Original Research

Remote Diagnosis of Congenital Heart Disease in Southern Arizona: Comparison Between Tele-Echocardiography and Videotapes

Jessica E. Haley, M.D.,[1] Scott E. Klewer, M.D.,[1] Brent J. Barber, M.D.,[1] F. John Meaney, Ph.D.,[2] Richard L. Donnerstein, M.D.,[1] Ronald S. Weinstein, M.D.,[3] Elizabeth Krupinski, Ph.D.,[3] Gregory Warda, M.D.,[4] Ana Maria Lopez, M.D.,[3] and Daniela Lax, M.D.[1]

[1]Section of Cardiology and [2]Department of Pediatrics, The University of Arizona, Tucson, Arizona.
[3]Arizona Telemedicine Program, Tucson, Arizona.
[4]Yuma Regional Medical Center, Yuma, Arizona.

Abstract

Objective: *We report our experience with tele-echocardiography and echocardiograms recorded digitally or on videotape (recorded-echos) at The University of Arizona from August 2006 to December 2010 and compare their quality and diagnostic accuracy.* ***Materials and Methods:*** *Tele-echocardiograms (tele-echos) were transmitted from the Yuma Regional Medical Center to The University of Arizona via a T-1 and aT-3 line at a bandwidth of 768 kilobits per second. Recorded-echos were shipped for interpretation to The University of Arizona by overnight mail. Diagnostic accuracy was assessed by comparing tele- and recorded-echos with electrocardiograms performed by a pediatric cardiologist (PedsCard-echos).* ***Results:*** *Three hundred forty-six tele-echos in 260 patients and 455 recorded-echos in 406 patients were performed (median age, 6 and 8 days, respectively). Indications included possible congenital heart disease (CHD), patent ductus arteriosus (PDA), and persistent pulmonary hypertension of the newborn. Diagnostic categories included complex CHD, non-critical disease, PDA, and other. PedsCard-echos were available for 27% of the tele-echo and 30% of the recorded-echo patients. Comparisons between tele- and PedsCard-echo yielded no discrepancies in 12 (23%), expected resolution of condition in 26 (49%), and minor in 14 (26%). One (2%) major discrepancy was detected. Comparisons between recorded- and PedsCard-echo showed no discrepancies in 28 (40%), expected resolution of condition in 14 (20%), and minor discrepancies in 28 (40%) patients. No significant difference with respect to discrepancies was detected between tele- and recorded-echos. There was significant ($p < 0.01$) improvement in tele- and recorded-echo study quality by 2010.* ***Conclusions:*** *(1) Tele-echocardiography can be performed successfully with excellent accuracy. (2) The quality of tele- and recorded-echo studies improved toward the end of the analysis period. (3) Although initially tele-echo studies were more accurate than recorded-echo studies, there was no difference between these two types of studies by the fourth year of the study. (4) Both tele- and recorded-echos were indispensible in the remote diagnosis of CHD.*

Key words: *telemedicine, telehealth, cardiology/cardiovascular disease*

Introduction

Pediatric cardiology consultation is critical for optimal neonatal care in rural nurseries. When access to a pediatric cardiologist is unavailable, remote interpretation of echocardiograms through modalities such as tele-echocardiography is indispensible in the day-to-day management of critically ill newborns.[1–5] Determining which neonates require urgent transfer to a tertiary-care center and avoiding unnecessary transport can also be cost saving.[5] The American Academy of Pediatrics recently published screening guidelines for critical congenital heart disease (CHD) using pulse oximetry.[6] Increased utilization of telemedicine technologies such as tele-echocardiography is anticipated as these guidelines become part of routine, standard care of newborns. Establishing reliable methods for accurately diagnosing CHD remotely will be an important aspect of neonatal care throughout the country as these guidelines are implemented.

Yuma Regional Medical Center (Yuma, AZ) is a 333-bed hospital with a 20-bed, Level III newborn intensive care unit and more than 3,000 newborn deliveries per year. On-site pediatric cardiology consultation is not available in this medium-sized city with a population of more than 93,000. The University of Arizona Medical Center, a major tertiary referral center for pediatric patients in Tucson, AZ, is located about 240 miles east of Yuma. In this study we report our experience with remote diagnosis of CHD via tele-echocardiography in Yuma. We compare the quality and diagnostic accuracy of tele-echocardiograms (tele-echo) with studies recorded digitally or on videotape and shipped for interpretation at a later time (recorded-echo).

Materials and Methods

Following approval by the The University of Arizona Human Subjects Protection Program, echocardiogram reports of all tele-echo and recorded-echo studies performed from August 2006 to December 2010 were reviewed. Data abstracted from patients' medical records during 2006–2010 included age at study, study indication, diagnosis, transmission quality, and study quality. The time interval between tele-echo or recorded-echo and subsequent diagnoses at follow-up echocardiogram during a pediatric cardiology clinic (PedsCard-echo) for studies from 2006 to 2009 was also recorded. In the year 2010 follow-up in patients with non-critical disease was recommended in selected patients only.

ECHOCARDIOGRAPHY

All imaging was performed with a Phillips IE33 echo machine with pediatric probes (8 and 12 MHz) by any one of three adult cardiac sonographers. One of the sonographers had received informal training in pediatric echocardiography during approximately six University of Arizona pediatric cardiology outreach clinics. The studies were transmitted to The University of Arizona by telemedicine (described below) one day of the week or, when the telemedicine network was not available, by echocardiograms recorded digitally or on videotape (recorded-echos) and shipped overnight by commercial service.

TELEMEDICINE

Weekly pediatric tele-echocardiography clinics were established at The University of Arizona with Yuma Regional Medical Center in 2006 and continue to the present (*Fig. 1*). Tele-echo studies were transmitted from Yuma Regional Medical Center via a T-1 line to Phoenix, where it was rerouted through a T-3 line to The University of Arizona, using a private, encrypted network with a bandwidth of 768 kilobits per second. Direct Internet, with a point-to-point protocol, was used. A high-definition camera was used at The University of Arizona end, and a direct analog input into the echocardiography machine was used at Yuma Regional Medical Center. A University of Arizona pediatric cardiologist provided real-time supervision of tele-echo studies. Instructions on optimal image and Doppler acquisition were given live to the sonographer at the time of tele-echo performance by the pediatric cardiologist as necessary.

FOLLOW-UP

Evaluation and echocardiography (PedsCard-echo) at a University of Arizona pediatric cardiology clinic were recommended for all patients with abnormal echocardiograms during the years 2006–2009; during the year 2010, all patients with complex CHD underwent PedsCard-echo. The PedsCard-echo was performed by a registered cardiac sonographer with training in pediatric echocardiology with onsite supervision and interpretation by a University of Arizona pediatric cardiologist. When a patient underwent more than one Yuma Regional Medical Center echocardiogram, the latest study was used in comparison with a follow-up PedsCard-echo.

The accuracy of tele-echo and recorded-echo diagnoses was estimated by comparing these diagnoses with PedsCard-echo. The following diagnostic criteria were used: no discrepancy, no significant difference in diagnoses; minor discrepancy, the difference in diagnoses did not affect management or prognosis of the patient's conditions (for example, one degree difference in valve regurgitation or stenosis was allowed); or major discrepancy (management or prognosis was affected). Not all patients kept their appointments for the PedsCard-echo at the recommended time. Because of the natural history of the condition, it is possible that some physiological conditions (e.g., patent ductus arteriosus [PDA], patent foramen ovale, and physiologic peripheral pulmonary artery stenosis) present at tele- or recorded-echo may have undergone spontaneous resolution by the time of the follow-up visit. Therefore the category "expected resolution of condition" was added to the diagnostic criteria.

We chose two methods of comparing accuracy between tele-echo and recorded-echo studies: (1) by comparing types of discrepancies between each and PedsCard-echos and (2) by detailed analysis of echocardiogram reports for statements reflecting inability of the pediatric cardiologist to confirm a conclusive diagnosis. For example, a defect or lesion that could not be excluded because the structure was not imaged adequately would be labeled as "data not adequate for diagnosis" (DNAD).

Chi-squared analysis was used to test statistical significance of differences among diagnoses and indicators by the type of study.[7]

Results

We performed 346 tele-echo studies in 260 patients at a median age 6 days (range, 0 days–9 years). All patients except 3 were inpatients in the newborn intensive care unit; these 3 were children ages 3, 3.5, and 9 years. Of these, 215 were initial studies, and 131 were follow-up tele-echo studies. No technical difficulty with transmission was encountered in any study. Four hundred fifty-five recorded-echo studies were performed on 406 patients at a median age

Fig. 1. Arizona Telemedicine Center. A pediatric cardiologist at The University of Arizona in Tucson discusses an echocardiogram with a sonographer at the Yuma Regional Medical Center, Yuma, AZ.

Table 1. Indications for Initial Tele-Echocardiogram ($n=215$) and Recorded Echocardiogram ($n=399$) Studies

	NUMBER (%)	
	TELE-ECHO	RECORDED-ECHO
Possible congenital heart disease	127 (59.1)	280 (70.2)
Patent ductus arteriosus	29 (13.5)	12 (3)
Persistent pulmonary hypertension of the newborn	16 (7.4)	19 (4.8)
Systemic hypertension	0	13 (3.2)
Other	11 (5.1)	55 (13.8)
No indication given	32 (14.9)	20 (5)

Recorded-echo, echocardiogram recorded digitally or on videotape; tele-echo, tele-echocardiogram.

Table 3. Diagnostic Categories

	NUMBER (%)	
	TELE-ECHO ($N=346$)	RECORDED-ECHO ($N=455$)
Complex CHD	14 (4)	3 (0.7)
Non-critical disease	248 (72)	279 (61.3)
PDA	50 (14.4)	111 (24.3)
Tumor	3 (0.9)	1 (0.2)
No significant heart disease	6 (1.7)	57 (12.5)
No information available	25 (7)	4 (0.8)

$p<0.001$ comparing the two distributions of diagnostic categories in tele-echocardiogram (tele-echo) versus echocardiogram recorded digitally or on videotape (recorded-echo) studies.

CHD, congenital heart disease; PDA, patent ductus arteriosus.

of 8 days (range, 0 days–18 years). Three hundred ninety-nine of the 455 were initial studies, and 56 were follow-up recorded-echo studies.

INDICATIONS

Indications for initial tele- and recorded-echo studies are shown in *Table 1*. The category possible CHD included heart murmur, respiratory distress, apnea, infant of a diabetic mother, cyanosis, or irregular heart rate, and shortness of breath. The category "other" included sepsis, fever, syncope, Kawasaki disease, *in utero* drug exposure, history of chemotherapy, chest pain, palpitations, possible Marfan syndrome, cardiomegaly, and hepatic thrombus. Indications for follow-up tele- and recorded-echo studies are listed in *Table 2*. The category "other" included chest pain, cocaine use, and chronic lung disease.

DIAGNOSTIC CATEGORIES

Diagnostic categories for tele- and recorded-echo studies are listed in *Table 3*. The category "non-critical disease," designated for conditions not requiring immediate intervention, included patent foramen ovale, physiological branch pulmonary artery stenosis, ventricular septal defect, atrial septal defect, mild pulmonary valve stenosis, mild aortic valve stenosis, tricuspid regurgitation, mitral regurgitation, bicuspid aortic valve, pulmonary insufficiency, mitral valve prolapse, left ventricular hypertrophy, and right ventricular hypertrophy. Numerous patients were diagnosed with PDA as well as non-critical disease; these patients were listed in the "PDA" category. We elected to categorize all diagnoses and include even physiologic findings such as physiologic peripheral pulmonary artery stenosis and patent foramen ovale in the non-critical category, to prevent missing potentially significant lesions in studies performed by sonographers initially inexperienced in CHD. Nine newborns, two infants, and three children were categorized as having complex CHD (*Table 4*). All of these newborns and one infant were transported urgently to a tertiary-care center. The other patients were all known to us and included a 56-day-old infant with tetralogy of Fallot and pulmonary atresia admitted for dehydration, a 3-year-old with Shone's complex who required frequent echocardiograms as part of her treatment of pulmonary hypertension, a 9-year-old with trisomy 21 with a repaired atrioventricular canal defect who underwent a routine study, and an 11-year-old with repaired interrupted aortic arch and fevers.

Table 2. Indications for Follow-Up Tele-Echocardiogram ($n=131$) and Recorded Echocardiogram ($n=56$) Studies

	NUMBER (%)	
	FOLLOW-UP TELE-ECHO	FOLLOW-UP RECORDED-ECHO
Patent ductus arteriosus	62 (47.3)	35 (62.5)
Atrial or ventricular septal defect	29 (22.1)	8 (14.3)
Other	37 (28.2)	13 (23.2)
No indication	3 (2.3)	0

Recorded-echo, echocardiogram recorded digitally or on videotape; tele-echo, tele-echocardiogram.

FOLLOW-UP PEDSCARD-ECHO STUDIES

Follow-up PedsCard-echo studies (*Table 5*) were available in 53 of 192 patients (27%) who had undergone tele-echo studies during the years 2006–2009 at a median age of 113 days (quartile range, 113 days) after the latest tele-echo. Comparisons between tele-echo and PedsCard-echo studies yielded no diagnostic discrepancies in 12 (23%) patients, expected resolution of the condition in 26 (49%), and minor discrepancy (management or prognosis not affected) in 14

Table 4. Patients with Complex Congenital Heart Disease

TELE-ECHO DIAGNOSIS	AGE (DAYS) AT TELE-ECHO	OUTCOME	PEDSCARD-ECHO DIAGNOSIS	DIAGNOSTIC DISCREPANCIES
Shone's complex: status post coarctation of the aorta repair, mitral valve replacement, pulmonary hypertension	908 (had 3 tele-echos)	Continue outpatient follow-up	Shone's complex, no mitral stenosis or regurgitation, moderate tricuspid regurgitation	None
TGA, complex CHD	0	Transfer to tertiary-care center	DILV, TGA, coarctation, VSD	Minor
Coarctation of the aorta could not be excluded, probable VSD, moderate tricuspid regurgitation	3	Transfer to tertiary-care center	NA	NA
VSD moderate, possible overriding aorta, left SVC, ASD, possible large coronary sinus (suspect complex disease)	2 and 30 (had 2 tele-echos)	1 month in YRMC, transferred to UAMC for CHF	VSD perimembranous, mild AI, left coronary artery-to-LA fistula (embolized)	Major
Large VSD, overriding aorta, truncus arteriosus versus PA	0	Transfer to tertiary-care center	TOF, pulmonary atresia, MAPCA	Minor
PS/PI mild–moderate, branch PA dilation/aneurysm, small descending aorta, ASD, VSD TOF variant	167	Transfer to tertiary-care center	NA	NA
VSD, pulmonary stenosis, possible TOF	1	Transfer to tertiary-care center	VSD moderate, perimembranous, large ASD, mild PS (23 mm Hg gradient)	Minor
TOF/PA, confluent hypoplastic PAs	0	Transfer to tertiary-care center	Pulmonary atresia, VSD	Minor
TOF absent PV, aneurysm of MPA, branches, small descending aorta, bidirectional ASD, VSD	0	Transfer to tertiary-care center	Absent pulmonary valve	None
Hypoplastic LV mitral stenosis, suspect coarctation, PAH	11	Transfer to tertiary-care center	Same (personal communication)	None
TOF/PA	56	Ongoing care	Same	None
Hypoplastic left heart syndrome[a]	1	Transferred to UAMC	Same	None
Repaired AV canal[a]	9 years	Continued outpatient follow-up	Same	None
Repaired interrupted aortic arch[a]	10.5 years	Continued outpatient follow-up	Same	None

[a]Underwent videotaped (recorded) echocardiogram studies; all others underwent tele-echocardiogram (tele-echo) studies.

AI, aortic insufficiency; ASD, atrial septal defect; AV, atrioventricular; CHD, congenital heart disease; CHF, congestive heart failure; DILV, double-inlet left ventricle; LA, left atrial; LV, left ventricle; MAPCA, multiple aortopulmonary artery collaterals; MPA, main pulmonary artery; NA, information not available; PA, pulmonary atresia; PAH, pulmonary artery hypertension; PI, pulmonary insufficiency; PS, pulmonary valve stenosis; PV, pulmonary valve; SVC, superior vena cava; TGA, transposition of great arteries; TOF, tetralogy of Fallot; UAMC, University of Arizona Medical Center; VSD, ventricular septal defect; YRMC, Yuma Regional Medical Center.

(26%). There was one (2%) major discrepancy—a missed coronary fistula in the context of a newborn with a significant ventricular septal defect and heart failure (*Table 4*). The patient was transported to The University of Arizona and on the initial PedsCard-echo study was also found to have a significant coronary artery-to-left atrial fistula. The patient underwent coil embolization of the fistula; therefore according to our definition, this condition was categorized as a major discrepancy.

Follow-up PedsCard-echo studies were available in 70 of the 229 patients (30%) who had undergone recorded-echo studies during the years 2006–2009, at a median age of 56 days (quartile range, 228 days) following the recorded-echo. Comparison between recorded-echo and PedsCard-echo yielded no diagnostic discrepancies in 28 (40%) patients, expected resolution of condition in 14 (20%) patients, and minor discrepancies in 28 (40%) patients. There were no major discrepancies seen. The overall distribution of diagnoses (categories are no discrepancy, expected resolution of condition, and major and minor discrepancies) differed significantly between the recorded-echo versus PedsCard-echo study category and the tele-echo versus PedsCard-echo study category. Although there was a higher percentage of total discrepancies in the recorded-echo versus PedsCard-echo study category (40% versus 28%), this difference was not statistically significant.

Four patients with complex CHD who had undergone tele- and recorded-echo studies during the year 2010 showed no significant discrepancies on follow-up PedsCard-echo studies. Only a few

Table 5. Comparison of Diagnoses Between Tele-Echocardiogram ($n = 53$) and Recorded Echocardiogram ($n = 70$) Studies Versus the Respective Follow-Up PedsCard-echo

	NUMBER (%)	
	TELE-ECHO VERSUS PEDSCARD-ECHO	RECORDED-ECHO VERSUS PEDSCARD-ECHO
No discrepancy	12 (23)[a]	28 (40)
Expected resolution of condition	26 (49)[a]	14 (20)
Minor discrepancy	14 (26)	28 (40)
Major discrepancy	1 (2)	0
Total discrepancies (major + minor)	15 (28)[a]	28 (40)

[a] $p < 0.01$ comparing these three tele-echocardiogram (tele-echo) categories with echocardiogram recorded digitally or on videotape (recorded-echo) versus echocardiogram performed by a pediatric cardiologist (PedsCard-echo) categories.

patients who had undergone tele- and recorded-echos during 2010 who were diagnosed with non-critical disease were available for follow-up, and no significant discrepancies were seen.

STUDY QUALITY ANALYSIS

There were 52 tele-echo and 106 recorded-echo reports in the category DNAD (*Table 6*). There was a significantly fewer total number of tele-echo studies in this category versus recorded-echo studies (18.6% versus 36%; $p < 0.001$) during the years 2006–2009. The annual percentage of tele-echo studies in this category remained stable during the years 2007, 2008, and 2009; however, by 2010 the number of tele-echo studies in this category decreased significantly ($p < 0.01$) to 4.5%. The percentage of recorded-echo studies in the DNAD category remained high during the years 2006–2008; a significant ($p < 0.001$) decrease was seen in 2009 versus 2008, and an additional, significant decrease ($p < 0.01$) to 6.6% was seen during year 2010. There was no significant difference in the number of studies in this category between tele-and recorded-echos during the year 2010. Additional review showed that 94% of tele-echo studies and 86% of recorded-echo studies in the DNAD category were in the diagnostic categories of non-critical disease and PDA.

Table 6. Tele-Echocardiogram and Echocardiogram Recorded Digitally or on Videotape Study Quality

	NUMBER OF TELE-ECHOS		NUMBER OF RECORDED-ECHOS	
YEAR	IN DNAD CATEGORY (%)	TOTAL PER YEAR	IN DNAD CATEGORY (%)	TOTAL PER YEAR
2006	2 (40)	5	1 (50)	2
2007	9 (17.3)	52	39 (32)[a]	122
2008	18 (19.5)	92	42 (58)[b]	73
2009	19 (17.4)	109	11 (18)[c]	61
2010	4 (4.5)[d]	88	13 (6.6)[e]	197

[a] $p = 0.05$, [b] $p < 0.001$ versus tele-echocardiogram (tele-echo).

[c] $p < 0.001$ versus echocardiogram recorded digitally or on videotape (recorded-echo) 2008.

[d] $p < 0.01$ versus tele-echo 2009.

[e] $p < 0.01$ versus recorded-echo 2009

DNAD, data not adequate for diagnosis.

Discussion

Echocardiography is a standard, reliable, and indispensable tool for diagnosing CHD and is essential to the management of newborns in intensive care units.[8] The accuracy of echocardiograms depends on technical expertise of the sonographer performing the study and expert interpretation of the images by a pediatric cardiologist. With the advent of telemedicine, sonographers not trained in CHD are performing pediatric echocardiograms. Although there are numerous reports/studies attesting to the value of tele-echocardiography in neonates and children,[9–14] little information exists on the change in study quality as adult sonographers gain knowledge and experience in CHD.

The most important finding of this study is that the quality of pediatric echocardiograms performed by adult sonographers appeared to have improved by the fourth year of this study. We found a significant decrease in both tele- and recorded-echo studies in the category DNAD in the year 2010 compared with the previous years. Although tele-echo studies appeared to be of higher quality compared with recorded-echo studies during the years 2007 and 2008, by 2009 the percentages of tele- and recorded-echo studies in this category were similar, and a further significant decrease was seen by 2010. In addition, we found no significant difference in discrepancies between tele- and recorded-echo studies. There was no change in equipment or in the adult cardiac sonographer staff during the years 2006–2010. Several possible reasons could account for the improved quality of these studies, including improved sonographer technique in obtaining views from subcostal or suprasternal notch windows, specific to pediatric echocardiograms, as well as enhanced experience in calming and controlling newborns during the studies. We speculate that direct supervision by a pediatric cardiologist during tele-echo studies played a role in the overall sonographer's improved technique.

Other investigators have addressed tele-echo study quality. Lewin et al.[15] reported fewer discrepancies in tele- versus recorded-echo studies and concluded that recorded-echo studies may be less accurate than tele-echo studies. Our data indicate that by the fourth year of our study more than 90% of both tele- and recorded-echo studies were technically adequate, and no difference in discrepancies was found during the study period. Sable et al.[2] concluded that supervised telemedicine encounters lead to improved diagnostic quality of echo studies but did not describe how this improvement was determined. Randolph et al.[16] noted that all patients with significant CHD required additional imaging directed by a cardiologist early in their study, but additional studies were rarely needed in these types of patients by the end of their study period. These results are consistent with our data, which showed significantly fewer unreliable tele- and recorded-echo studies in the fourth year of our study.

There are established American Society of Echocardiography guidelines on training pediatric cardiac sonographers[17]; however, there are no standard recommendations for transitioning adult cardiac sonographers to become skilled in pediatric echocardiography. In light of the recent American Academy of Pediatrics recommendations suggesting the use of pulse oximetry to screen for serious CHD, it is anticipated that more pediatric echocardiograms will be performed remotely by sonographers not trained in CHD. Many of these may be via telemedicine with supervision or recorded without supervision and transmitted for interpretation at a later time. Our data suggest that it will be important to take sonographer experience with CHD into account when interpreting remote echocardiograms in newborns with abnormal pulse oximetry.

The data in our study show that both tele- and recorded-echo studies aided in the remote diagnosis of CHD and in evaluating neonates, infants, and children who require echocardiograms. Telemedicine has the additional advantage of immediate interpretation and diagnosis, which enhance efficiency and timely care of patients. Telemedicine will continue to play an important role in patient care, especially as the technology and infrastructure becomes more widespread.

Our data are consistent with those of other investigators[1,2,5,15] and show that large numbers of tele-echo studies were performed successfully with excellent-quality technical images and accuracy. Possible reasons for the marked increase in recorded-echo studies during the year 2010 include neonatologists' and pediatricians' preferences for ordering echocardiograms. The difference in the distributions of diagnostic categories between tele- and recorded-echo studies could be due to elective referral from outside pediatricians of some of the patients in the recorded-echo category compared with newborn intensive care unit-based referrals of almost all patients in the tele-echo category.

Several possible limitations could affect the results of our study. First, the data were reviewed in a retrospective manner. Second, there was no objective measurement of sonographers' skills. Third, the percentage of follow-up PedsCard-echo studies was 27–30%. This rate of follow-up is, however, within the range reported in the literature.[5,14,18]

Taken together, our data show that (1) large numbers of tele-echo studies were performed with excellent quality and accuracy, (2) there was improvement in sonographer skill during the fourth year of the study, and (3) although initially tele-echo studies were more accurate than recorded-echo studies, there was no significant difference in quality between tele- and recorded-echo studies by the fourth year of the study. This information could be important as the new American Academy of Pediatrics screening guidelines for serious CHD in newborns are implemented.

Acknowledgments

The authors are grateful to Ms. Phyllis Webster, The University of Arizona Telemedicine Program Senior Coordinator, for her skilled assistance with telemedicine echocardiogram clinics and to the cardiac sonographers at Yuma Regional Medical Center, Yuma, AZ, who participated in this work.

Disclosure Statement

No competing financial interests exist.

REFERENCES

1. Sable CA, Cummings SD, Pearson GD, et al. Impact of telemedicine on the practice of pediatric cardiology in community hospitals. *Pediatrics* **2002;**109:E3.
2. Sable C, Roca T, Gold J, et al. Live transmission of neonatal echocardiograms from underserved areas: Accuracy, patient care, and cost. *Telemed J* **1999;**5:339–347.
3. Finley JP, Human DG, Nanton MA et al. Echocardiography by telephone—Evaluation of pediatric heart disease at a distance. *Am J Cardiol* **1989;**63:1475–1477.
4. Sable C. Digital echocardiography and telemedicine applications in pediatric cardiology. *Pediatr Cardiol* **2002;**23:358–369.
5. Grant B, Morgan GJ, McCrossan BA, et al. Remote diagnosis of congenital heart disease: The impact of telemedicine. *Arch Dis Child* **2010;**95:276–280.
6. Kemper AR, Mahle WT, Martin GR, et al. Strategies for implementing screening for critical congenital heart disease. *Pediatrics* **2011;**128: e1259–e1267.
7. Preacher KJ. Calculation for the chi-square test: An interactive calculation tool for chi-square tests of goodness of fit and independence [computer software]. April 2001. Available at http://quantpsy.org (last accessed February 2012).
8. Lai WW, Geva T, Shirali GS, et al. Guidelines and standards for performance of a pediatric echocardiogram: A report from the task force of the Pediatric Council of the American Society of Echocardiography. *J Am Soc Echocardiogr* **2006;**19:1413–1430.
9. McCrossan BA, Grant B, Morgan G, et al. Diagnosis of congenital heart disease in neonates by videoconferencing: An eight-year experience. *J Telemed Telecare* **2008;**14:137–140.
10. Tsilimigaki A, Maraka S, Tsekoura T, et al. Eighteen months' experience with remote diagnosis, management and education in congenital heart disease. *J Telemed Telecare* **2001;**7:239–243.
11. Widmer S, Ghisla R, Ramelli GP, et al. Tele-echocardiography in paediatrics. *Eur J Pediatr* **2003;**162:271–275.
12. Huang T, Moon-Grady AJ, Traugott C, Marcin J. The availability of telecardiology consultation and transfer patterns from a remote neonatal intensive care unit. *J Telemed Telecare* **2008;**14:244–248.
13. Sable C. Telemedicine applications in pediatric cardiology. *Minerva Pediatr* **2003;**55:1–13.

14. Gomez R, Rossi R, Lima S, et al. Pediatric cardiology and telemedicine: Seven years' experience of cooperation with remote hospitals. *Rev Port Cardiol* **2010;**29:181–191.

15. Lewin M, Xu C, Jordan M, et al. Accuracy of paediatric echocardiographic transmission via telemedicine. *J Telemed Telecare* **2006;**12:416–421.

16. Randolph GR, Hagler DJ, Khandheria BK, et al. Remote telemedical interpretation of neonatal echocardiograms: Impact on clinical management in a primary care setting. *J Am Coll Cardiol* **1999;**34:241–245.

17. Ehler D, Carney DK, Dempsey AL, et al. Guidelines for cardiac sonographer education: Recommendations of the American Society of Echocardiography sonographer training and education committee. *J Am Soc Echocardiogr* **2001;**14:77–84.

18. Justo R, Smith AC, Williams M, et al. Paediatric telecardiology services in Queensland: A review of three years' experience. *J Telemed Telecare* **2004;**10(Suppl 1):57–60.

Address correspondence to:
Daniela Lax, M.D.
Department of Pediatrics
Arizona Health Sciences Center, 3302
The University of Arizona
P.O. Box 245073
1501 North Campbell Avenue
Tucson, AZ 85724

E-mail: dlax@peds.arizona.edu

Received: February 10, 2012
Revised: March 19, 2012
Accepted: March 19, 2012