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ORIGINAL RESEARCH



# Evaluation of the use of telemedicine in pediatric intensive care units: a cluster-randomized trial

Gabriela de Oliveira Laguna Silva [a], Emanuele König Klever [a], Jacqueline Castro da Rocha [a], Mariana Motta Dias da Silva [b], Jerusa da Rosa de Amorim [a], Vanessa Cristina Jacovas [a], Bárbara Marina Simionato [a], Luciane Gomes da Cunha [a], Ana Paula Berni Zaupa [a], João Ronaldo Mafalda Krauzer [a], Aristóteles de Almeida Pires [a], Felipe Cezar Cabral [a], Taís de Campos Moreira [a] and Hilda Maria Rodrigues Moleda Constant [a]

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**ABSTRACT**

**Introduction:** Telemedicine has shown promising results, allowing specialists to provide rapid and effective care in remote locations. However, to our knowledge, current evidence is not robust enough to prove the effectiveness of this tool. This cluster-randomized trial (CRT) aimed to evaluate the impact of telemedicine on clinical care indicators in pediatric intensive care units (PICUs).
**Methods:** An open-label CRT was conducted in 16 PICUs within the Brazilian public health system. The trial took place from August 2022 to December 2023 and compared an intervention group, which received telemedicine support, with a control group, which received usual PICU care. The primary outcome was the PICU length of stay. The main secondary outcomes were mortality rate and ventilator-free days.
**Results:** A total of 1393 participants were included, 657 in the control group and 736 in the intervention group. The mean PICU length of stay was 10.42 (SD, 10.71) days for the control group and 11.52 (SD, 10.80) days for the intervention group. The overall mean of ventilator-free days was 6.82 (SD, 7.71) days. Regarding mortality, 7.54% of participants died in total. No significant difference was found in the outcomes between the groups.
**Conclusion:** Despite the potential benefits of telemedicine, its effective implementation in the Brazilian public health system faces considerable challenges, highlighting the continued importance of investigating and improving the role of telemedicine in pediatric critical care.
**Clinical trial registration:** ClinicalTrials.gov NCT05260710 and ReBEC – RBR-7×j4wyp.

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**KEYWORDS**
Telemedicine; intensive care units; pediatrics

## Introduction

Digital health is a tool that offers substantial benefits such as the ability to provide specialized care to patients in remote areas, reducing geographic barriers to increase access to health care, optimizing resource utilization, and improving the efficiency of health care delivery [1–3]. It also plays a crucial role in the continuing education of health professionals, allowing knowledge sharing and staff training in places with a shortage of specialists [4,5].

In intensive care units (ICUs), telemedicine-based models [6,7] use technology to deliver critical care through real-time digital platforms, overcoming the shortage of intensivists in these units [8]. This model of care is associated with improved mortality indicators [6–8], decreased health care costs [8], and increased satisfaction of both family members and health professionals with the use of telemedicine [9], and it can be used in adult, pediatric [10], and neonatal ICUs.

The literature points to the prospect of increased use of telemedicine in pediatric ICUs (PICUs) [11] due to the shortage of pediatric critical care physicians [12,13], enabling the delivery of critical care to this population and the possibility of sharing knowledge quickly and easily in underserved areas [14]. Although there are publications that address telemedicine in the PICU, the results remain inconsistent and require further investigation [8]. A prior pilot study conducted by the researchers of this study comparing pre- and post-telemedicine usage in two PICUs in Brazil demonstrated promising results in reducing mortality, which justified conducting this study with a robust methodology. Additionally, using telemedicine in PICUs appears to be an alternative for providing intensive care to children in need in countries like Brazil, with vast territories that are difficult for professionals to access and have limited resources for medical specialists. The use of telemedicine leads to more appropriate utilization of healthcare services, delivering higher-quality and comprehensive care, and promoting evidence-based practices [15].

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Therefore, this cluster-randomized trial (CRT) aimed to evaluate the impact of telemedicine on clinical care indicators in PICUs within the Brazilian public health system.

## Methods

An open-label CRT was conducted in PICUs with a 1:1 allocation ratio, where the hospitals are the clusters, to compare an intervention group (telemedicine support for patients admitted to the PICU) with a control group (usual PICU care). The CRT took place from August 2022 to December 2023 in 16 PICUs within the Brazilian Unified Health System (*Sistema Único de Saúde*, or SUS for short, in Portuguese), which is a government-funded universal health care system that includes provision of core physician and hospital services for any citizen without copayments or patient charges. The trial was conducted in accordance with resolution 466/12 of the Brazilian National Health Council after approval by the applicant institution's Research Ethics Committee (CAEE 53,762,221.31001.5330). The CRT followed the design and methodology outlined in the CONSORT 2010 Statement [16–18]. Before starting data collection, a Steering Committee, consisting of external members with research expertise, was created to ensure overall supervision of the study development and its implementation in accordance with the Good Clinical Practice Guidelines.

The CRT was conducted as part of the Qualification of Care by Telemedicine in the ICU (Tele-ICU) project, developed by a Brazilian center of excellence in partnership with the Brazilian Ministry of Health through the SUS Institutional Development Program (PROADI-SUS, for the acronym in Portuguese). The project uses telemedicine to offer multidisciplinary telerounds for distance education and analysis of clinical cases in remote ICUs, with the purpose of organizing care delivery, improving the quality of care provided, mitigating risks in hospitalized patients, and improving health care indicators in partner ICUs [19]. The CRT was registered at ClinicalTrials.gov, number NCT05260710, and at the Brazilian Registry of Clinical Trials (ReBEC), number RBR-7×j4wyp.

### *Eligibility criteria for PICUs (clusters)*

Participating centers were selected using a specific methodology [19]. The trial was conducted in 16 PICUs that provide care through the SUS. For standardization purposes, only level II ICUs were selected according to the Brazilian Ministry of Health classification, which categorizes ICUs according to the level of resources available for critical care (number of physicians, multidisciplinary team, and access to appropriate equipment and examinations) [20]. Furthermore, the ICUs should have no more than 10 beds, since the proposed methodology determines the provision of care to a maximum of 10 patients. The protocol for this CRT provides a more detailed description of the eligibility criteria for PICUs [18].

### *Eligibility criteria for participants*

Eligible participants were all pediatric patients aged ≥29 days and <18 years admitted to the selected PICUs who had a PICU length of stay >24 h or, in case of death, who had stayed in the PICU for at least 8 h. Patients were excluded if they had incomplete medical records or missing data on the institution's database, had PICU length of stay >90 days, had been included in the intervention group but did not receive care via telemedicine, or whose parents/guardians refused to participate in the study and/or did not sign the consent forms. Participants were allocated to the control or intervention group according to the cluster randomization of their respective hospitals.

### *Randomization*

Randomization to the intervention or control arm was performed with a 1:1 allocation ratio using random block sizes (2 and 4) and stratified by the number of PICU beds (≤10 and >10) and efficacy measures (mean length of stay of the units). We stratified patients using the number of PICU beds because Brazil is a very diverse country with varying hospital and ICU profiles, resulting in significant discrepancies in the number of beds across ICUs nationwide. Regarding the efficacy measure, we chose the mean length of stay because it was a more robust metric in the participating hospitals. Other indicators, such as mortality rate, were not standardized, robust, and well-organized. Randomization was performed consecutively based on each PICU's consent for entry into the trial, after approval by the research ethics committee. The allocation sequence was created using the R commander by a statistical consultant with no involvement in the trial to ensure allocation concealment.

### *Intervention*

The intervention group participated in telerounds from Monday to Friday, with the presence of specialists as needed, using a telemedicine cart that facilitated physicians' visualization and communication. The telerounds consisted of case discussions with remote pediatric intensivists and other specialty physicians available on demand to debate treatment strategies based on the best scientific evidence. The intensivists conducted consultations through specially prepared rooms for telemedicine, featuring sound isolation and high-resolution audio and video equipment. Case discussions involved remote pediatric intensivists, as well as specialists from other fields as needed, to evaluate evidence-based approaches. These bedside medical consultations were conducted to: (i) establish diagnosis, (ii) guide therapeutic management, and (iii) perform clinical follow-up. The intensivist or specialist connected daily with the teams at participating PICUs and discussed hospitalized patients, following a protocol developed by the project team to guide care. Each teleround lasted one hour with each participating center.

The physicians at the participating centers could decide to accept or reject the recommendations, subject to reevaluation in the next teleround, maintaining a horizontal care approach from the first day of hospitalization to patient discharge. Additionally, continuing education was made available to all care team members at the participating centers through distance education courses, video lectures, and discussions of complex cases with specialists invited by the project's medical care team. The activities have been previously described in detail by Silva et al. [18] and Jacovas et al.[19]

### Control

The control group received the usual in-person care provided by the PICU. Additionally, after the data collection period, the same continuing education activities as in the intervention group were made available to care team members in the control group.

### Data collection

Data were collected by the PICU's health professionals, who were trained by the project's team to enter the data in the Research Electronic Data Capture (REDCap®), an electronic data capture tool used for capturing, storing, and managing research data [21,22]. After training, all centers conducted a 15-day pilot collection to familiarize themselves with the platform and 15-day pilot telerounds to learn the dynamics of the intervention. At the end of the pilot data collection, the data began to be officially collected and monitored weekly by a researcher and a statistician from the project team, as described in detail by Silva et al.[18]

The auxological parameters considered to define ideal weight and low body weight in childhood were those established by the World Health Organization [23].

### Outcomes

The primary outcome was PICU length of stay, calculated as the difference between the discharge date and admission date. Secondary outcomes included mortality rate, number of ventilator-free days, duration of antibiotic therapy, duration of vasoactive therapy, and duration of sedation/analgesia. For this study, we expected to reduce ICU length of stay through telemedicine, lower mortality rates, and enhance other clinical indicators in the participating units of the intervention group.

### Sample size

The sample size was calculated using a method that considers the intra-cluster correlation previously described in detail by Silva et al coefficient (ICC), as detailed in the study protocol [18]. A total sample size of 1600 participants (100 participants in each participating center) was necessary to detect a difference of 2 days in PICU length of stay between the intervention and control groups, with a standard deviation of 6.24 days for the control group and 7.13 days for the intervention group (data resulting from the project's previous Tele-ICU activities), considering an ICC of 0.05, a power of 80%, and a 5% significance level. To this end, the study selected 16 PICUs, of which 8 were randomly allocated to the intervention group and 8 to the control group. However, because the project activities stopped earlier than planned, as requested by the study sponsor, the final sample included 1393 participants.

### Statistical analyses

Statistical analyses were conducted using both intention-to-treat and per-protocol methods. For the intention-to-treat analysis, all patients who met the eligibility criteria for both groups were considered. For the per-protocol analysis, patients in the intervention arm who did not fully complete the proposed teleround protocol were excluded.

Categorical variables were presented as absolute and relative frequencies, while continuous variables were assessed for normality and presented as mean and standard deviation (SD) or median and interquartile range (IQR), depending on their distribution. A noninferiority analysis for the primary outcome was conducted using generalized mixed models, considering the correlation of data within each ICU and adjusting for relevant variables. For secondary outcomes, correlated data models were used, considering the type of outcome evaluated. Sensitivity analyses were performed only for the primary outcome in the intervention group to assess the impact of adherence to telerounding on the length of stay. All statistical analyses were performed considering a significance level of 0.05. See the study protocol [18]. for more details on the analysis.

## Results

The intention-to-treat results are presented here because they provide a more comprehensive view of the results obtained.

### General characteristics of the sample

A total of 1822 records of patients admitted to PICUs were screened, 1393 of which met the inclusion criteria (Figure 1). The median patient age was 25.00 (IQR, 5.00–76.00) months, 57.00% were male and 68.75% self-identified as Brown. The median body weight was 11.60 (IQR, 6.30–20.00) kg. The most common reason for admission was clinical (83.70%), and the most common diagnosis was related to the International Classification of Diseases 10th Revision (ICD-10) Chapter X – Diseases of the respiratory system (51.62%) (Table 1).

### Analysis of primary and secondary outcomes

The outcomes were analyzed by intention to treat, considering all eligible participants evaluated within each hospital. The maximum PICU length of stay was 78 days for both groups, with a mean of 10.42 (SD, 10.71) days for the control group and 11.52 (SD, 10.80) days for the intervention group. The overall mean of ventilator-free days was 6.82 (SD, 7.71) days. Regarding mortality, 7.54% of participants died in total. No significant difference was found in the outcomes between the groups, even after adjustment for the following variables: study group (intervention and control), hospital of origin, age, low body weight, and Pediatric Index of Mortality 2 (PIM2) (Table 2).

The results of the analyses for both the primary and secondary outcomes, analyzed per protocol, are available in Table 1S and Table 2S of the Supplementary Material. However, they did not reveal significant differences. Other participants' clinical conditions

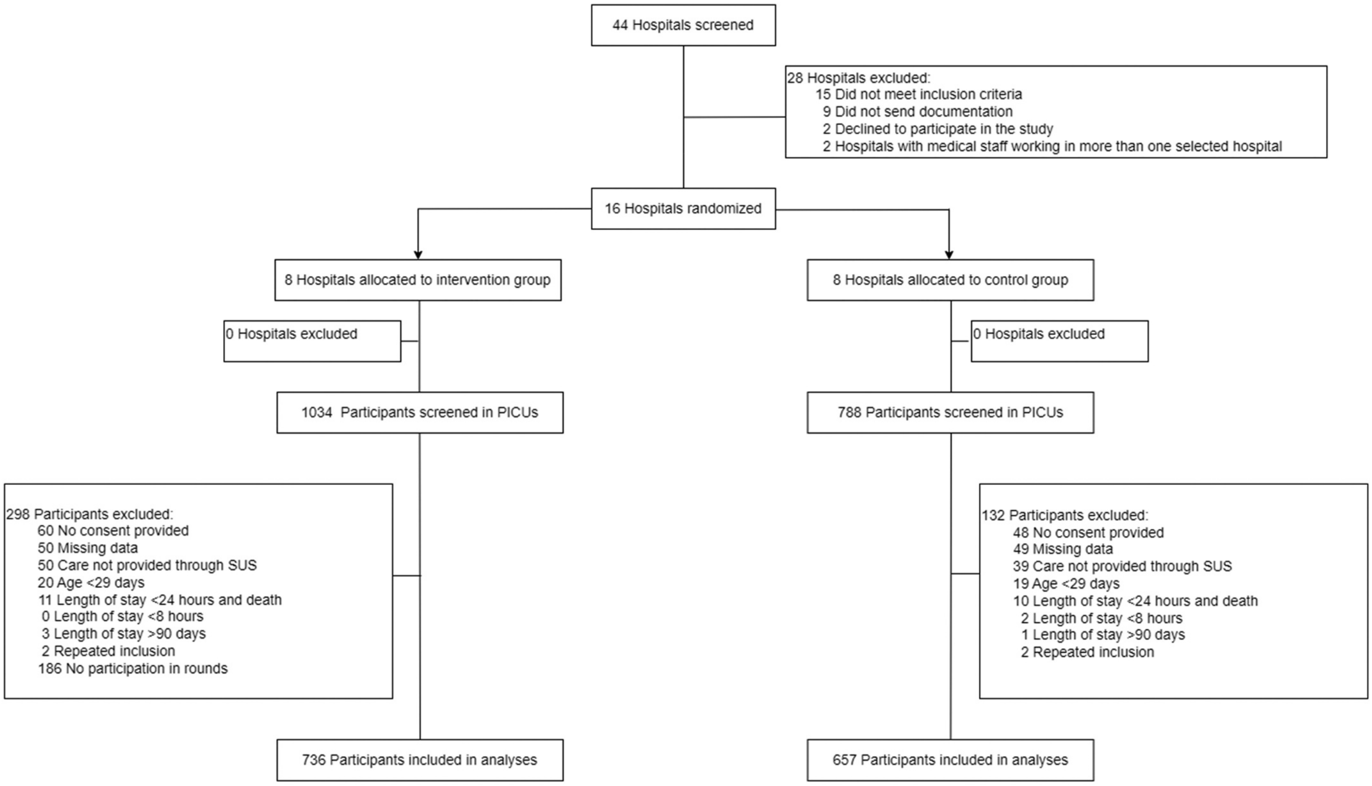


**Figure 1.** Study flowchart.

analyzed by intention to treat can be found in Table 3S of the Supplementary Material. To complement the analysis, a descriptive analysis was included in Table 4S of the Supplementary Material, dividing the disease groups and the length of stay between control and intervention groups to highlight the differences for this variable.

## Discussion

To our knowledge, this is the first randomized clinical trial to evaluate the use of telemedicine in clinical care indicators in PICUs within the SUS. Regarding PICU length of stay, ventilator-free days, and mortality, the results indicate no significant differences between the intervention and control groups. These findings are consistent with those of Lopez-Magallon et al. [24], who found no significant differences in length of stay and mortality when evaluating Colombian children with cardiopulmonary failure in PICUs. The use of telemedicine has great potential to improve processes, qualify patient care teams, and improve patient outcomes in critical care settings [8]. However, the purpose of this study was not to evaluate care team qualifications but rather to evaluate the clinical outcomes of these patients.

Our findings regarding PICU length of stay, although without statistically significant differences between the groups, suggest increased length of stay for patients allocated to the intervention group. This result agrees with the findings reported by Moynihan et al. [25], who suggested that length of stay can be increased with the use of telemedicine due to shared care. Conversely, prolonged hospitalizations may mean that early deaths have been avoided. In our study, a reduction in patients' PICU length of stay was expected. However, with shared care, there was a tendency toward an increase in length of stay, as new management options were offered, innovative treatments were tested, and techniques that required greater care and attention were employed, thus prolonging children's hospitalizations.

Regarding mortality, more deaths occurred in the intervention group, although without a significant difference between the groups. Alfraij et al. [26], in a study on telemedicine for antimicrobial use, also found no significant differences in mortality. In our study, we observed that patients in the intervention group had a higher PIM2 score, possibly due to the selection of more severe cases for discussion in the telerounds with intensivists and specialists. Although the guidance was that all patients in the unit should be cared for according to the proposed intervention, we assume that the logic of prioritizing care may have, at times, generated this selection. The hospitals selected to enter the study had a shortage of specialists. This difficulty in having specialists available for assistance may have led PICU staff to choose patients with greater severity to be discussed. Therefore, patients with more stable clinical conditions were not included in the project execution plan. Furthermore, the greater severity of the condition in the intervention group was supported by a larger number of participants requiring invasive ventilation, vasoactive drugs, sedation/analgesia, and antifungal agents. These factors may explain the higher number of deaths in this group.

Our findings demonstrate that the intervention group had more ventilator-free days than the control group, although this difference was not significant. These results are similar to those

Table 1. Sociodemographic and clinical characteristics of participants, overall and by arm.

| Variable | Total $N = 1393$ | Control $N = 657$ | Intervention $N = 736$ |
|---|---|---|---|
| **Age, months** median (IQR) | 25.00 (5.00-76.00) | 22.00 (5.00-68.00) | 29.00 (5.75-82.25) |
| **Age** n/N (%) | | | |
| <12 years | 1289/1393 (92.53) | 609/657 (92.69) | 680/736 (92.39) |
| ≥12 years | 104/1393 (7.47) | 48/657 (7.31) | 56/736 (7.61) |
| **Sex** n/N (%) | | | |
| Female | 599/1393 (43.00) | 279/657 (42.47) | 320/736 (43.48) |
| Male | 794/1393 (57.00) | 378/657 (57.53) | 416/736 (56.52) |
| **Self-identified ethnicity** n/N (%) | | | |
| White | 224/1393 (16.08) | 122/657 (18.57) | 102/736 (13.86) |
| Black | 58/1393 (4.16) | 10/657 (1.52) | 48/736 (6.52) |
| Brown | 957/1393 (68.70) | 396/657 (60.27) | 561/736 (76.22) |
| Yellow | 11/1393 (0.79) | 9/657 (1.37) | 2/736 (0.27) |
| Indigenous | 7/1393 (0.50) | 0/657 (0.00) | 7/736 (0.95) |
| Not reported | 136/1393 (9.76) | 120/657 (18.26) | 16/736 (2.17) |
| **Body weight** median (IQR) | 11.60 (6.30-20.00) | 11.00 (6.00-19.00) | 12.00 (6.55-22.00) |
| **Ideal body weight** n/N (%) | | | |
| Yes | 923/1393 (66.26) | 429/657 (65.30) | 494/736 (67.12) |
| No | 470/1393 (33.74) | 228/657 (34.70) | 242/736 (32.88) |
| **Low body weight** n/N (%) | | | |
| Yes | 381/1393 (27.35) | 189/657 (28.77) | 192/736 (26.09) |
| No | 1012/1393 (72.65) | 468/657 (71.23) | 544/736 (73.91) |
| **Reason for admission** n/N (%) | | | |
| Clinical | 1166/1393 (83.70) | 532/657 (80.97) | 634/736 (86.14) |
| Emergency surgery | 84/1393 (6.03) | 35/657 (5.33) | 49/736 (6.66) |
| Elective surgery | 136/1393 (9.76) | 88/657 (13.39) | 48/736 (6.52) |
| Other | 7/1393 (0.50) | 2/657 (0.30) | 5/736 (0.68) |
| **Origin** n/N (%) | | | |
| Emergency department | 330/1393 (23.69) | 143/657 (21.77) | 187/736 (25.41) |
| Surgical unit | 161/1393 (11.56) | 97/657 (14.76) | 64/736 (8.70) |
| Home | 13/1393 (0.93) | 6/657 (0.91) | 7/736 (0.95) |
| Inter-hospital transfer | 580/1393 (41.64) | 281/657 (42.77) | 299/736 (40.62) |
| Ward | 291/1393 (20.89) | 119/657 (18.11) | 172/736 (23.37) |
| Other | 18/1393 (1.29) | 11/657 (1.67) | 7/736 (0.95) |
| **Expected mortality risk – PIM2** | | | |
| Sum | 51.97 | 19.01 | 32.96 |
| Mean ± SD | 0.04 ± 0.08 | 0.03 ± 0.06 | 0.04 ± 0.10 |
| Median (IQR) | 0.01 (0.01-0.03) | 0.01 (0.01-0.03) | 0.01 (0.01-0.04) |
| **ICD on PICU admission** n/N (%) | | | |
| Respiratory diseases | 719/1393 (51.62) | 365/657 (55.56) | 354/736 (48.10) |
| Neurological diseases | 104/1393 (7.47) | 37/657 (5.63) | 67/736 (9.10) |
| Injury, poisoning and external causes | 85/1393 (6.10) | 15/657 (2.28) | 70/736 (9.51) |
| Infectious diseases | 77/1393 (5.53) | 27/657 (4.11) | 50/736 (6.79) |
| Diseases of the digestive system | 63/1393 (4.52) | 41/657 (6.24) | 22/736 (2.99) |
| Endocrine and metabolic diseases | 50/1393 (3.59) | 28/657 (4.26) | 22/736 (2.99) |
| Diseases of the blood | 45/1393 (3.23) | 19/657 (2.89) | 26/736 (3.53) |
| Diseases of the circulatory system | 26/1393 (1.87) | 12/657 (1.83) | 14/736 (1.90) |
| Neoplasms | 22/1393 (1.58) | 4/657 (0.61) | 18/736 (2.45) |
| Other [1] | 202/1393 (14.50) | 109/657 (16.59) | 93/736 (12.64) |
| **ICD at PICU discharge** n/N (%) | | | |
| Respiratory diseases | 698/1393 (50.11) | 365/657 (55.56) | 333/736 (45.24) |
| Neurological diseases | 107/1393 (7.68) | 35/657 (5.33) | 72/736 (9.78) |
| Infectious diseases | 95/1393 (6.82) | 32/657 (4.87) | 63/736 (8.56) |
| Injury, poisoning and external causes | 86/1393 (6.17) | 18/657 (2.74) | 68/736 (9.24) |
| Diseases of the digestive system | 61/1393 (4.38) | 38/657 (5.78) | 23/736 (3.12) |
| Diseases of the blood | 51/1393 (3.66) | 29/657 (4.41) | 22/736 (2.99) |
| Endocrine and metabolic diseases | 52/1393 (3.73) | 19/657 (2.89) | 33/736 (4.48) |
| Diseases of the circulatory system | 33/1393 (2.37) | 13/657 (1.98) | 20/736 (2.72) |
| Neoplasms | 26/1393 (1.87) | 6/657 (0.91) | 20/736 (2.72) |
| Other [1] | 184/1393 (13.21) | 102/657 (15.53) | 82/736 (11.14) |

Abbreviations: SD: standard deviation, IQR: interquartile range, PIM2: Pediatric Index of Mortality 2, ICD: International Classification of Diseases.

[a]Other: ICD belonging to the following chapters: Mental and behavioral disorders; Diseases of the eye; Diseases of the skin and subcutaneous tissue; Diseases of the musculoskeletal system and connective tissue; Diseases of the genitourinary system; Pregnancy, childbirth and the puerperium; Certain conditions originating in the perinatal period; Congenital malformations, deformations and chromosomal abnormalities; Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified; and Factors influencing health status and contact with health services.

reported by Watanabe et al. [13] also using telemedicine in critical care, highlighting the importance of intensivists to ensure appropriate decision-making regarding ventilation and other aspects of care, considering the lack of expertise from other specialties on ventilation settings, ventilator weaning, sedation, and early rehabilitation. This may be reflected in our findings, as we observed that the teams of the participating PICUs often did not have an intensivist. The vast majority of these teams consisted primarily of pediatricians without critical care expertise.

Table 2. Analysis of outcomes.[a,b]

| Outcome | Control $N = 657$ | Intervention $N = 736$ | MD/OR (95% CI) – Crude | MD/OR (95% CI) – Adjusted | Adjusted p-value |
|---|---|---|---|---|---|
| Length of stay | 10.42 ± 10.71 | 11.52 ± 10.80 | 1.18 (0.89-1.56) | 1.17 (0.88-1.54) | 0.280 |
| Ventilator-free days | 6.33 ± 7.60 | 7.25 ± 7.79 | 1.20 (0.87-1.65) | 1.23 (0.91-1.68) | 0.182 |
| Death | 36/657 (5.48) | 69/736 (9.38) | 1.93 (0.73-5.48) | 1.80 (0.77-4.17) | 0.174 |

Abbreviations: MD: Mean differences; OR: odds ratio; CI: confidence interval.
[a]Independent variables included in the adjusted model: study group (intervention and control), hospital of origin, age, low body weight, and Pediatric Index of Mortality 2.
[b]Continuous variables presented as mean ± SD, and discrete variables as n/N (%).

Our study has several limitations, including the difficulty in applying the PIM2. Despite training to apply the PIM2, most remote PICU teams were unfamiliar with this score. Many of these units did not routinely use the PIM2 score, which created difficulties in assessing the severity of patients' condition in the study. This issue has also been highlighted in previous studies, such as those by Arias Lopez et al. [27] and Mangia et al. [28], who pointed out the inadequate calibration of the PIM2 in Latin American countries. Mangia et al. [28] also highlighted that Brazilian ICUs present several discrepancies in human, technological, and economic factors compared with ICUs in high-income countries, where the PIM2 score was developed.

Another limitation concerns the selection of patients to be included in the study, which was determined by the PICU itself. We observed that the intervention group included more severe cases, intended for discussion with specialists, whereas the control group included less critical cases with a few days of hospitalization. This may have introduced bias in the comparison between the groups, affecting the generalization of the results, since this difference in the severity of the cases may interfere with the findings and the practical application of the proposed intervention. Additionally, the difference of 2 days in the length of stay has a considerable effect. However, to detect a smaller difference between the groups, a larger number of patients would be required. Despite the limitations observed in our study, using telemedicine in PICUs has numerous benefits. Knowledge sharing between medical teams, easier access to specialists, and improved clinical decision-making suggest a valuable role for telemedicine in optimizing pediatric critical care [29]. Chagas et al. [9] provide additional evidence of the potential of telemedicine in pediatrics, demonstrating a significant reduction in mortality rates and an increase in PICU length of stay.

From this perspective, we highlight positive results from the implementation of pediatric telemedicine in high-income countries [3]. However, similar studies, such as those by Lopez-Magallon et al. [24] in Colombia and Alfraij et al. [26] in Kuwait, point out the difficulty in achieving substantial results to improve clinical care indicators. This observation also applies to our results because of barriers encountered in Brazilian PICUS that provide care through the SUS. Telemedicine in Brazil faces considerable challenges, such as socioeconomic barriers, its integration into the health system, technological infrastructure, and health professional training [30]. Structural and logistic constraints (e.g. internet connection issues) and lack of resources (e.g. shortage of qualified physicians and limited beds) also have a direct impact on the effective implementation of telemedicine [30,31]. These difficulties reflect the complexity of the process and the need for approaches that consider different aspects. Furthermore, the development of studies that address subjective outcomes may also contribute to a better understanding of the impact of this tool. Our experience in this study allowed us to determine the satisfaction of the health professionals who participated in the project, as well as to observe important structural changes in the participating units, which contributed to better care. Through interactions with professionals at participating centers and the relationships fostered via daily telerounds, we observed high satisfaction with teleconsultations and a transformation in clinical practices driven by the exchange of knowledge and experience, as well as the implementation of clinical protocols developed by experts. Several participating centers integrated telerounds into their daily routine in the PICU, utilizing this intervention as a supportive tool in patient care.

However, these are aspects that we did not plan to measure but that can be taken into consideration in future studies. For example, using a qualitative-quantitative research design would allow an analysis of this intervention model while also taking these subjective aspects into account. Additionally, it might be interesting to include other variables in future analyses, such as adherence rates and recommendation acceptance rates.

## Conclusion

The results regarding ICU length of stay (primary outcome), days without mechanical ventilation, and mortality did not show significant differences between the intervention and control groups. However, telerounds in intensive care units, especially in regions with a shortage of directly operating certified intensivists, revealed other significant benefits. These include facilitating case discussions and personalized therapies tailored to patients' needs, adapted to institutional resources. Real-time interaction at the bedside enabled a comprehensive patient assessment, describing observed signs and symptoms, along with continuous monitoring allowing immediate adjustments to ventilatory parameters and continuous medication administration.

Furthermore, telerounds enabled imaging studies in centers with necessary equipment but a shortage of specialized professionals for operation. Using high-resolution cameras, project professionals guided bedside personnel in the proper placement of transducers, enabling real-time reporting and guiding immediate surgical interventions when necessary.

The practice of telerounds also influenced the shift changeover between teams, enhancing care continuity in centers where this practice was not routine. During these sessions, both medical and nursing teams could exchange experiences and knowledge, proposing targeted interventions to minimize adverse events resulting from patients' clinical conditions. Mutual learning between teams proved to be crucial for both sides. Identifying challenges in caring for children admitted to intensive care units and planning qualified and effective care with available resources allowed for high-level discussions among professionals. For those at the patients' bedside, it provided an opportunity to exchange experiences with experienced professionals in the field. Meanwhile, for professionals in centers with adequate resources, it meant better treatment options and a deeper understanding of the needs of intensive care units in Brazil. Witnessing the daily evolution of care through these bedside discussions was a constant source of satisfaction from the teams who declared that they were very satisfied with the project's actions in the units. This result suggests that, despite the potential benefits of telemedicine, its effective implementation in the Brazilian public health system faces considerable challenges, highlighting the continued importance of investigating and improving the role of telemedicine in pediatric critical care.

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## Author contributions

Felipe Cezar Cabral, João Ronaldo Mafalda Krauzer, Taís de Campos Moreira, Hilda Maria Rodrigues Moleda Constant, Vanessa Cristina Jacovas, Aristóteles de Almeida Pires made a substantial contribution to the concept and design of the study. Gabriela de Oliveira Laguna Silva and Emanuele König Klever researched literature. Mariana Motta Dias da Silva did the data analysis. Gabriela de Oliveira Laguna Silva and Mariana Motta Dias da Silva interpreted the data. Gabriela de Oliveira Laguna Silva wrote the first draft of the manuscript. Gabriela de Oliveira Laguna Silva, Taís de Campos Moreira, and Emanuele König Klever wrote the final draft of the manuscript. Felipe Cezar Cabral, João Ronaldo Mafalda Krauzer, Taís de Campos Moreira, Hilda Maria Rodrigues Moleda Constant, Vanessa Cristina Jacovas, Aristóteles de Almeida Pires, Luciane Gomes da Cunha, Bárbara Marina Simionato, and Bárbara Marina Simionato revised it critically for important intellectual content. All authors reviewed and approved the final version of the manuscript.

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