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TECHNOLOGY AND PEDIATRICS (E EISENSTEIN AND Y EVANS, SECTION EDITORS)

Telemedicine in Pediatric Intensive Care Units: Perspectives From a Brazilian Experience

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Abstract

Purpose of Review To present the implementation of a telemedicine project (TeleICU) in pediatric intensive care units (ICU) throughout different Brazilian regions.

Recent Findings Although telemedicine in pediatric ICUs has shown evidence of benefit in numerous studies with potential to 18 mitigate existing disparities, in Brazil, its use is still under development. Brazil has several opportunities for implementing this resource since, according to the National Registry of Healthcare 20 Establishments (NRHE), there is a discrepancy in the density of pediatric intensive care physicians per patient and the availability 21 of pediatric ICU beds per number of inhabitants.

Summary Health technologies are being widely used to fill gaps in the healthcare system. Telemedicine has been an important tool to meet demands in intensive care units, especially the demand for specialized assistance. TeleICU is a Brazilian model of telemedicine that performs multidisciplinary telerounds in remote pediatric ICUs and develops continuing education activities for the healthcare teams. The project aims to systematize and to qualify care, as well as to reduce risks for patients admitted to pediatric ICUs engaged in the project. Preliminary results have demonstrated a positive impact regarding this approach, providing medical care to 6640 inpatients-day in two Brazilian pediatric ICUs, for 616 patients during 946 daily telerounds.

Keywords Telemedicine · Pediatric intensive care unit · Pediatrics and critical care

Abbreviations

PIM2	Pediatric Index Mortality 2
PICU	Pediatric Intensive Care Unit
ICU	Intensive Care Unit
NRHE	National Registry of Healthcare Establishments
PROADI-SUS	Institutional Development Program of the Brazilian National Health System
HMV	Hospital Moinhos de Vento
IT	Information Technology
ICD-10	International Classification of Diseases

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Introduction

The use of telemedicine in the intensive care unit (ICU) is defined as the remote delivery of clinical intensive care services through videoconferencing and monitoring technologies [1••]. The methodology can be simpler, from audiovisual systems that allow two-way communication in real time between intensivists, bedside clinical staff, specialists, subspecialists, and patients, to the integration of these resources with portable devices for carrying out bedside examinations at a distance [1••]. In pediatric ICUs, telemedicine allows different types of patient care, such as continuous remote monitoring and teleconsultations with specialists [2]. Telemedicine in pediatric ICUs has been widely used to extend or complement healthcare capacity, to bring care from specialized intensive care physicians to units that are difficult to access or where the availability of medical specialists is insufficient, and to improve the quality perceived by healthcare professionals and caregivers, demonstrating numerous benefits [3, 4, 5••].

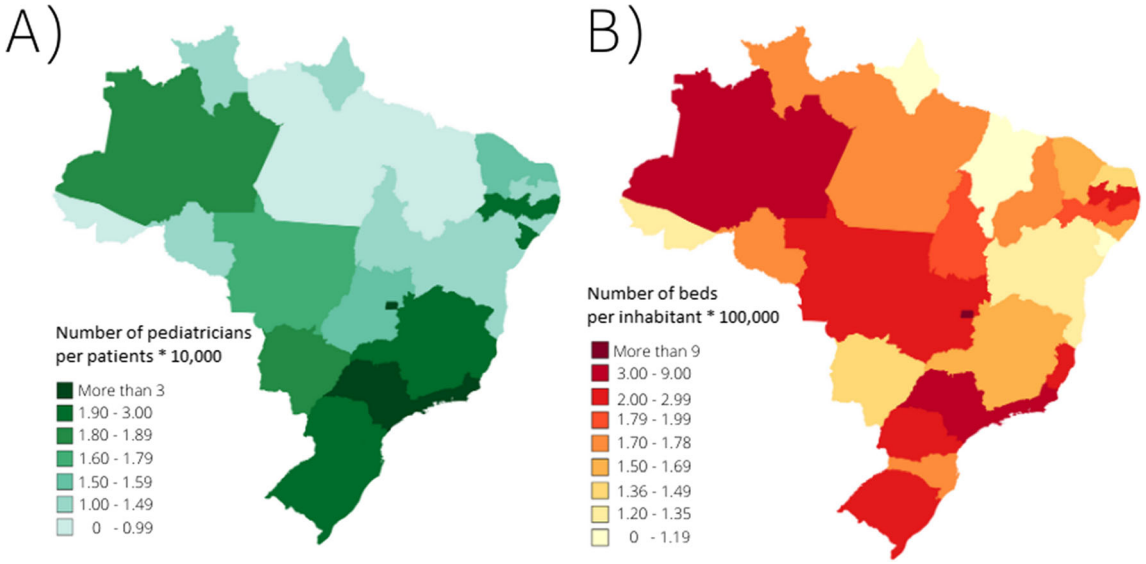

Fig. 1 **A** Graphic representation of the density of pediatric physicians in Brazil (number of pediatric physicians/total population *times* 10,000; **B** Graphic representation of the density of pediatric ICU beds in Brazil (number of available beds/total population *times* 100,000) according to federative unit (source: adapted from the National Registry of Healthcare Establishments)

Brazil has several opportunities to implement this resource, considering it is a country with a broad demographic area, with resources distributed unevenly between regions and between public and private health systems. According to the National Registry of Healthcare Establishments (NRHE), the number of pediatric physicians per 10,000 patients is 3.77 in the Federal District and 3.18 in São Paulo, comparting to a density of 0.73 and 0.96 in less developed regions such as the states of Maranhão and Acre (Fig. 1A) [6]. The same discrepancy happens regarding hospital ICU beds in these regions. The Federal District and São Paulo show a number of ICU beds per 100,000 inhabitants of 9.23 and 3.20 respectively; meanwhile, states such as Maranhão and Acre have a density of less than 1.5 ICU beds (Fig. 1B) [6].

Telemedicine is rapidly becoming a pattern of healthcare assistance, and technologies are progressively more present in healthcare services, especially in ICUs. Combining telemedicine and the demand for specialized assistance in Brazil, the project TeleICUs was developed to address pediatric ICUs, offering multidisciplinary telerounds in remote pediatric ICUs as well as developing continuing education activities in order to train the healthcare teams. Also, the project aims to systematize healthcare assistance, improving the quality of healthcare services and reducing risks for patients hospitalized in the pediatric ICUs that participate in the project. Being developed since 2018, the project hopes to improve clinical indicators in its operation sites. This article describes the experience of using telemedicine in pediatric ICUs in Brazil, presenting the main findings of its first 2 years of operation.

Methods

Selection of Participating Centers and Project Implementation

In partnership with the Brazilian Ministry of Health throughout the Development Program of the Brazilian National Health System (PROADI-SUS) and Hospital Moinhos de Vento (HMV) implemented the project TeleICUs "Qualification of Intensive Care Assistance through Telemedicine," which selected two pediatric ICUs in the north and northeast regions in order to perform the daily multidisciplinary telerounds.

In order to select the hospitals, a methodology specifically planned for the project was used, considering the following stages:

Stage 1: generating a list containing all Brazilian public hospitals (100% of its care should be dedicated to the Brazilian Nonprofit Healthcare System — SUS) that have pediatric ICUs.
Stage 2: rating the ICU according to its complexity (the project selected type II units — according to the Brazilian Ministry of Health regulation n° 3.432, august 12th 1998 [7], ICUs can be classified as type I, II, or III, regarding the appropriate number of medical physicians, multidisciplinary team, and access to appropriate equipment and exams).

Stage 3: categorizing it according to the number of beds, ICUs with 8 to 12 beds moved on to the next stage;
Stage 4: contacting all the eligible ICUs (considering stages 1, 2, and 3) through phone call or e-mail, inviting the head of the pediatric ICUs to engage in the project;
Stage 5: all heads of the pediatric ICUs that showed interest in participating answered a questionnaire to assess feasibility (Supplementary Appendix 1);
Stage 6: considering the answers to the feasibility questionnaire, a meeting with the eligible ICUs was organized and a team from HMV (comprised by a pediatric intensive care physician and nurse, a researcher and an information technology (IT) professional) visited the ICUs. Throughout the visit, each specialist assessed its specific domain, and the whole team assessed an overall domain (called the "big picture view"). For the final rating, the weight of each specialist was relative to the impact of its interaction with the remote center (Fig. 2).
Stage 7: after finishing the visits, a ranking with the hospitals assessments was developed and two centers with higher scores were selected to participate in the project.

The Telerounds

The telerounds comprised the connection between an office located at Hospital Moinhos de Vento, referred to as the command center. The command center was equipped with computers and a high-definition audiovisual system (Fig. 3A and B). The team was formed by a pediatric intensive care physician and nurse, as well as a multidisciplinary team and medical specialists, according to the demand identified by the command center's team. The two hospitals that received assistance were referred to as the remote centers, and had a telemedicine cart equipped with an integrated audio and video system (with PTZ-Pan/Tilt/Zoom system — which allows horizontal and vertical movement, as well as zoom, that can be adjusted by the command team) and no break with 1.5 h of autonomy, which allowed the cart to make visits to all patients by the bedside (Fig. 3C and D).

The telerounds occurred from Monday to Friday, in a previously schedule meeting time. Each inpatient was visited daily e his clinical path, as well as screening tests, were discussed. During the teleround, the command center team registers the appointments in the project's own electronic platform and at the end provides individual recommendations for each patient. The following day, the teleround begins with the assessment of the recommendations and whether they were followed or not. We call this process "acceptance recommendation," and we consider this an adherence to the recommendations given by telemedicine. The protocol for telemedicine appointments involves several steps and during the first appointment the following information is assessed: patient history, which includes the reason for hospitalization and previous medical history, and physical examination. The patient's complications and relevant responses are evaluated daily, specifically considering the following aspects: nutritional,

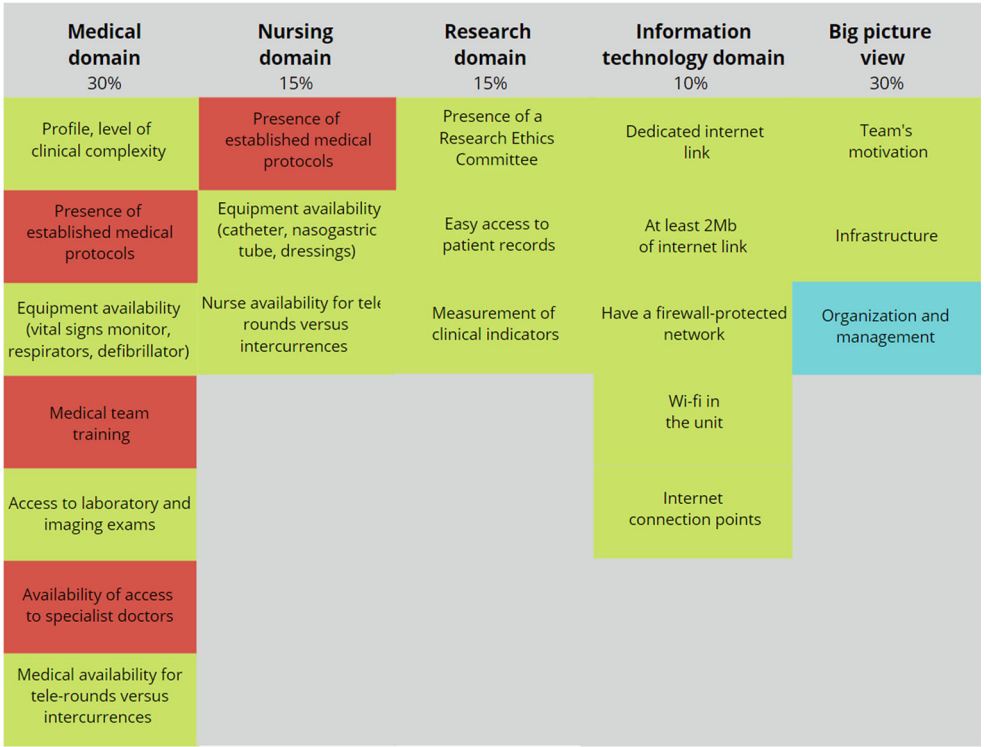

Fig. 2 Items assessed in each domain considered in the project's implementation visits. Red cells represent a negative score (the worse the assessment, the greater the weight). Green cells represent a positive score (the better the assessment, the better the scores). Blue cells represent negative scores towards the extreme evaluations (very good and inadequate) and positive scores in regular evaluations

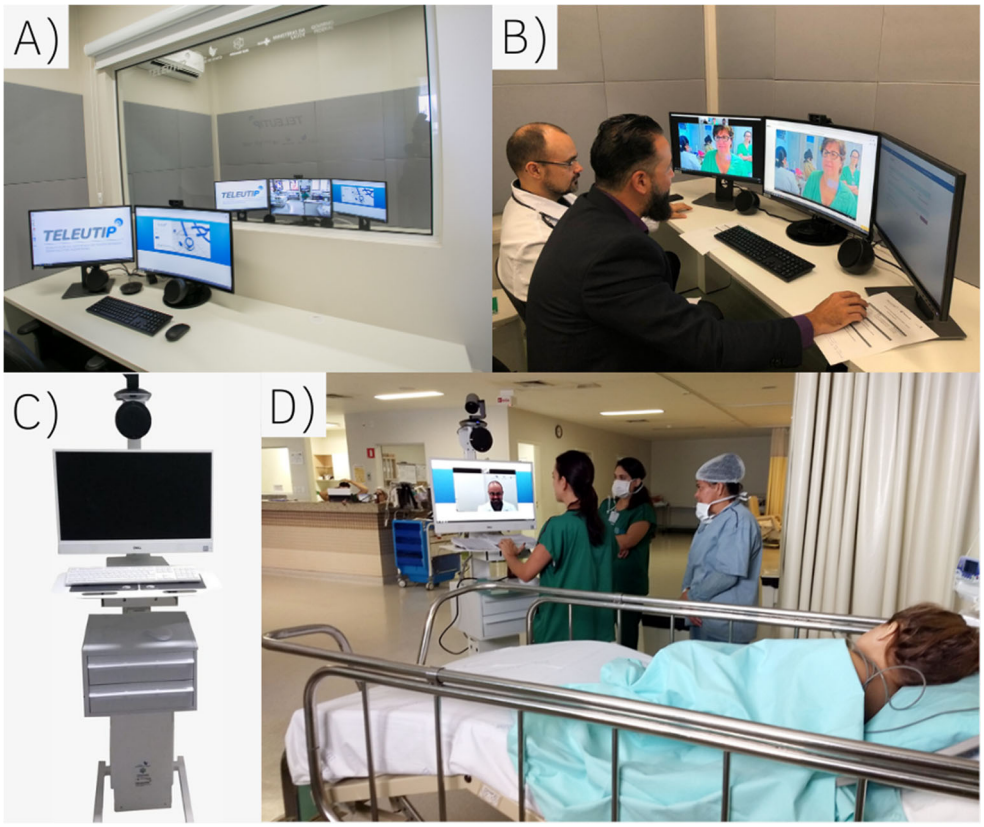

Fig. 3 **A** Photo of the telemedicine station located in the command center (Hospital Moinhos de Vento, Porto Alegre, RS) and **B** telemedicine station and the intensive care pediatric physicians. The remote center is equipped with a telemedicine cart (**C**), which is located by the team by the bedside in order to allow patients' assessments (**D**)

respiratory, analgesia and sedation, motor, hemodynamic, digestive/renal, antibiotics and culture, blood products, other tests, social, and evaluation by specialists and multidisciplinary staff. The complete protocol regarding the pediatric clinical teleround can be found in the Supplementary Appendix 2.

Educational Activities

Concurrently with the project's healthcare activities, educational activities were carried out, aiming to provide continuing education to the healthcare professionals involved in the telerounds and to the remaining ICUs' staff. Thus, periodically, educational activities were carried out in 3 different ways:

I. Online classes: set with a specific date and time, they are organized to be streamed live, with the professor lecturing from the command center and the remote centers' teams connected and interacting with the professor throughout the class. The presentations last approximately 45 min, followed by 15 min set aside specifically for questions. Moreover, the classes are recorded and remain available in an online educational platform, so that they can be seen by healthcare professionals that were not able to attend live;
II. Clinical case discussions: also set with a specific date and time, in each round one of the participating hospitals presents a complex clinical case from their institution. The command center is responsible for inviting medical specialists to participate and to contribute to the discussion by sharing an overview of the subject as well as relevant scientific articles regarding the issue. The presentations last approximately 15 min, followed by 45 min of discussion between healthcare professionals and medical specialists. The clinical case discussions are also recorded and remain available to the healthcare professionals that were not able to attend live.
III. Distance education (DE) courses: distance education courses were developed and made available in the EDX educational platform in a self-learning format, with tutoring also available. The course's subjects were previously defined according to relevance in the pediatric intensive care setting.

Results

During the project's implementation period (from Dec./2018 to Dec./2020) in two Brazilian pediatric ICUs. During this period, 6640 inpatients-day (inpatient-day: measurement unit that represents assistance provided to a patient hospitalized for 1 day) (Table 1). Median length of stay was 8 days and the

Table 1 Characteristics of the ICUs engaged in the project

	Unit A	Unit B	Total
Number of inpatients-day seen[1]	4,222	2,418	6,640
Number of patients seen	297	362	664
Number of inpatients-day seen by specialists	953	384	1137
Median length of stay[2] (IQR)	8 (16–4)	8 (16–4.75)	8 (16–4.75)
Number of recommendations	7,452	4,894	12,346
Readmission rate[3]	14.47%	8.28%	-

[1] Inpatient-day: measurement unit that represents assistance provided to a patient hospitalized for 1 day

[2] Median length of stay measured in days

[3] Number of unplanned readmissions *times* 100 *divided* by the number of hospital admissions

main reason for ICU discharge was pneumonia in both remote centers (Table 2). Patients' median age was 19 months (IQR 68.5–7) in unit A and 25.5 months (IQR 88.25–6) in unit B. Female patients represented 43.6% (n = 158) in unit A and 33.3% (n = 99) in unit B.

Unit A accounted for 516 daily telerounds and unit B accounted for 430. HMV's physicians provided 12,346 recommendations through telemedicine, 7452 for unit A, which adherence approximately 88.2% of the given recommendations, and 4894 for unit B, which adherence 78.9% of the recommendations. The project carried out 1137 teleconsultations with specialists according to each units' needs (Table 3).

During the execution of the project's educational activities, the project trained 476 healthcare professionals from the remote centers: 165 individuals participated of 21 online classes, 272 participants engaged in the clinical case discussions, and 39 participants participated in 5 different DE courses (Basic life support [n = 18], Pediatric advanced life support [n = 2], Prevention of pediatric primary bloodstream infections: intravenous therapies and infectious aggravations [n = 6] and Pediatric pain assessment [n = 6]).

Discussion

This study described a telemedicine program implemented in pediatric ICUs in the North and Northeast regions of Brazil, within the scope of the Brazilian Unified Health System. Data shows the positive contributions of the project by using telemedicine and the success in the units where it was implemented. Pediatric ICUs have been a useful setting for the use of telemedicine, with different intervention models to facilitate pediatric care. Its uses range from screening the patients in order to help identify who should be transferred to the ICU and to define the need for transport of critically ill patients, to daily healthcare provided in intensive care units [4, 8, 9]. Previous literature regarding the use of telemedicine in pediatric ICUs already shows interesting results in other countries, for example, in the USA. Dayal et al. showed a decrease in

Table 2 Main diagnosis at ICU discharge of patients seen by telemedicine in each pediatric ICU

ICD-10	Code	n	%
Unit A (n=297)			
Unspecified bacterial pneumonia	J15.9	25	8.42
Acute respiratory failure	J96.0	20	6.73
Hydrocephalus	G91.0	9	3.03
Spinal muscular atrophy, type I (Werdnig-Hoffman)	G12.0	8	2.69
Craniosynostosis	Q75.0	8	2.69
Unit B (n=362)			
Pneumonia, unspecified organism	J18.9	66	18.23
Acute abdomen	R10.0	25	6.91
Unspecified bacterial pneumonia	J15.9	25	6.91
Acute appendicitis with generalized peritonitis	K35.2	19	5.25
Sepsis, unspecified organism	A41.9	17	4.70

The 5 main diagnoses of each unit were considered and the percentages were calculated based on the number of patients. *ICD-10* International Classification of Diseases

Table 3 Teleconsultations with specialists

Physician specialty	n	%
Unit A (n=953)		
Diagnostic radiology	543	56.98
Infectious diseases	365	38.30
Neurology	30	3.15
General practitioner/palliative care	4	0.42
Pneumology	3	0.31
Unit B (n=384)		
Diagnostic radiology	237	61.72
Infectious diseases	138	35.94
Cardiology	4	1.04
Pneumology	2	0.52
Endocrinology	2	0.52

The 5 main medical specialties that provided care to each unit were considered here and the percentages were calculated based on the number of teleconsultations with specialists

length of stay and hospital mortality by using telemedicine during the patient transfers from the emergency room to the pediatric ICU [4]. However, studies that assess telemedicine in pediatric ICUs are very heterogeneous, especially regarding the chosen methodology [5••]. Therefore, in order to properly assess improvements in clinical healthcare indicators regarding telemedicine approaches in the ICUs, the development of more robust clinical studies is necessary.

In our study, pediatric ICU length of stay was similar to other studies [10] which used telemedicine in order to monitor patients hospitalized in intensive care units, demonstrating that the use of this technology brings benefits to patients regardless of where it was implemented [4, 5]. The clinical profile of the hospitalized patients in both participating ICUs was very similar, evidenced by the most frequent diagnosis according to the ICD-10, which was respiratory conditions in both units. This profile also reflects on the medical specialties that most participated in teleconsultations, specialists in diagnostic radiology and infectious diseases. The similar profile was beneficial because it allowed for the standardization of the intervention and the clinical protocol used in the telemedicine approach. The use of telemedicine and digital health has the potential to improve the efficiency of pediatric care, guiding intensive care workflows and helping to solve underserved demands [11].

It is important to highlight that both daily healthcare activities and educational activities, which include online classes, clinical case discussion, and distance education courses, contribute to the education and qualification of healthcare professionals, and consequently to their care routines [12••, 13]. Thus, we seek to train these professionals and qualify them so that with the discontinuity of the project in these ICUs, the quality of health care provided to patients can become a permanent gain.

The strategy we described contributes to the literature, demonstrating that the use of telemedicine in pediatric ICUs has the potential to improve patients' clinical outcomes and the healthcare indicators from the ICUs where this method is being used to guide patient care. This approach's format is pragmatic, reproducible, and can be generalized and expanded, considering it does not require advance technologies or sophisticated equipment. We hope the experience and the findings shared in this study are able to provide sufficient information so that other healthcare professionals can incorporate these interventions into their own practice, especially in places similar to Brazil, where distances are large and there is a shortage of healthcare specialists.

The use of telemedicine in pediatric ICUs seems to be a solution to solve the disparities in access to specialized assistance, allowing intensive care to be provided for seriously ill patients in distant locations and with a low density of doctors per inhabitant [11]. It is known that this is a necessity in countries with persistent geographical inequalities and insufficient funding [14].

In the future perspectives, the project aims to expand beyond the pediatric field and to increase the number of ICUs in Brazil that receive telerounds. Also, an important step is to evaluate the clinical impact of the use of telemedicine on healthcare indicators such as length of stay and mortality. In addition, in order to obtain more robust scientific evidence, implementing a randomized clinical trial would be appropriate. Finally, we also expect to evaluate burnout syndrome among the healthcare teams, aiming to study a potential reduction of physical and emotional tiredness attained through the use of telemedicine, considering patient care is shared with the HMV's team. With these studies, it will be possible to strengthen the use of telemedicine in pediatric ICUs in Brazil.

Conclusion

Telemedicine has proven to be an important tool to fill gaps in healthcare services, as well as to provide support to healthcare professionals, to improve healthcare quality, and to provide education and updates in a continuous and facilitated way. The COVID-19 pandemic setting has opened space and created opportunity to promote and to validate telemedicine technologies, contributing to its strengthening in Brazil. Therefore, publications regarding the current findings as well as developing more researches in the field will strengthen the scientific evidence available.

The TeleICU project is a Brazilian telemedicine service model that has proven to have a positive impact in the ICUs it currently operates. Future perspectives suggest enlarging the

project, as well as performing more robust analyses such as impact assessment through randomized clinical trials and the economic impact of its use.

New evidence of the applicability of this healthcare model may in the future provide an important tool to the healthcare system, thus contributing to attain universal healthcare access and knowledge transfer on an ongoing basis.

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Code Availability Not applicable

Author Contribution VCJ, MEVC, TCM, MCCM and FCC: Conceived and designed this review. VCJ, MEVC, HMRMC, SSA, JRMK, LRG, AAP, LGC, MCCM, TCM and FCC: Wrote the paper.

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Data availability Not applicable.

Declarations

Ethics Approval Approved by the Institutional Review Board (CAAE 00781218.0.0000.5330).

Conflict of Interest The authors declare no competing interests.

References

Papers of particular interest, published recently, have been highlighted as:
•• Of major importance

1.•• Udeh C, Udeh B, Rahman N, Canfield C, Campbell J, Hata JS. Telemedicine/virtual ICU: where are we and where are we going? Methodist Debakey Cardiovasc J. 2018;14(2):126–33. https://doi.org/10.14797/mdcj-14-2-126 **An important review compiles data on teleICU structure, operations, clinical outcomes, and costs**.
2. Marcin JP. Telemedicine in the pediatric intensive care unit. Pediatr Clin N Am. 2013 Jun;60(3):581–92. https://doi.org/10.1016/j.pcl.2013.02.002.
3. Marcin JP, Nesbitt TS, Kallas HJ, Struve SN, Traugott CA, Dimand RJ. Use of telemedicine to provide pediatric critical care inpatient consultations to underserved rural Northern California. J Pediatr. 2004;144(3):375–80. https://doi.org/10.1016/j.jpeds.2003.12.017.
4. Dayal P, Hojman NM, Kissee JL, Evans J, Natale JE, Huang Y, et al. Impact of telemedicine on severity of illness and outcomes among children transferred from referring emergency departments to a children's hospital PICU. Pediatr Crit Care Med. 2016;17(6):516–21. https://doi.org/10.1097/PCC.0000000000000761.
5.•• Nadar M, Jouvet P, Tucci M, Toledano B, Cyr M, Sicotte C. The implementation of a synchronous telemedicine platform linking off-site pediatric intensivists and on-site fellows in a pediatric intensive care unit: a feasibility study. Int J Med Inform. 2019;129:219–25. https://doi.org/10.1016/j.ijmedinf.2019.06.009 **This article provides a feasibility study of implementing a synchronous telemedicine platform in a pediatric intensive care unit**.
6. CNES; http://cnes.datasus.gov.br/ Accessed 12 Jan 2021.
7. BRASIL. Ministério da Saúde. Gabinete do Ministro. Portaria n° 3.432, de 12 de agosto de 1998. Brasília, 1998
8. Munoz RA, Burbano NH, Motoa MV, Santiago G, Klevemann M, Casilli J. Telemedicine in pediatric cardiac critical care. Telemed J E Health. 2012 Mar;18(2):132–6. https://doi.org/10.1089/tmj.2011.0090.
9. Fugok K, Slamon NB. The effect of telemedicine on resource utilization and hospital disposition in critically ill pediatric transport patients. Telemed J E Health. 2018;24(5):367–74. https://doi.org/10.1089/tmj.2017.0095.
10. Lopez-Magallon AJ, Otero AV, Welchering N, Bermon A, Castillo V, Duran Á, et al. Patient outcomes of an international telepediatric cardiac critical care program. Telemed J E Health. 2015 Aug;21(8):601–10. https://doi.org/10.1089/tmj.2014.0188.
11. Ellenby MS, Marcin JP. The role of telemedicine in pediatric critical care. Crit Care Clin. 2015 Apr;31(2):275–90. https://doi.org/10.1016/j.ccc.2014.12.006.
12.•• Kovacevic P, Dragic S, Kovacevic T, Momcicevic D, Festic E, Kashyap R, et al. Impact of weekly case-based tele-education on quality of care in a limited resource medical intensive care unit. Crit Care. 2019;23(1):220. https://doi.org/10.1186/s13054-019-2494-6 **An important article that shows the impact of teleeducation through the discussion of clinical cases, on clinical care indicators of intensive care units**.
13. Eisenstein E, Kopacek C, Cavalcante SS, Neves AC, Fraga GP, Messina LA. Telemedicine: a bridge over knowledge gaps in healthcare. Curr Pediatr Rep. 2020;1:1–6. https://doi.org/10.1007/s40124-020-00221-w Epub ahead of print.
14. Castro MC, Massuda A, Almeida G, Menezes-Filho NA, Andrade MV, de Souza Noronha KVM, et al. Brazil's unified health system: the first 30 years and prospects for the future. Lancet. 2019;394(10195):345–56. https://doi.org/10.1016/S0140-6736(19)31243-7.