

Original Research

Telemedicine in Pediatric Cardiac Critical Care

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Abstract

Objective: To describe our international telemedicine experience in pediatric cardiac critical care. **Materials and Methods:** This is a case series of pediatric patients teleassisted from the Cardiac Intensive Care Unit (CICU) at Children's Hospital of Pittsburgh of University of Pittsburgh Medical Center, Pittsburgh, PA, to the CICU at Hospital Valle del Lili, Cali, Valle, Colombia, between March and December 2010. An attending intensivist from the CICU in Pittsburgh reviewed cases, monitored real-time vital signs, and gave formal medical advice as requested by the attending physician in Cali. The network connection is a Cisco (San Jose, CA)-based Secure Sockets Layer virtual private network via the Internet that allows access to the web-based interface of the Dräger® (Lübeck, Germany) physiological monitor system. The videoconferencing equipment consists of a standard component on a custom-made mobile cart that uses an APC® (West Kingston, RI) uninterruptible power supply for portable power and 3Com® (Hewlett-Packard, Palo Alto, CA) for wireless connectivity. A post-intervention survey regarding satisfaction with the telemedicine service was conducted. **Results:** Seventy-one recommendations were given regarding 53 patients. Median age and weight were 10 months and 7.1 kg, respectively. Ventricular septal defect, transposition of the great vessels, and single ventricle accounted for most cases. The most frequent recommendations were related to surgical conduct, management of arrhythmias, and performance of cardiac catheterization studies. No technical difficulties were experienced during the monitoring of the patients. Satisfaction rates were equally high for technical and medical aspects of telemedicine service.

Conclusions: Telemedicine is a feasible option for pediatric intensivists seeking experienced assistance in the management of complex cardiac patients. Real-time remote assistance may improve the medical care of pediatric cardiac patients treated in developing countries.

Key words: cardiology/cardiovascular disease, e-health, telemedicine, telehealth

Introduction

Pediatric cardiac critical care is a challenging discipline of pediatric medicine where decisions requiring a high degree of academic preparation and clinical expertise must be made in a timely fashion. One difficulty currently observed in numerous countries is the shortage of pediatric cardiac intensivists.¹ Developing countries face additional challenges such as limited technology, insufficient nursing staff, shortage of medical supplies, limited access to continuous medical education and medical literature, and low salaries for medical professionals. The aforementioned restrictions make even more obvious the discrepancy between the supply and demand of adequately trained medical subspecialists available to care for the growing population of surviving children with complex congenital heart defects.

Several studies have shown that the use of telemedicine is a feasible option in the critical care setting; however, their clinical results have been controversial.²⁻¹⁰ Previous studies have reported the use of telemedicine for pediatric cardiology consultation and echocardiograms.¹¹⁻¹³ Although the use of international telemedicine in pediatric cardiac intensive care has not been reported in the medical literature, it may be a valuable tool for pediatric intensivists in developing countries seeking advice from more experienced international centers for the medical management of complex patients.

This study was designed with the primary goal of sharing our institutional experience with international telemedicine in pediatric cardiac critical care by describing collaboration between the Hospital Valle del Lili in Cali, Valle, Colombia and Children's Hospital of Pittsburgh of University of Pittsburgh Medical Center (UPMC) in Pittsburgh, PA.

Materials and Methods

We studied a cohort of patients admitted to the Cardiac Intensive Care Unit (CICU) of the Foundation Valle del Lili in Cali who were teleassisted from Children's Hospital of Pittsburgh of UPMC between March 1, 2010 and December 31, 2010. The study was approved separately by the institutional review boards of both institutions, which waived the need for written, informed consent. The Foundation Valle del Lili is a 368-bed tertiary-care teaching hospital with one

Pediatric Intensive Care Unit (PICU) (10 beds) and one independent CICU (six beds). The CICU has two full-time pediatric cardiac intensivists (high-intensive physician staffing)⁸ who deliver continuous intensivists coverage for 100% of the patients and perform rounds at least once per day. Children's Hospital of Pittsburgh of UPMC also has a PICU (36 beds) and an independent CICU (12 beds). The CICU has two full-time cardiac intensivists and one full-time pediatric intensivist with vast experience in cardiac critical care. The telemedicine consultation was always carried out between the same cardiac intensivist in Pittsburgh and one of the two on-call cardiac intensivists in Cali. There was no other rotation for the intensivist at Children's Hospital of Pittsburgh of UPMC or in Cali. If cardiac surgery consultation was needed, the same cardiac surgeon and cardiologist from Children's Hospital of Pittsburgh attended the videoconference.

The tele-CICU system consists of two identical mobile carts: One located in the administrative office of the remote cardiac intensivist in Children's Hospital of Pittsburgh of UPMC (Fig. 1) and the other located in the CICU of the Foundation Valle del Lili. Each cart has two main components: a LifeSize® (Austin, TX) or Polycom® (Pleasanton, CA) videoconferencing unit and a 22-inch LCD screen. The carts are equipped with full audiovisual capabilities and use a wireless Internet connection given the availability of bandwidth Internet on both ends. The videoconferencing equipment is a LifeSize Express 200 system at Valle del Lili and a Polycom HDX7000 in Pittsburgh, a standard component on a custom-made mobile cart that uses an APC® (West Kingston, RI) uninterruptible power supply for portable power. The cart can run for up to 2 h without being connected to electrical power.



Fig. 1. Telemedicine cart in Children's Hospital of Pittsburgh of University of Pittsburgh Medical Center.

The cart in the Foundation Valle del Lili uses two 3Com® (Hewlett-Packard, Palo Alto, CA) 7760 access points running bridge mode to allow for a wireless network connection. When the physiological monitor system is viewed, a Cisco (San Jose, CA)-based Secure Sockets Layer virtual private network via the Internet is used that allows encrypted access to the Web-based interface of the Dräger® (Lübeck, Germany) physiological monitor system. In most cases, the physiological monitor data were viewed by using the camera on the videoconferencing cart. When detailed waveform information was required, the physician would use virtual private network software via the Internet to access a Web browser-based gateway to the hospital monitoring system. Echocardiograms and radiographic images were viewed by having the remote physician display the images on a workstation and then using the camera on the videoconferencing cart to view them. Additionally, a portable laptop computer was provided to the remote intensivist in Pittsburgh to ensure 24-h access to the telemedicine system from any location with an Internet connection by using the virtual private network to access the monitor system or Polycom PVX software to connect to the video cart. The telemedicine cart videoconferencing systems use 512,000 bits per second of bandwidth during a call, which is also encrypted to protect the confidentiality of the information being transmitted.

The aforementioned telemedicine system was put in full operation in February 2010. Whenever the local intensivist in Cali felt that he or she needed advice to manage a patient, he or she contacted the remote intensivist in Pittsburgh via e-mail, which was converted to and immediately delivered as a page. Telemedicine consultations were obtained at the discretion of the local attending intensivist and were usually limited to the more complex and sicker patients. Upon receiving a page from the intensivist in Cali, the remote intensivist in Pittsburgh initiated a videoconference using the mobile cart or the portable laptop computer by means of a phone call through the system. Once the call is accepted, the system enters full operation mode (real-time audio and video), and the cart in Cali is transported to the appropriate location in the CICU, using either a power outlet or the rechargeable battery supply. Using the videoconference system, the patient's case was presented to the remote intensivist in the following clinical format: Cardiovascular, respiratory, renal, hematologic, infectious, metabolic, nutritional, and neurologic. The remote intensivist had access to visual information from anywhere in the CICU in Cali as the cart was freely moved through the unit. After the clinical case was presented, medical advice was given by means of an academic discussion of the case (including review of diagnostic laboratories or images, specific pharmacological therapy, and catheterization or surgical procedures). After the pertinent medical advice had been given the videoconference was terminated, and the local intensivist in Cali then decided how much of the given recommendation to follow for the continued management of his or her patients.

In addition to the 24-h tele-CICU system, multidisciplinary videoconferences were scheduled and conducted monthly. One cardiac intensivist, one cardiac surgeon, and one interventional cardiologist from Children's Hospital of Pittsburgh along with two cardiac intensivists, two cardiac surgeons, two cardiologists, and one cardiac

anesthesiologist from the Hospital Valle de Lili participated in these monthly videoconferences. The purposes of these monthly videoconferences were mainly specific case reviews and education.

At the end of the 10-month study period an anonymous post-intervention survey of participating medical professionals at the Foundation Valle del Lili was conducted regarding the satisfaction among these professionals with the telemedicine service. A questionnaire consisting of 12 questions written in Spanish by a native Spanish speaker was created and sent electronically to the cardiac intensivists, cardiac surgeon, intensive care fellows rotating in the CICU, and the chief of nursing in Cali. The practitioners opened a link in the Internet and were asked to rate the quality of the technical and medical aspects of the consulting service, as well as the general satisfaction with the videoconferences.

SPSS (Chicago, IL) Statistic version 18 for the Mac was used for statistical analysis. Continuous variables are expressed as mean ± standard deviation or medians and ranges when appropriate. Categorical variables are reported as frequencies and percentages.

Results

From March 1, 2010 to December 31, 2010, consultations were conducted for 53 pediatric cardiac critical care patients using telemedicine. Demographic information is shown in *Table 1*. Median age was 10 months (range, 7 days–20 years), and median weight was 7.1 kg (range, 2–70 kg). Seventy percent of the patients were males, and 72% of the patients were surgical patients. Patients' primary cardiac diagnoses are shown in *Table 2*. Ventricular septal defect,

transposition of the great vessels, and single ventricle accounted for one-third of the total cases.

During our study period, we had approximately two to three telemedicine contacts per week, and during these sessions we performed one or more consultations. In total, 71 telemedicine recommendations were given for the 53 patients (*Table 3*). The time of consultation was not recorded, but based on our experience, the time range was between 10 to 45 min with an average of 20 min. The most frequent recommendations were related to the surgical conduct, the management of arrhythmias, and the performance of cardiac catheterization studies. Consultations were conducted for 65% of the patients during the postoperative period, and consultations for the 35% remaining were during the preoperative period.

The response rate to the questionnaire was 89% (eight of nine), and it was answered by all staff of the CICU in Cali. Because of technical problems, two surveys were faxed anonymously. Only one Fellow did not answer the survey, and although we do not know the specific reason, we speculate Internet access difficulties as well as problems opening the link with the survey. Among those who responded, the

Table 1. Demographic Information

DEMOGRAPHIC	VALUE
Gender (male/female) (n)	37/16 (53)
Age (months)	10 (7 days–20 years)
Weight (kg)	7.1 (2–70)
Surgery [n (%)]	46 (87)
RACHS-1 [n (%)]	
1	1 (2)
2	11 (24)
3	15 (33)
4	11 (24)
NA	8 (17)
CPB [n (%)]	32 (70)
Perfusion time (min)	120 (42–410)
Clamp time (min)	48 (18–180)

Data are presented as median and range, except when specified. CPB, cardiopulmonary bypass; NA, not applicable; RACHS-1, Risk Adjustment for Congenital Heart Surgery.

Table 2. Cardiac Diagnoses

PRIMARY CARDIAC DIAGNOSIS	N
Ventricular septal defect	8
Transposition of great arteries	7
Single ventricle	5
Anomalous pulmonary venous connection	4
Ebstein anomaly	4
Tricuspid atresia	4
Double outlet right ventricle	3
Atrioventricular canal	2
Truncus arteriosus	2
Pulmonary atresia	2
Dilated cardiomyopathy	2
Atrial septal defect	1
Aortic coarctation	1
Interrupted aortic arch	1
Double aortic arch	1
Shone's syndrome	1
Plurivalvular disease	1
Pulmonary stenosis	1
Endomyocardial fibroelastosis	1
Subaortic membrane	1
Infectious endocarditis	1

Table 3. Telemedicine Recommendation

RECOMMENDATION	N
Surgery	15
Management of arrhythmia	8
Catheterization	7
Low cardiac output	6
Management of pulmonary hypertension	6
Mechanical ventilation	4
Sedation	3
Other diagnosis studies	3
Antibiotic	2
Airway	1
ECMO	1
POP	15

ECMO, extracorporeal membrane oxygenation; POP, postoperative management.

answers were relatively consistent, and there were no outliers; six of eight of those who responded used the system once or more per week, and two of eight used it two to three times per month. They all agreed to continue using the system and would recommend it to other pediatric intensivists. All respondents reported being satisfied (2/8) to very satisfied (6/8) with the telemedicine consulting system. Regarding the technical aspects of the telemedicine system (speed of the connection, quality of the audio and video signal, frequency of interruption of the communication, and mobility of the cart), 100% of participants reported being satisfied to very satisfied. Responders also agreed on being satisfied to very satisfied with the medical aspects of the telemedicine system (timeliness of the remote intensivist's response, time dedicated to the clinical cases by the remote intensivist, local feasibility of the clinical recommendation, immediate clinical outcome, and concurrence of local team with recommendation given by the remote intensivist). Four of the eight responders stated they always and three of the eight stated they regularly followed the telemedicine recommendation, and the remaining did half of the time. Six of the eight who answered the survey attributed the improvement in the clinical state of the patient to the telemedicine recommendation. When asked about the frequency of change in different aspects of daily medical care produced by the telemedicine recommendations, 84% of responders admitted to having changed their medical plan in at least at 50% of the cases. Everyone agreed that the monthly multidisciplinary teleconferences were useful.

Discussion

Although the tele-CICU program between Children's Hospital of Pittsburgh of UPMC and the Foundation Valle del Lili is a pilot

collaborative initiative started in 2010, these two hospitals have been working side-by-side since 2008. Children's Hospital of Pittsburgh of UPMC has been providing services of medical consultation and training of medical staff in the field of pediatric cardiology, and beginning in 2008 a telephone-based consulting system was initiated between the two hospitals to provide medical consultations on an as-needed basis. That service proved to be valued highly by local intensivists in Cali and led to the development 2 years later of the current videoconference system used to connect the two institutions. Although useful, the former phone-based system had the obvious limitation of not including video information for patients, such as access to the patient's general appearance, the monitoring system, and the diagnostic images. Additionally, consultations were briefer in nature, and when compared with the current system, the quality of information was based solely on the subjective, personal interpretations of the local intensivist. Follow-ups were not common.

The use of mobile videoconference systems as well as transmission from decoded data from the monitoring system allows remote intensivists to have direct access to the patient's room, vital signs, pressure numeric values, and curve shapes anytime during the communication. This additional information widens the visual field of the remote intensivist and facilitates a more objective approach to the clinical case presented.

Our results show that telemedicine is a feasible tool for pediatric cardiac intensivists in developing countries seeking medical advice from more experienced international centers. Usage of Internet versus other media types, such as optic fiber, to transmit data makes the system highly versatile, easy to access, low-cost, user friendly, and secure. In our study, issues concerning connectivity and low quality of the audio or video signal were seen in less than 5% of all calls, which is reflected by the high percentage (100%) of satisfaction with the technical aspects of the system. Although we did not use an objective means of quantifying the clinical outcomes after recommendations given through telemedicine, we believe that the clinical appreciation of those directly involved in the care of the patient is relevant. Six of the eight responders agreed that the improvement in clinical condition of patients was related to the telemedicine recommendation.

According to the local intensivists, two of the most important changes that have taken place in the CICU in the Hospital Valle del Lili in Cali since the beginning of the telemedicine program are the more opportune surgical decisions and increased utilization of catheterization studies. In addition, the extracorporeal membrane oxygenation (ECMO) program was started at Foundation Valle del Lili during the last 2 years, with the telemedicine program already on course. However, recommendations related to ECMO were not frequent, which may be due to the low number of patients at the Foundation Valle del Lili treated with ECMO in 2010.

Total mortality during the telemedicine period in the CICU at the Hospital Valle del Lili in Cali was 4% compared with 9.3% from the previous year. Because of the design of the present study it is not possible to attribute such a decrease in mortality to the telemedicine

program; however, we do think that prospective studies addressing this specific outcome will confirm this observation.

LIMITATIONS AND POTENTIAL SOLUTIONS

1. This investigation was retrospective and descriptive. For the future we are designing a prospective and randomized study.
2. During this study there was no full-time tele-intensivist in our unit. Currently, we have a full-time physician providing tele-consultations.
3. There was not always a multidisciplinary medical group available to discuss patient care.
4. Outcomes are not presented in terms of mortality, frequency of complications, length of stay in the CICU, or costs. These data will be included in our future studies.
5. Because of the relatively low number of consults, we have expanded our service to other hospitals in Colombia.

Conclusions

Telemedicine is a feasible option for pediatric cardiac intensivists seeking experienced assistance in the management of complex cardiac patients. Real-time remote assistance may improve the medical care of pediatric cardiac patients treated in developing countries.

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Disclosure Statement

No competing financial interests exist.

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