Original Research

Patient Outcomes of an International Telepediatric Cardiac Critical Care Program

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Abstract

Background: An optimal model for telemedicine use in the international care setting has not been established. Our objective was to describe variables associated with patient outcome during the implementation of an international pediatric cardiac critical care (PCCC) telemedicine program. **Materials and Methods:** A retrospective review was performed of clinical records and a telemedicine database of patients admitted to the cardiac intensive care unit (CICU) at the Fundacion Cardiovascular de Colombia, Bucaramanga, Colombia, during the initial 10 months of our program, compared with patients admitted during a previous period. Information collected included demographic data, cardiac diagnosis and associated factors, Risk Adjustment for Congenital Heart Surgery (RACHS)-1 classification, and perioperative events. Primary outcome was composed of CICU and hospital mortality. Secondary outcomes were CICU and hospital length of stay (LOS). **Results:** Of the 553 patients who were included, teleconsultation was done for 71 (12.4%), with a total of 156 encounters, including 19 for patients on extracorporeal membrane oxygenation. Three hundred twenty-one recommendations were given, and 42 real-time interventions were documented. RACHS-1 distribution was similar between study periods ($p=0.427$). Teleconsulted patients were significantly younger (44 versus 24 months; $p=0.03$) and had higher surgical complexity than non-teleconsulted patients ($p=0.01$). RACHS-1 adjusted hospital survival was similar between study periods. CICU and hospital LOS intervals were significantly shorter in the telemedicine period (10 versus 17 days [$p=0.02$] and 22

versus 28 days [$p<0.001$]). In surgical cases, preoperative CICU LOS was significantly shorter (3 versus 6 days; $p<0.001$). Variables associated with hospital mortality were higher RACHS-1 categories, lower weight, bypass time longer than 150 min, and use of circulatory arrest, as well as the presence of sepsis or necrotizing enterocolitis. Those associated with increased LOS were lower weight, extracorporeal membrane oxygenation, and cross-clamp time longer than 60 min. **Conclusions:** An international telemedicine service in PCCC was associated with lower CICU and hospital LOS. Prospective telemedicine interventions aimed to decrease mortality and LOS should focus on patients with higher RACHS-1 categories, lower-weight infants, and those with prolonged operative time and selective perioperative complications.

Key words: telemedicine, telecardiology, cardiology/cardiovascular disease, pediatrics

Introduction

Critical care of infants, children, and adult patients with congenital heart disease require experienced and skilled staff. The scarcity of such specialized physicians is a constant and widespread problem, especially in developing countries.^{1,2} Telemedicine has become a useful instrument to provide clinical care and medical education at a distance, in both the intensive care and pediatric cardiology settings.³ The use of mobile videoconference systems allows remote intensivists to have direct access to the patient's room, vital signs, and monitoring during the communication, and several studies have demonstrated it as a feasible and reliable option to provide medical care.³⁻⁸ As bigger areas can be served, it may enable a better service to the patient, save time, and reduce the costs for physicians and families.³

Reports from the intensive care setting have shown conflicting findings related to any effect from a telemedicine system in patient outcomes,⁹ but some investigators were able to demonstrate a decrease in mortality and better clinical practice adherence to best evidence-based guidelines while applying systematic telemedicine interventions within a multilayered quality project. Furthermore, in the telemedicine

group a decrease in preventable complications and a shorter length of stay (LOS) were detected.⁸

Nevertheless, the ideal format to deliver medical care in the international telemedicine setting has not been established. In order to do so, we have previously reported our initial experience with the delivery of telemedicine-assisted pediatric cardiac critical care (PCCC) in an international setting, with a survey demonstrating a high rate of remote physician satisfaction,¹⁰ as well as our multicenter experience during the first 2 years of our international telemedicine program, finding significant differences in staff composition, patient population, and perception of needs among the different remote centers, making a “one size-fits-all” approach unworkable.¹¹

The objective of this study was to describe factors associated with cardiac intensive care unit (CICU) and hospital survival, as well as hospital LOS, during the first 10 months of the implementation of an international telemedicine program in PCCC in a subset of patients from our previous report,¹¹ specifically, the ones from the Fundacion Cardiovascular de Colombia (FCV), Bucaramanga, Colombia, in anticipation for future prospective interventions.

Materials and Methods

This was a pre- and postintervention study. A retrospective review was performed of clinical records for all cardiovascular admissions in patients admitted to the CICU at FCV and a telemedicine clinical database of those for whom teleconsultation was done by the Children’s Hospital of Pittsburgh of UPMC (CHP), Pittsburgh, PA, from July 15, 2011 to May 15, 2012 (Telemed group), compared with patients admitted during a previous period from July 1, 2010 to February 1, 2011 (Pre-Telemed group). Telemed patients represent a subset of patients from our previously reported multicenter study.¹¹

The institutional review board of both institutions approved this study separately.

CENTERS’ CHARACTERISTICS

The FCV is a 26-year-old tertiary-level hospital treating patients with heart disease, both children and adults. It has a general pediatric unit with 22 beds, a CICU with 24 beds, a general pediatric intensive care unit with 10 beds, and neonatal intensive and intermediate care units, each

one with 20 beds. CHP is a state-of-the-art children’s hospital with 289 licensed beds. It has a 36-bed pediatric intensive care unit and an independent 12-bed CICU.

PROGRAM DESCRIPTION

A complete description of our international telemedicine program in PCCC as well as pertinent technical information has been published elsewhere.^{10,11}

In brief, a tele-intensivist from the CHP CICU reviewed patients, providing monitoring and support as well as pertinent studies, and gave formal medical advice at the request by the remote attending physician at the FCV. Patients could be followed as many times as needed according to local physician criteria.

A real-time intervention was defined as any activity performed according to tele-intensivist recommendation and taking place during teleconsultations.

DATA COLLECTION

Unidentified data were extracted from our prospectively collected database (e-CICU database). We included specific telemedicine information such as date of consultation, consult type (first versus follow-up), evaluated information (clinical data, X-ray, monitor, electrocardiogram, echocardiogram, computer-assisted tomography scan, angiography, etc.), activities (diagnostic study interpretation, diagnostic change, real-time intervention), type of patient (preoperative versus postoperative and medical), recommendations given, and connection quality.

Fig. 1. Flowchart of study patients. Pre-Telemed, pretelemedicine; Telemed, telemedicine.

Table 1. Comparison Between Study Periods

	TELEMEDICINE STUDY PERIOD	PRETELEMEDICINE STUDY PERIOD	P
Patients (n)	264	307	
Hospital admissions (n)	303	330	
Diagnosis [n (%)]			<0.001
Cardiovascular	282 (93.1)	269 (81.5)	
Noncardiovascular	21 (6.9)	61 (18.5)	
Cardiovascular patients			
Demographic and clinical features			
Gender [n (%)]			0.39
Male	129 (45.7)	133 (49.4)	
Female	153 (54.3)	136 (50.6)	
Age (months)	8.36 (0, 651)	7.93 (0, 312)	0.65
Weight (kg)	5.7 (2.08, 99)	5.7 (1.99, 70)	0.48
Length (cm)	62.5 (39, 172)	60 (43, 178)	0.69
Associated factors [n (%)]			
LCOS	19 (6.7)	22 (8.2)	0.63
Sepsis	20 (7.1)	23 (8.6)	0.53
Arrhythmia	20 (7.1)	27 (10)	0.23
Ventricular failure	9 (1.6)	6.7 (3.3)	0.075
PAH	19 (6.7)	20 (7.4)	0.86
Diaphragm paralysis	3 (1.1)	5 (1.9)	0.49
Atelectasis	3 (1.1)	2 (0.7)	1
Vocal cord paralysis	18 (6.4)	12 (4.5)	0.35
Pneumonia	14 (5)	17 (6.3)	0.58
NEC	10 (3.5)	9 (3.3)	1
DIC	1 (0.4)	1 (0.4)	1
Renal failure	1 (0.4)	5 (1.9)	0.11
Hemorrhage	4 (1.4)	6 (2.2)	0.53
Seizure	4 (1.4)	4 (1.4)	1
Encephalopathy	3 (1.1)	0	0.24
Malnourishment	6 (2.1)	17 (6.3)	0.018
Down's syndrome	20 (7.1)	16 (5.9)	0.60
ECMO [n (%)] ^a	13 (4.9)	5 (1.6)	0.03
Outcomes			
Survival [n (%)]			
CICU	255 (90.4)	241 (89.6)	0.77
Hospital	249 (88.3)	238 (88.5)	1

Table 1. continued

	TELEMEDICINE STUDY PERIOD	PRETELEMEDICINE STUDY PERIOD	P
LOS (days)			
CICU	6 (0.5, 148)	11 (0.5, 199)	<0.001
Hospital	14 (0.5, 185)	21 (1, 266)	<0.001

Data are median (minimum, maximum) values unless indicated otherwise.

^aPercentage calculated from total number of patients.

CICU, cardiac intensive care unit; DIC, disseminated intravascular coagulation; ECMO, extracorporeal membrane oxygenation; LCOS, low cardiac output syndrome; LOS, length of stay; NEC, necrotizing enterocolitis; PAH, pulmonary artery hypertension.

Surgical procedures were classified according to Risk Adjustment for Congenital Heart Surgery (RACHS)-1 categories. This method allows for discrimination in mortality risk according to surgical complexity, with 1 being the group with the lowest and 6 the one with highest anticipated mortalities, respectively.¹²

In addition to the telemedicine data, a second group of data was collected by the staff from the FCV, including demographic data, cardiac diagnosis, operative data including type of surgery, cardiopulmonary bypass and cross-clamp times, use of circulatory arrest, and minimal transoperative temperature.

The primary outcome was hospital mortality. Secondary outcomes were CICU and hospital LOS.

DATA ANALYSIS

SPSS version 20 software (SPSS, Inc., Chicago, IL) was used for statistical analysis. We conducted descriptive statistics for all patients in each group (Pre-Telemed, Telemed, and Teleconsulted). We did a log transformation for continuous variables with a skewed distribution. We performed a comparison between study periods and between teleconsulted and non-teleconsulted patients within the Telemed group. For categorical variables we conducted Fisher's exact test and *t* test for continuous variables. For primary cardiac surgery, we compared RACHS-1 distribution between periods by the Mann-Whitney U test. For comparison of RACHS-1 adjusted CICU and hospital LOS between study periods we used two-way analysis of variance; when the equality of error variances test was significant we used the Kruskal-Wallis test. Results were considered significant when the *p* value was <0.05. Potential risk markers, including weight, age, RACHS-1 category higher than >3, extracorporeal membrane oxygenation (ECMO), presence of low cardiac output syndrome, sepsis, or necrotizing enterocolitis, bypass time longer than 150 min,

Table 2. Comparison Between Study Periods in Cardiac Surgical Cases

	TELEMEDICINE STUDY PERIOD	PRETELEMEDICINE STUDY PERIOD	<i>P</i>
Primary cardiac surgery (<i>n</i>)	150	168	
Operative variables			
Circulatory arrest [<i>n</i> (%)]	10 (7.4)	27 (24.1)	<0.001
Bypass time (min)	95 (1, 403)	83 (15, 470)	0.95
Cross-clamp time (min)	49 (1,155)	44 (2, 197)	0.76
RACHS-1 [<i>n</i> (%)]			0.43 ^a
Category 1	16 (10.9)	16 (9.5)	
Category 2	45 (30.6)	62 (36.9)	
Category 3	51 (34.7)	58 (34.5)	
Category 4	30 (20.4)	24 (14.3)	
Category 6	5 (3.4)	8 (4.8)	
Outcome			
Survival [<i>n</i> (%)]			
CICU	137 (91.3)	158 (94)	0.39
Hospital	132 (88)	157 (93.5)	0.11
LOS (days)			
CICU	9 (0.5, 48)	16 (1, 186)	0.012
Hospital	25.5 (2, 185)	27.5 (1, 186)	0.65
Preoperative LOS (days)			
CICU	0.5 (0.5, 55)	2 (0.5, 156)	<0.001
Hospital	5 (0.5, 86)	6 (0.5, 156)	0.056
Postoperative LOS (days)			
CICU	8 (0.5, 104)	10.3 (1, 171)	0.04
Hospital	17.5 (0.5, 171)	18.6 (1, 171)	0.25

Data are median (minimum, maximum) values unless indicated otherwise.

^aBy Mann-Whitney U test.

CICU, cardiac intensive care unit; LOS, length of stay; RACHS, Risk Adjustment for Congenital Heart Surgery.

circulatory arrest during surgery, and cross-clamp time longer than 60 min, were identified and included in the full multivariate regression model as covariates. For hospital mortality we used Cox proportional hazards, and for CICU and hospital LOS we used a linear regression model.

Results

During the study period, there were, in total, 676 hospital admissions for 571 patients. After 43 admissions were excluded

Table 3. Teleconsultation Characteristics

TELECONSULT CHARACTERISTICS	<i>N</i> (%)
Staff participation	
CICU staff	156 (100)
Cardiothoracic surgery team	36 (23.1)
Neonatology	7 (4.5)
Type of encounter	
First consult	76 (49)
Follow-up	80 (51)
Image quality	
Good	134 (85.9)
Fair	3 (2)
Poor	1 (1.3)
Assessed information	
Medical history	156 (100)
Patient monitor	112 (71.8)
Chest X-ray	106 (68)
Patient	106 (68)
Echocardiography	69 (44.2)
Electrocardiogram	26 (16.7)
Computer-assisted tomography catheterization	3 (2)
Real-time interventions	
Patients	34 (21.8)
Total	42
Type	
Echocardiographic directions	31 (20)
Pharmacologic interventions	3 (2)
Rhythm/electrophysiology interventions	3 (2)
Ventilator parameter adjustment	3 (2)
ECMO weaning trial/adjustment	2 (1.2)
Recommendations	
Total	321
Type	
Pharmacologic therapy	121 (37.7)
Surgical recommendation	64 (20)
Diagnostic study suggestion	51 (15.8)
Additional echocardiographic imaging	22 (6.8)
Diagnostic hemodynamic study	19 (6)
ECMO	19 (6)
Ventilator support adjustment	16 (5)
Interventional catheterization	7 (2)
Cardioversion	2 (0.6)

CICU, cardiac intensive care unit; ECMO, extracorporeal membrane oxygenation.

Table 4. Telemedicine Period Patients According to Teleconsultation Status

	TELECONSULTED	NONTELECONSULTED	P
Patients (n)	71	193	
Hospital admissions (n)	71	232	
Demographic and clinical features			
Gender [n (%)]			0.02
Male	45 (63.4%)	96 (41.4)	
Female	26 (36.65%)	136 (58.6)	
Age (months)	3.2, (0.03, 230)	10.3 (0.03, 651)	0.002
Weight (kg)	4.7 (2.08, 99)	6 (2.08, 54.5)	0.077
Length (cm)	60 (49, 172)	65 (45, 163)	0.085
Associated factors [n (%)]			
LCOS	8 (11.3%)	12 (5.2)	0.16
Sepsis	8 (11.3%)	15 (6.5)	0.43
Arrhythmia	12 (16.9%)	8 (3.4)	<0.01
Ventricular failure	3 (4.2%)	5 (2.2)	0.22
PAH	7 (9.9%)	14 (6)	0.28
Diaphragm paralysis	1 (1.4%)	2 (0.9)	0.55
Atelectasis	1 (1.4%)	2 (0.9)	0.55
Vocal cord paralysis	7 (9.9%)	11 (4.7)	0.09
Pneumonia	5 (7%)	11 (4.7)	0.54
NEC	3 (4.2%)	7 (3)	0.70
DIC	1 (1.4%)	0 (0)	0.23
Renal failure	0	1 (0.4)	1
Hemorrhage	2 (2.8%)	2 (0.9)	0.23
Seizure	2 (2.8%)	4 (1.7)	0.63
Encephalopathy	1 (1.4%)	3 (1.3)	1
Malnourishment	3 (4.2%)	3 (1.3)	0.14
Down's syndrome	0	21 (9.1)	0.06
ECMO [n (%)]	10 (14.1%)	3 (1.3)	<0.01
Outcomes			
Survival [n (%)]			
CICU	58 (81.7%)	215 (92.7)	0.01
Hospital	53 (74.6%)	214 (92.2)	<0.01
LOS (days)			
CICU	17 (1, 148)	3.5 (0.5, 93)	<0.01
Hospital	41 (1, 185)	9 (0.5, 132)	<0.01
Primary cardiac surgery	55	95	

Table 4. continued

	TELECONSULTED	NONTELECONSULTED	P
Operative variables			
Circulatory arrest [n (%)]	6 (11)	4 (4.2)	0.09
Bypass time (min)	120 (32, 403)	76 (1, 304)	<0.01
Cross-clamp time (min)	62.5 (3, 154)	41 (1, 152)	0.034
RACHS-1 [n (%)]			<0.01 ^a
Category 1	2 (3.8)	14 (14.9)	
Category 2	10 (19)	35 (37.2)	
Category 3	22 (41.5)	29 (30.9)	
Category 4	14 (26.4)	16 (53.3)	
Category 6	5 (9.1)	0	
Outcome			
Survival [n (%)]			
CICU	47 (85.5)	90 (94.7)	0.07
Hospital	43 (78.2)	89 (93.7)	<0.01
LOS (days)			
CICU	17 (1, 148)	3.5 (0.5, 93)	<0.01
Hospital	41 (1, 185)	9 (0.5, 32)	<0.01
Preoperative LOS (days)			
CICU	0.5 (0.5, 31)	0.5 (0.5, 55)	<0.01
Hospital	6 (0.5, 55)	2 (0.5, 55)	<0.01
Postoperative LOS (days)			
CICU	14.8 (2, 104)	7 (0.5, 82)	<0.01
Hospital	36.5 (2, 171)	12 (0.5, 131)	<0.01

Data are median (minimum, maximum) values unless indicated otherwise.

^aBy Mann-Whitney U test.

CICU, cardiac intensive care unit; DIC, disseminated intravascular coagulopathy; ECMO, extracorporeal membrane oxygenation; LCOS, low cardiac output syndrome; LOS, length of stay; NEC, necrotizing enterocolitis; PAH, pulmonary artery hypertension; RACHS, Risk Adjustment for Congenital Heart Surgery.

because of missing data as well as 82 additional ones in noncardiovascular patients, in total, 551 cardiovascular admissions in 533 patients were included for analysis: 269 and 282, respectively, for the pretelemedicine and telemedicine periods. A flowchart of patient admissions is shown in *Figure 1*. Demographic data and operative variables are described in *Tables 1* and *2*.

TELEMEDICINE STUDY PERIOD

During the telemedicine study period, 264 patients were admitted, including 71 patients receiving teleconsultations. Hospital and CICU admissions were 303 and 312, respectively.

Table 5. Risk Adjustment for Congenital Heart Surgery-1 Adjusted Survival for Primary Surgical Cases

RACHS-1 CATEGORY	CICU SURVIVAL			HOSPITAL SURVIVAL		
	TELEMEDICINE STUDY PERIOD	PRETELEMEDICINE STUDY PERIOD	<i>P</i>	TELEMEDICINE STUDY PERIOD	PRETELEMEDICINE STUDY PERIOD	<i>P</i>
1	16 (100)	16 (100)	1	16 (100)	16 (100)	1
2	45 (100)	61 (98.4)	1	43 (95.6)	61 (98.4)	0.57
3	44 (86.3)	54 (93.1)	0.34	44 (86.3)	53 (91.4)	0.54
4	25 (83.3)	21 (87.5)	0.72	23 (76.7)	21 (87.5)	0.48
6	5 (100)	6 (75)	0.48	4 (80)	6 (75)	1

Data are *n* (%).

CICU, cardiac intensive care unit; RACHS, Risk Adjustment for Congenital Heart Surgery.

Telemedicine period patients had similar demographic variables and RACHS-1 distribution compared with pretelemedicine patients; however, there were higher proportions of patients with cardiovascular diagnosis (Telemed versus Pre-Telemed, 93.1% versus 81.5%; $p < 0.001$) and ECMO cases (Telemed versus Pre-Telemed, 4.9% versus 1.6%; $p = 0.030$).

TELECONSULTATIONS

One hundred eighty-nine telemedicine consultations were conducted for 71 (12.4%) patients. Thirty-three telemedicine

encounters were excluded because hospital admission occurred before the study period or information was incomplete.

The number of teleconsultations by patient ranged from 1 to 11, with a mean of 2. Characteristics of teleconsultations are described in *Table 3*. In total, 42 real-time interventions were documented in 34 teleconsultations (21.8%). Three hundred twenty-one recommendations were given. The most frequently recommended surgery by teleconsultation was ventricular septal defect closure ($n = 10$), followed by arterial switch operation ($n = 6$), pulmonary artery banding ($n = 6$), re-intervention ($n = 5$), and hybrid approach ($n = 4$).

TELECONSULTED PATIENTS

Characteristics of patients receiving teleconsultation are described in *Table 4*. The most frequent diagnosis in teleconsulted patients was atrioventricular canal ($n = 7$, 9.9%), followed by hypoplastic left heart syndrome ($n = 6$, 8.5%), ventricular septal defect ($n = 5$, 7%), and transposition of great arteries ($n = 5$, 7%). The most common associated factors present in these patients were arrhythmia ($n = 12$, 17%), low cardiac output syndrome ($n = 7$, 9.9%), sepsis ($n = 7$, 9.9%), and pulmonary artery hypertension ($n = 7$, 9.9%). Ten (14.1%) were ECMO cases.

Within the Telemed group, teleconsulted patients had a significantly increased proportion of male patients and a younger age, had higher surgical complexity as categorized by RACHS-1 distribution, and longer bypass and cross-clamp times compared with patients without teleconsultation (*Table 4*).

Fig. 2. Length of stay (LOS) of cardiovascular patients. Error bars indicate 95% confidence intervals. CICU, cardiac intensive care unit.

Table 6. Risk Adjustment for Congenital Heart Surgery-1 Adjusted Length of Stay for Surgical Cases

RACHS-1 Catego	CICU LENGTH OF STAY (DAYS)			HOSPITAL LENGTH OF STAY (DAYS)		
	TELEMEDICINE STUDY PERIOD	PRETELEMEDICINE STUDY PERIOD	<i>p</i> ^a	TELEMEDICINE STUDY PERIOD	PRETELEMEDICINE STUDY PERIOD	<i>p</i> ^a
1	5 ± 7.72	5.5 ± 7.93	0.65	20 ± 20.86	14.5 ± 14.27	0.35
2	8 ± 29.07	12 ± 31.77	0.54	19 ± 36.10	21 ± 34.61	0.83
3	8 ± 21.28	17.5 ± 27.75	0.017	24 ± 29.14	33 ± 34.33	0.09
4	16 ± 25.04	21 ± 50.15	0.047	42.5 ± 29.21	42.5 ± 48.04	0.44
6	19 ± 58.67	46 ± 29.87	0.29	58 ± 64.47	51.5 ± 32.31	0.89

Data are median ± standard deviation values.

^aBy *t* test for logarithmic variable.

CICU, cardiac intensive care unit; RACHS, Risk Adjustment for Congenital Heart Surgery.

OUTCOME ANALYSIS

Overall surgical CICU and hospital mortalities were 7.2% and 9.1%, respectively, for the telemedicine and pretelemedicine periods. RACHS-1 adjusted CICU and hospital survival were similar between study periods (Table 5).

CICU and hospital LOS intervals were significantly shorter in the telemedicine period as described in Table 1 and Figure 2.

RACHS-1 adjusted CICU and hospital LOS are described in Table 6 and Figures 3 and 4, respectively.

After potential confounding factors were examined using a Cox proportional hazard model, patients with higher RACHS-1 categories, lower weight, bypass time longer than 150 min, use of circulatory arrest during the procedure, and the presence of sepsis or NEC were associated with higher hospital mortality (Table 7).

To identify independent risk factors for prolonged CICU LOS and hospital LOS, a multivariate linear regression model was conducted. Lower weight, ECMO, and cross-clamp time longer than 60 min were identified as significant (Table 8).

Fig. 3. Cardiac intensive care unit (CICU) length of stay (LOS) by surgical category (Risk Adjusted for Congenital Heart Surgery [RACHS]-1). Error bars indicate 95% confidence intervals. *By *t* test for logarithmic variable.

Discussion

Different models of care have been proposed for the management of critical patients with congenital heart disease, and one of the most accepted one includes the use of a dedicated CICU covered by pediatric cardiac intensivists.¹³ Consequently, there is a demand for a high number of skilled physicians, who are lacking worldwide. At the same time, every pediatric cardiovascular center team goes through a necessary learning curve in the process of acquiring collective expertise, with a potential for an excess in complications or problems at multiple levels in the process of care. A telemedicine model can be an alternative to the scarcity of specialized physicians, and it can be used to leverage quality improvement interventions,

Fig. 4. Hospital length of stay (LOS) by surgical category (Risk Adjusted for Congenital Heart Surgery [RACHS]-1). Error bars indicate 95% confidence intervals.

thus potentially shortening the learning curve while providing real-time quality assurance to remote teams.

Since 2010, CHP developed an international telemedicine program in PCCC, and this study represents the first reported experience related with patient outcome in this setting.

Table 7. Multivariate Analysis for Hospital Mortality			
VARIABLE	HOSPITAL MORTALITY		
	HR	95% CI	P
Telemedicine	1.909	0.5–3.2	0.34
RACHS-1 > 3	9.43	7.2–11.5	0.04
ECMO	1.071	–0.9 to 3	0.94
Age	0.894	–0.2 to 2	0.85
Weight	12.575	9.8–15.3	0.07
Bypass time > 150 min	3.09	1.8–4.3	0.07
CC time > 60 min	0.767	–0.5 to 2.1	0.70
LCOS	0.99	–0.3 to 2.3	0.98
Sepsis	3.608	1.8–5.4	0.16
NEC	3.725	1.6–5.7	0.20
Circulatory arrest	2.633	1.1–4.1	0.21

CC, cross-clamp; CI, confidence interval; ECMO, extracorporeal membrane oxygenation; HR, hazard ratio; LCOS, low cardiac output syndrome; NEC, necrotizing enterocolitis; RACHS, Risk Adjusted for Congenital Heart Surgery.

Typically, telemedicine models in the critical care setting (a complex system) allow for complex interventions, potentially impacting both the CICU workflow and model of care. Consequently, its effects may be seen in admitted patients irrespective of their consultation status.¹⁴ Given this and the fact that different interventions unrelated to telemedicine were being implemented at the same time (i.e., an increase in the proportion of cardiovascular patients) as well as the relatively short period of observation, we are cautious in ascribing a distinct causal association between patient outcome and the use of telemedicine technology. Nonetheless, there are some observations worth mentioning.

In cardiovascular patients, there was no significant difference in hospital mortality. Adjusted for surgical complexity (RACHS-1) in surgical patients, there was no significant difference in CICU and hospital mortality. This is not unexpected given the short observation time since program inception, as discussed above.

There was a significantly shorter CICU and hospital LOS for cardiovascular patients in the telemedicine period compared with those in the pretelemedicine period. Likewise, in surgical patients there was a significantly shorter CICU LOS; in particular, both the preoperative and CICU LOS were significantly shorter in the telemedicine period, suggesting a possible effect of telemedicine consultations in earlier surgical decisions. After adjusting for surgical complexity, we observed this decrease mainly in surgical complexity categories 3 and 4, and in category 6 patients there was also a decrease that did not reach significance, probably because of the small sample size in that subgroup of patients. We believe these findings suggest that telemedicine use had its major impact in higher surgical risk patients.

A systematic approach focusing on specific aspects of care may be an important component of effective telemedicine interventions. Therefore, we sought to define specific variables associated with survival and LOS: namely, patients in the higher surgical complexity categories (RACHS-1 of > 3), lower weight, longer bypass times (> 150 min), use of circulatory arrest during surgery, and the presence of necrotizing enterocolitis or sepsis were identified for mortality, whereas lower weight, use of ECMO, and longer cross-clamp times (> 60 min) were identified for hospital LOS. These findings are in accordance with multiple previous reports on series of pediatric patients postoperative from heart surgery, including the analysis of the European Association for Cardiothoracic

Table 8. Linear Regression Model

	HOSPITAL LENGTH OF STAY		CICU LENGTH OF STAY	
	EXPONENTIATED PARAMETER ESTIMATE	P VALUE	EXPONENTIATED PARAMETER ESTIMATE	P VALUE
Telemedicine	1.084	0.164	1.080	0.257
Weight	1.530	0.005	1.735	0.002
Age	0.999	0.992	1.008	0.915
RACHS-1 >3	1.079	0.226	1.032	0.664
ECMO	1.340	0.034	1.508	0.011
LCOS	1.199	0.078	1.204	0.122
Sepsis	1.036	0.752	1.079	0.566
NEC	1.005	0.983	1.202	0.463
Bypass time > 150 min	1.029	0.729	1.146	0.160
Circulatory arrest	1.156	0.060	1.113	0.239
Cross-clamp time > 60 min	1.207	0.006	1.181	0.039

Estimates are of the effect on unit increase in absolute value of length of stay.

CICU, cardiac intensive care unit; ECMO, extracorporeal membrane oxygenation; LCOS, low cardiac output syndrome; NEC, necrotizing enterocolitis; RACHS, Risk Adjusted for Congenital Heart Surgery.

Surgery Congenital Database,¹⁵ demonstrating that neonates with lower body weight, higher Aristotle Score, longer cardiopulmonary bypass time, longer aortic cross-clamp time, longer circulatory arrest time, and univentricular physiology were risk factors for hospital mortality.

These findings are very important to us in order to modify our current telemedicine model for these patients, so we can focus our attention in patients with higher risk of mortality and prolonged LOS, as well as focusing on preventive strategies for selected complications with the goal to produce a major impact in patient survival and overall quality of care.

Finally, teleconsulted patients were significantly younger, had longer bypass and cross-clamp times, and different RACHS-1 distribution, with a higher frequency of complex heart surgery, which may explain their appropriately lower CICU and hospital survival and longer CICU and hospital LOS.

STUDY LIMITATIONS AND FUTURE DIRECTIONS

The retrospective nature of this study limited a more powerful data analysis. In particular, we were not able to make a more detailed analysis in nonsurgical patients. Subgroup sample size was small when patients were analyzed by RACHS-1 categories. Other variables among multiple interventions during the typical hospital stay of these patients with the potential to alter outcomes were not included. Further research is warranted to establish whether

a more systematic approach, considering the findings in this report, will be of additional benefit for children with cardiovascular disease in the international cardiac critical care setting.

Conclusions

Compared with a historical cohort, an international telemedicine service in PCCC was associated with lower CICU and hospital LOS in pediatric cardiovascular patients. Patients postoperative of congenital heart surgery had comparable survival adjusted for surgical complexity but shorter CICU and preoperative LOS. Prospective telemedicine interventions aimed to decrease mortality and LOS should focus on patients with a higher RACHS-1 category, neonates and lower-weight infants, and those with prolonged operative times and selective perioperative techniques and complications. Potential effects from such interventions may impact both teleconsulted and nonteleconsulted patients.

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Disclosure Statement

No competing financial interests exist.

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