and middle-income countries, including Brazil, conditions that favor mortality in the PICU remain significant. Compared to developed countries, there is a shortage of skilled human resources, lower availability of technological resources, greater difficulty of access [4] [5] and a higher incidence of infections, including both those acquired prior to admission and those resulting from treatment and hospitalization (*i.e.*, healthcare-associated infections (HAIs)). In Brazil, there is no information system that allows the monitoring of mortality or adverse events in the PICU, and most studies rely on manual data collection from medical records.

HAIs in the PICU include ventilator-associated pneumonia and catheter-related bloodstream infections [6] [7]. These infections are associated with longer hospital stays, increased hospital costs [8] and increased mortality [6] [9]. Actions for the prevention of HAIs, such as the implementation of care protocols, training of human resources, rational use of antimicrobial agents, standardiza-

tion of hand-washing techniques and monitoring of invasive devices such as orotracheal tubes and vascular and urinary catheters [7] [10], can minimize the occurrence of negative outcomes.

In this context, the present study aimed to analyze the impact of some care measures on the health outcomes of children admitted to the PICU of a high-complexity hospital in South Brazil. In this PICU, there was a high mortality rate (17.8%) in 2013, a situation that remained practically unchanged throughout 2014, when the mortality rate was 15.6%. Measures were adopted starting at the end of 2014, with the majority implemented at the beginning of 2015, and included, among others, technology acquisition, expansion, and training of the multidisciplinary team.

2. Material and Methods

2.1. Setting

This study was conducted at the PICU of a teaching and high-complexity public hospital in the state of Paraná, located in the South region of Brazil. In this region, which consists of three states, there are 6099 ICU beds, which represent 14.6% of the beds available in Brazil. The study hospital is a referral hospital in the state of Paraná for pediatric surgery and care for child victims of external injuries, including extensive burns. The PICU admits children from birth to age 14 and, in exceptional cases, children up to 17 years of age, with mixed causes of hospitalization. It has seven PICU beds out of a total of 36 in the city where it is located and 246 in the state of Paraná [1].

2.2. Care Measures

The measures adopted in the PICU began in October 2014 with training of the multidisciplinary team for the prevention of ventilator-associated pneumonia (VAP) based on guidelines from the Centers for Disease Control and Prevention (CDC) [11]. The team was trained on strategies for securing definitive airways and caring for the devices used to artificially ventilate patients. There was full adherence by the pediatric intensive care residents, the nursing and physical therapy staff, and approximately 30% of attending physicians.

Between March and April 2015, other measures were incorporated to minimize airway injuries and complications related to orotracheal intubation and to reduce the mechanical ventilation duration. A protocol was adopted for the orotracheal intubation of children, physical therapy care was increased from four to 15 hours per day, and four high-tech ventilation devices were acquired to replace limited-function ventilators with few therapeutic modes. In June of the same year, a protocol was adopted to standardize pulmonary mechanical ventilation discontinuation for the entire multidisciplinary team.

At the same time the new ventilators were introduced, six multiparameter monitors were acquired to evaluate vital signs, replacing those used previously, which were limited to monitoring only some of these signs. Thus, early detection

of clinical instability and timely treatment for complications became possible.

Additionally, in March 2015, a set of measures to reduce catheter-related bloodstream infections was introduced. Sterile transparent film dressings were acquired for the fixation of central vascular devices. Those responsible for catheter care received training that covered catheter insertion, maintenance and removal and defined the duties of each professional. The catheter dressing technique was standardized for better stabilization of the device and visualization of the insertion site to reduce the number of manipulations and the risk of infection. Protection of the dressings during bathing or hygiene was adopted as a standard measure to avoid contamination. In addition, a reference team was established for catheter placement in children treated at the institution.

2.3. Study Design and Population

This before-after epidemiological study compared admissions during two three-year periods: 2012 to 2014 (primarily prior to the measures) and 2015 to 2017 (after the measures were implemented, which mainly occurred at the beginning of this triennium). The study population comprised all children admitted to this PICU during the study period. The data were obtained from medical records and entered in an Excel[®] spreadsheet by the principal investigator. Admissions were observed until 31 December 2018, and those that extended beyond this date were excluded. To avoid confounding regarding the child's severity at the time of admission when comparing the two three-year periods, admissions that resulted in death within the first 48 hours of hospitalization were excluded.

2.4. Outcomes

The health outcomes analyzed were mortality, length of PICU stay greater than seven days, diagnosis of catheter-related bloodstream infection (CRBSI), need for ventilatory support, mechanical ventilation duration greater than seven days and diagnosis of ventilator-associated pneumonia (VAP).

The cutoff point of seven days for the length of hospital stay and duration of pulmonary mechanical ventilation was based on data from the literature [12]. For the diagnosis of VAP, the Clinical Pulmonary Infection Score, validated by the CDC, was considered [11]. Blood cultures were obtained by peripheral vein puncture and from the central catheter, with a maximum interval of 15 minutes between collections. CRBSI was diagnosed when there was microorganism growth in two blood cultures based on the following criteria: same etiological agent in both cultures, positive result first in the blood culture collected through the catheter and a minimum interval of two hours between the onset of growth of microorganism colonies.

2.5. Statistical Analysis

Data were tabulated using the Statistical Package for Social Sciences (SPSS) ver-

sion 19.0 (IBM Corp., Armonk, NY). Variables were compared between the two three-year periods using the Wilcoxon-Mann-Whitney test and binary logistic regression. All analyses were adjusted by child age (in months) and by vasoactive drugs use to control for differences in severity of cases admitted in the two periods. Crude odds ratios (ORs) and adjusted ORs (adjOR), along with 95% confidence intervals (95% CI) and p-values were reported. The level of significance was set at 5%.

2.6. Ethical Considerations

The study was part of a project approved by the institution's research ethics committee. Because the study was based on secondary data, informed consent was waived by this committee.

3. Results

From 2012 to 2017, there were 1172 admissions to the PICU. One admission was excluded because it extended beyond 31 December 2018. Thirty-one admissions (13 in the first triennium and 18 in the second triennium) were excluded due to death within the first 48 hours after hospitalization. A total of 1140 admissions were thus considered for analysis. In the first triennium (2012-2014), 470 admissions were recorded; in the second (2015-2017), 670 admissions were recorded, representing an increase of 42.6%.

The age of the study population ranged from 0 to 189 months, with medians of 11.5 months (interquartile range [IQR]: 1 - 57 months) and 9 months (IQR: 1 - 48 months), respectively, in the first and second trienniums and no significant difference between the periods ($p = 0.399$). Only two admissions were of patients older than 14 years (15 and 16 years old), and both occurred in the second triennium. The length of PICU stay ranged from 0 to 142 days, with medians of 5 days (IQR: 2 - 11 days) in the first triennium and 4 days (IQR: 2 - 9 days) in the second ($p = 0.004$).

Table 1 shows the analyzed outcomes in the first and second trienniums. All outcomes occurred less frequently in the admissions from 2015-2017. The observed reductions were statistically significant, with the exception of VAP. Mortality showed the most striking reduction (over 50%). After adjustments for age and use of vasoactive drugs, reductions remained statistically significant for mortality (adjusted OR [adjOR] = 0.54), length of stay greater than 7 days (adjOR = 0.75) and mechanical ventilation duration greater than seven days (adjOR = 0.54).

4. Discussion

This study compared health outcomes between two trienniums in a PICU in which the implementation of care measures and technology acquisition occurred mainly at the beginning of the second triennium. Except for ventilator-associated pneumonia, the frequency of all analyzed outcomes significantly declined in the

Table 1. Distribution of outcomes according to the triennium of admission to a pediatric intensive care unit in Paraná, Brazil.

Outcome	2012-2014		2015-2017		Unadjusted analysis		Adjusted analysis*		
	Out/Adm	%	Out/Adm	%	OR	95% CI	adjOR	95% CI	p
Mortality	57/470	12.1	41/670	6.1	0.47	0.31 - 0.72	0.54	0.34 - 0.84	0.007
Length of stay > 7 days	179/470	38.1	200/670	29.9	0.69	0.54 - 0.89	0.75	0.57 - 0.97	0.031
CRBSI	26/470	5.5	20/670	3.0	0.53	0.290 - 0.95	0.61	0.33 - 1.12	0.111
Need for PMV	303/470	64.5	389/670	58.1	0.76	0.598 - 0.97	0.85	0.65 - 1.12	0.238
PMV > 7 days	133/303	43.9	111/389	28.5	0.51	0.372 - 0.70	0.54	0.39 - 0.74	0.000
VAP	36/303	11.9	37/389	9.5	0.78	0.480 - 1.27	0.81	0.50 - 1.31	0.385

*Adjusted for age (months) and use of vasoactive drugs. CRBSI: Catheter-Related Bloodstream Infection. PMV: Pulmonary Mechanical Ventilation. VAP: Ventilator-Associated Pneumonia. Out/Adm: Outcomes/Admission. Numbers in bold: Statistically significant.

second triennium. However, after adjustments for age and use of vasoactive drugs, only mortality, length of PICU stay and time on mechanical ventilation remained statistically significant.

The adoption of a set of measures in the PICU does not allow the identification of which measures had the greatest impact on each analyzed outcome. However, the reduced duration of ventilatory support may be partially related to the expansion of physical therapy care at the studied unit. Physical therapy care contributes to greater success in weaning and discontinuation of mechanical ventilation, according to a study that showed that having two or more physiotherapy sessions was the main predictor of successful weaning [13]. Longer durations of physical therapy care provide more time for the application of resources such as maneuvers for pulmonary expansion, drainage of upper and lower airway secretions and changes in position that increase the speed of recovery of respiratory capacity.

Another measure adopted at the PICU under study, a protocol for extubation, may have contributed to the improved duration of the mechanical ventilation indicator. A pragmatic, multicentre clinical trial of 17 hospitals in the UK showed that among infants and children who required prolonged mechanical ventilation, a sedation and ventilator release protocol intervention demonstrated a statistically significant reduction in time to first successful extubation [14]. With the systematization of ventilator weaning, there is a lower incidence of orotracheal extubation failure, characterized as the need for reintubation within 48 hours after ventilator withdrawal [14]. Extubation failure is considered an adverse event capable of prolonging the duration of mechanical ventilation and hospital stays and is associated with a higher risk of death [15].

The document containing the Brazilian recommendations for mechanical ventilation describes strategies for the intubation of patients who require ventilatory support and maintenance and for the discontinuation of this intervention [16]. After the acquisition of the new devices, it was possible for the PICU under

study to adopt these recommendations; the devices allowed greater control of the supplemental oxygen supply and the amount of air administered in each respiratory cycle, better synchrony between the child and the ventilator, and a reduction of the deleterious effects of ventilatory support, which also may have contributed to the reduction in mechanical ventilation duration.

Although the rate of catheter-related bloodstream infection (CRBSI) declined from 5.5% to 3.0%, this decrease did not remain statistically significant after adjustments for age and use of vasoactive drugs, probably due to the high association between the need for vasoactive drugs and their administration via a central catheter. However, it is possible that the standardization of care of central vascular devices and the acquisition of new dressings may have played a role in this non-significant reduction. A study completed in 2019 demonstrated that central line care bundles are an effective solution to prevent fungus-related central line-associated bloodstream infections [17].

Proportionally fewer ventilator-associated pneumonia (VAP) events were diagnosed in the second triennium, but this difference was not statistically significant. Despite the training for the prevention of this complication in the last trimester of the first triennium, the low adherence to training by attending physicians may have reduced its potential impact. Another hypothesis is that with the increase in admissions observed in the second triennium, there was a proportional increase in intubated children in other hospitals or in other sectors of the study hospital, where the protocols used in the PICU were not applied. These results indicate the need for new studies to identify the causes of VAP and for new measures aimed at reducing this condition. A systematic review study showed a lower incidence of VAP when continuing education is provided for the nursing team on oral hygiene, care of ventilation devices, and lung-protective ventilator strategies [18]. Another study found a reduction in the incidence of VAP after the adoption of care measures such as headboard elevation (30°), oral hygiene, and control of the pressure inside tracheal tube cuffs [19].

It is believed that the significant reduction in mortality occurred because this event is intrinsically related to the other analyzed outcomes. Thus, a shorter PICU stays and mechanical ventilation duration reduce children's exposure to events such as colonization by multiresistant microorganisms, prolonged use of antimicrobials, airway trauma, pressure ulcers resulting from prolonged horizontal positioning, malnutrition and deprivation of family members and the home environment [9] [20] [21] [22] [23] [24], which consequently reduces mortality.

Some considerations regarding the methods used in this study should be highlighted. Data were collected manually, and the study was based on a limited amount of data. Despite the existence of a severity at admission score, no such score was recorded for most admissions over the study period, which precluded its inclusion in the adjusted analyses. In view of this specific limitation, analyses were adjusted by age and a marker of illness severity, *i.e.*, the need of vasoactive drugs. In addition, cases that resulted in death within 48 hours of admission

were excluded in both triennia to reduce the potential confounding effect of the severity of the child's state on the analyzed outcomes. Regarding the study design, the outcomes may be associated not only with the treatments or instituted care measures but also with patient characteristics or the reasons for hospitalization, which may have differed between the triennia.

5. Conclusions

The results indicate the benefits of certain care measures for children admitted to the PICU as a result of the adoption of protocols, the expansion and training of human resources or technological improvement. In addition to the reduced mortality, the reduced length of PICU stay allowed greater availability of beds for new admissions, represented by the more than 40% increase in the number of admissions in the second three-year period. The increased patient turnover represents public health gains by expanding access for children who require this level of care in the context of Brazil, where public PICU beds are still lacking [4] [5], thus contributing to the universality and integrality of care at this life stage.

Conflicts of Interest

The authors declare that they have no competing interest.

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