SHORT REPORT

Expanding telehealth through technology: Use of digital health technologies during pediatric electrophysiology telehealth visits

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Introduction

Technology has become increasingly prominent in the healthcare field, ranging from consumer-based digital health (DH) technologies to evolving telehealth (TH) programs. Importantly, TH programs have been reported as high quality and safe, and have increased access to patients located in geographic regions with limited access to resources.[1,2] In the field of pediatric cardiology, TH programs underwent exponential growth during the during the COVID-19 pandemic to limit exposure to both patients and providers.[3] The fundamental importance of video-based teleconsultations has been linked to reduced travel time and costs; however, there remains significant concern about the long-term viability of TH programs, given the absence of vital sign measurements, physical exam, and routine cardiac testing.[4] Recent advancement in DH and wearable technologies may offer potential solutions to these limitations.[5] Although improvements in DH technologies have the capacity to expand TH practices, the inconsistent reliability of device data and burden to patients and the hospital system are potential limitations to widespread adoption.[5]

This study aims to create a loaner program of DH cardiothoracic technologies (both prescription and direct to consumer) by providing patients with technologies to augment the TH visit, including pulse oximetry, electrocardiography (ECG), and cardiopulmonary auscultation, and to assess patient and provider usability preferences for these devices.

KEYWORDS Pediatrics; Cardiac wearable devices; Digital health; ECG monitoring; Pulse oximetry; Electronic stethoscope; Digital stethoscope
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Methods

After receiving approval from the Washington University School of Medicine Institutional Review Board, patients that met study inclusion criteria were contacted via telephone by the research team and verbal consents (and assents, for patients <18 years old) were obtained. Inclusion criteria were as follows: (1) patients scheduled for a TH clinic visit with a pediatric electrophysiology (EP) provider at Washington University, (2) valid mailing address, (3) the ability to use a smartphone, and (4) access to the MyChart application in the EPIC electronic medical record (EMR) (if the patient did not have MyChart access, the study team assisted the patient/family in obtaining MyChart access). Exclusion criteria included the following: (1) non-English-speaking patients, (2) patients who were wards of the state, and (3) preterm newborns. The research team performed a thorough literature review of available pediatric data in a variety of DH technologies; and if data were unavailable, in-house testing was completed to assess quality prior to using a technology in this study.

Demographic data, diagnosis, and zip codes were collected from electronic chart review for the enrolled patients. After consent was obtained, and prior to the TH appointment, a DH "technology kit" was mailed (via FedEx) to the patient. There were 2 kits, which were serially cleaned and sent to patients as part of the study. Kits contained DH technologies for real-time cardiothoracic data collection during their TH appointment, including chargers and cables. Six DH technologies were included: an iPhone SE for data collection and app use, 3 ECG devices (Apple Watch Series 6, Coala monitor, and AliveCor Kardia monitor [single lead]), 2 pulse oximeters (Apple Watch Series 6 and iHealth pulse oximeter), and 2 digital stethoscopes (Coala monitor and Stethee Pro device) (Figure 1) In addition, the kit also contained a printed copy of the telephone consent for the patient to keep, a prepaid shipping label, a patient usability

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KEY FINDINGS

- A digital health (DH) technology kit was assembled and mailed to patients prior to their pediatric electrophysiology telehealth (TH) visit.
- Use of these technologies during the study demonstrated that patients had increased confidence in their TH visit; providers agreed that incorporation of these DH technologies in the TH visit did enhance the experience.
- Patients expressed high likelihood to schedule repeat TH visit if DH technologies were included.
- This type of DH technology kit loaner program could be used to increase outreach potential.
- Electronic medical record integration of these data is integral to long-term sustainability of this type of model.

survey, and a user guide for the visit. Patients were asked to ensure all the devices in the technology kit were charged prior to the initiation of the TH appointment and to connect the iPhone to a local wireless internet connection. At the start of the visit, a member of the research team ensured that all DH technologies were connected via Bluetooth to the preloaded iPhone. Patients were instructed on the use of each DH device and real-time cardiovascular data were obtained. Typically, visits began with use of the digital stethoscopes, obtaining both cardiac and lung auscultation recordings, which were then uploaded to the patients' respective dashboards, which could be accessed by the provider. Pulse oximetry data were obtained as follows: (1) using the iHealth device, with verbal reporting of results via the iHealth app (preloaded on the iPhone in the "technology kit"); and (2) using the AW6 and verbal reporting of result. Finally, ECG tracings were obtained and either exported to iCloud via the Notes application (KardiaMobile and AppleWatch) or to the company-specific dashboard (Coala). These tracings were reviewed by the provider and discussed during the TH visit.

Upon termination of the appointment, the patients and providers separately filled out a satisfaction/usability survey. The responses were quantified using a Likert scale, ranging from 1 to 5 (1 = strongly disagree to 5 = strongly agree).

Statistical analysis

Descriptive analyses are reported with frequencies and percentages. Where appropriate, mean averages are provided (with range).

Results

Demographic data

Thirty patients were enrolled in this study; 55.7% (17/30) were female. Average patient age was 11.6 years (range 0.4–20 years) and 70% of patients (21/30) were between ages 10 and 20 years. The most frequent diagnoses prior to the TH appointment included supraventricular tachycardia / atrial tachycardia (15/30, 50%), family history of inherited arrhythmia syndrome (4/30, 13.3%), and syncope / near syncope (3/30, 10%). The TH appointments were conducted by 4 pediatric EP providers at Washington University in St. Louis / St. Louis Children's Hospital (Table 1).

Equipment and mailing costs

The total cost for equipment per technology kit was $2127.98, including an iPhone SE 64GB ($399.99), iPhone case ($9.99), Apple Watch Series 6 ($599.00), Apple Watch charger ($29.00), Coala monitor ($414.00), Stethee Pro ($499.00), iHealth wireless pulse oximeter ($59.99), AliveCor KardiaMobile Monitor ($89.00), and AliveCor KardiaMobile Carry Pod ($29.00). The average round-trip shipping cost per technology kit was $18.13 (range $8.83–$42.05) using the University FedEx account.

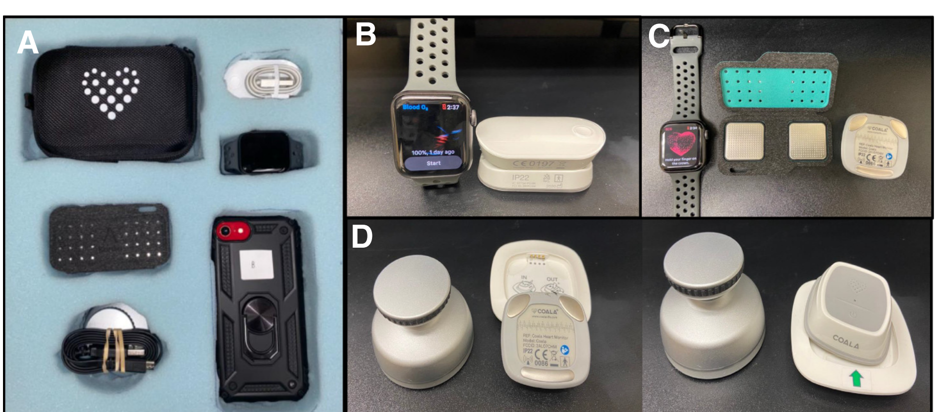

Figure 1 Digital health (DH) technology kit. **A:** Full DH technology kit containing all technologies and their chargers. **B:** Pulse oximetry devices: Apple Watch Series 6 and iHealth pulse oximeter. **C:** Electrocardiography devices: Apple Watch Series 6, AliveCor Kardia monitor, and Coala monitor. **D:** Digital stethoscopes: Stethee Pro and Coala monitor.

Table 1 Demographic data

	Value (N = 30 patients)
Sex	
Female	17 (56.7%)
Male	13 (43.3%)
Age range	
0–5 years	4 (13.3%)
6–9 years	5 (16.7%)
10–14 years	10 (33.3%)
≥15 years	11 (36.7%)
Primary diagnosis	
SVT / atrial tachycardia	16 (53.3%)
Family Hx of arrhythmia syndrome	4 (13.3%)
Syncope / near-syncope	3 (10.0%)
Inherited arrhythmia syndrome / genetic mutation	2 (6.7%)
Sinus pause	2 (6.7%)
Inappropriate sinus tachycardia	1 (3.3%)
Abnormal ECG	1 (3.3%)
Palpitations	1 (3.3%)
Distance from clinic, mean average (miles)	115.6 miles (12.6–222.6 miles)

ECG = electrocardiogram; Hx = history; SVT = supraventricular tachycardia.

Data quality

Data quality from the DH devices were assessed by providers using the postvisit usability survey. For ECG devices, providers reported high-quality tracings (Figure 2) from KardiaMobile (62%; 18/29), Apple Watch (93%; 28/30), and Coala monitor (86%; 24/28), with no physician preference in type of ECG or pulse oximetry device used. Assessment of digital stethoscopes found high-quality heart sounds in 52% (15/29) and lung sounds in 69% (20/29) from the Coala monitor, vs 67% (18/27) for heart sounds and 74% (20/27) for lung sounds from the Stethee Pro. Navigation of the Coala monitor and Stethee Pro dashboards was reported as easy, 78% (18/23) and 84% (21/25), respectively, and were equally easy to use (Figure 3A).

Provider survey results

From the provider survey, 90% (26/29) of responses agreed that DH devices used during the appointment were easy for patients to use, and those DH technologies assisted with patients' diagnosis and counseling 67% of the time (20/30 responses). Providers agreed that the data from the DH devices were available in real time 86% (25/29) of the time. In 63% (19/30) of visits, providers agreed that DH technologies were helpful in medical decision-making and 70% (21/30) agreed / strongly agreed that using DH technologies during the appointment enhanced the experience (Figure 3B).

Patient survey results

A total of 98% (29/30) of patients or families agreed / strongly agreed that DH devices and applications used during the appointment were easy to use, with ease of use at 97% (28/29) for ECG devices, 100% (29/29) for pulse oximeter, and 100% (30/30) for digital stethoscopes (Figure 4A), also with no significant preference for any device in any category (Figure 4B). All patients agreed that the use of DH

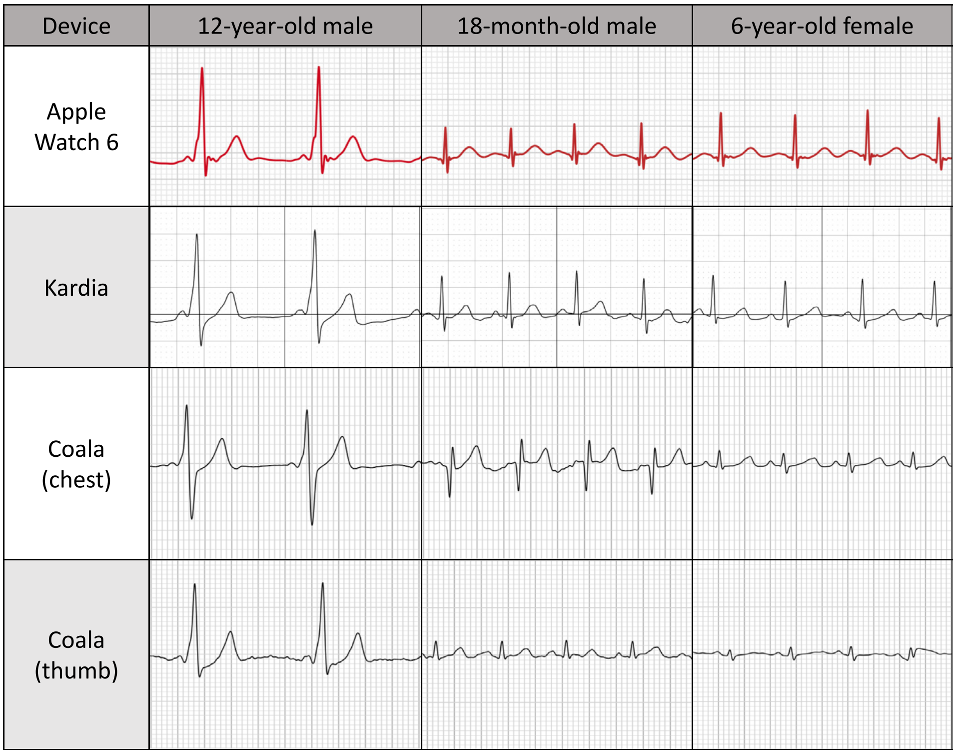

Figure 2 Comparison of electrocardiography tracings across devices for 3 patients of different ages.

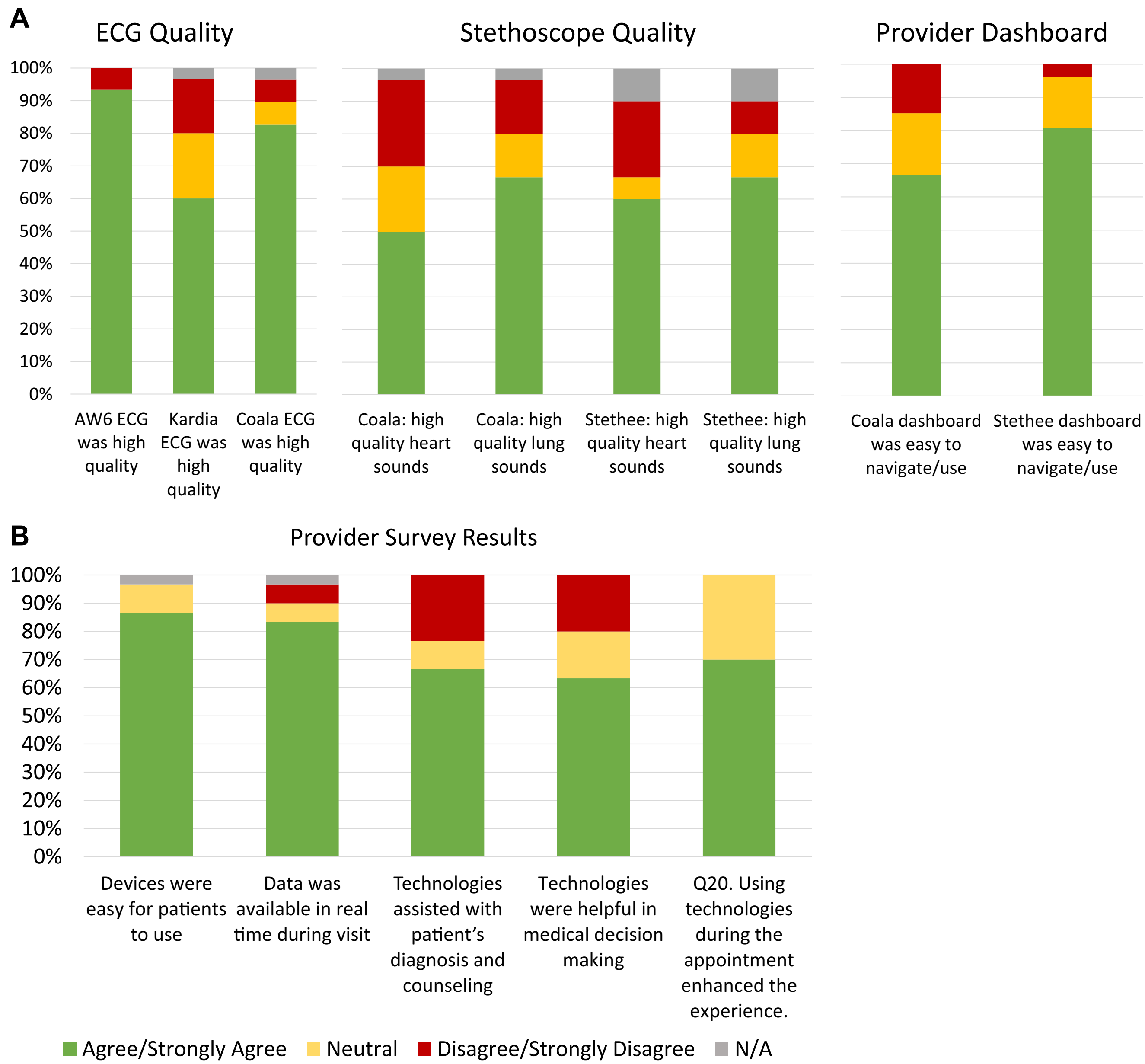

Figure 3 Provider survey results. **A:** Device usability and satisfaction responses. Statements shown along the x-axis and percentage response on the y-axis. The green bars represent percentage of providers that agreed / strongly agreed with the statement. Yellow bars represent percentage of providers that were neutral, red represents percentage of providers that disagreed / strongly disagreed, and gray bars represent percentage of responses that were blank or N/A. **B:** Data quality. Statements regarding data quality on the x-axis and percentage of responses on y-axis. Same color representation as Figure 4A. AW6 = Apple Watch Series 6; ECG = electrocardiogram; N/A = not applicable.

technologies during the appointment made them more confident in the quality of the visit. Of the 9 patients that had a previous in-person visit with an electrophysiologist, all (9/9, 100%) agreed that their TH visit was as good as their in-person visit. Importantly, 87% (26/30) of responders agreed that they would be more likely to schedule a TH visit if DH technologies were used.

Discussion

DH technology kits have been used to reduce readmission following cardiac surgery; however, to our knowledge, this is the first usability study for returnable DH technology kits in pediatric EP.[6] Importantly, these data demonstrate that patients had increased confidence in their TH visit with the incorporation of DH technologies, and providers agreed that incorporating DH technologies into the TH visit did enhance the experience. Additionally, these data demonstrate a high likelihood that patients would schedule TH clinics again if DH technologies were included. These results suggest that this type of program could be adopted on a larger scale and increase a clinic's outreach potential.

Integration of data acquired from DH technologies into the EMR will become essential for DH technologies moving

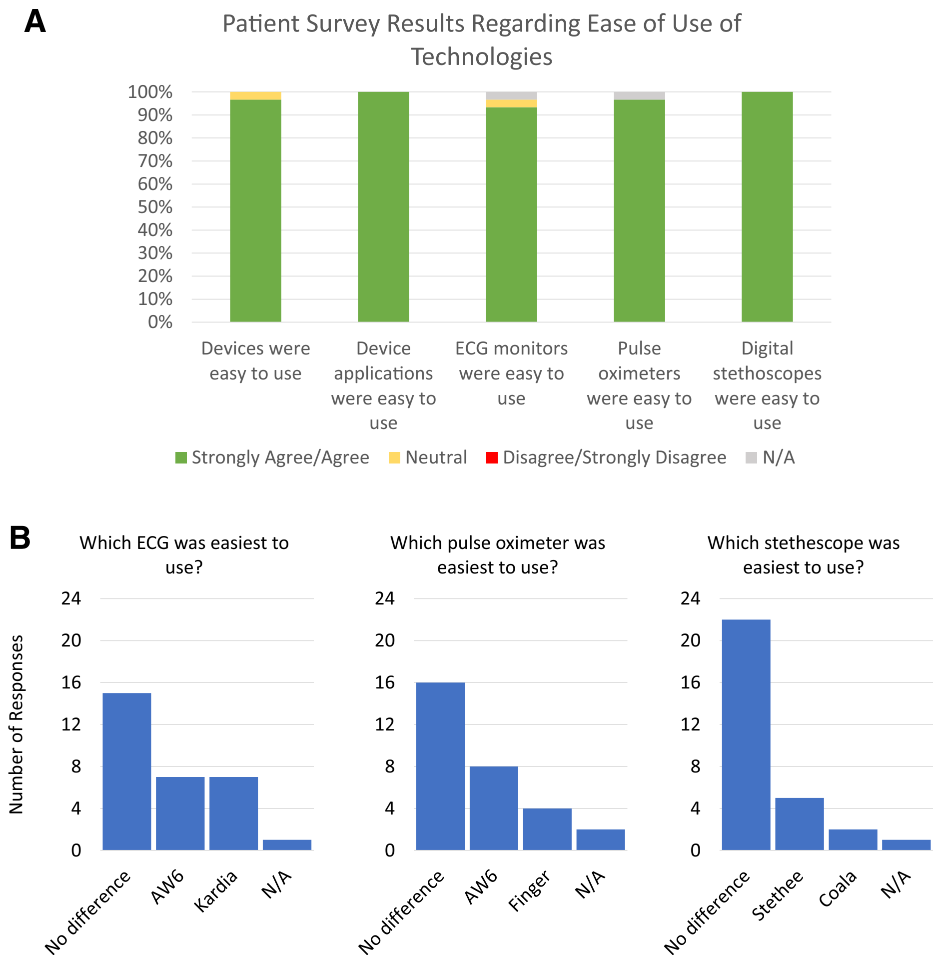

Figure 4 Patient survey results. **A:** Patient device preference. Responses shown on x-axis and number of responses on y-axis. **B:** Responses regarding ease of use. Statements shown along the x-axis and percentage response on the y-axis. The green bars represent percentage of patients that agreed / strongly agreed with the statement. Yellow bars represent percentage of patients that were neutral, red represents percentage of patients that disagreed / strongly disagreed, and gray bars represent percentage of responses that were blank or N/A. AW6 = Apple Watch Series 6; ECG = electrocardiogram; N/A = not applicable.

forward. Previously, we have described our method for integration of ECG data from patients with direct-to-consumer ECG devices.[7] While the data during this study were not incorporated into the patient's EMR, the sustainability of a program like this would necessitate this incorporation. We observed that the electronic stethoscopes provided both a report (including heart rate, systolic and diastolic time, etc) and a scannable QR code, which links to the patient's audio file for cardiac and pulmonary auscultation. This report could be added to the EMR and, ideally, linked to the patient visit, allowing for long-term, longitudinal follow-up data. This addition of audio files to the EMR may be of particular use in monitoring for progression of murmurs, including valvar insufficiency or stenosis. Additionally, artificial intelligence–assisted digital stethoscopes now have the potential to inexpensively and noninvasively assess, and potentially prognosticate, clinical progression in valvular heart disease, heart failure, and other cardiac structural and functional heart disease. Continued investigation into the use of digital stethoscopes in a more heterogeneous pediatric cardiology cohort may be useful in determining quality of digital auscultation across substrates.

Based on our experience creating this program, it would be prudent to consider implementing a "rental agreement" between the clinic and the patient. Additionally, to support a high-volume TH program with technology kits, support staff would be needed to manage kit shipping and maintenance. Reimbursement issues, which have historically limited the widespread adoption of TH, will be an issue when implementing TH programs with DH loaner technology kits. We are unaware of CMS TH modifier codes to account for real-time assessment of ECG data or cardiothoracic auscultation information during TH visits. This may add to the barrier of widespread adoption of such a program moving forward.

Study limitations

An important limitation of this study is the reliance on patient-accessible Wi-Fi networks, coupled with a working knowledge of DH technologies. We observed that our younger patients often had an incomplete data set, which may be attributable to poor contact and small anatomy. Inconsistent availability of device-specific dashboards owing to University firewalls may inhibit the ability to assess data in real time. Lastly, none of these technologies were assessed in this study against their gold-standard counterparts, so no assessment of data accuracy or reliability can be made, though previous studies in the literature have supported the use of both KardiaMobile and Apple Watch 6 in the pediatric population.[8–12]

Conclusion

DH technology loaner kits enhance the TH visit by providing patients and providers with a modified physical examination and diagnostic tools. Our study shows that DH technologies were widely accepted by our pediatric EP patients and families for both their ease of use and the increased confidence provided during their TH visits. Expansion of TH can provide high-quality TH appointments by increasing access and equity in specialized care.

Funding Sources

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Disclosures

The authors have no relevant conflicts to disclose. J.N.A.S. is the co-inventor and co-founder for Sentiar and has licensed intellectual property to that entity. These disclosures are not relevant to the presented work.

Authorship

All authors attest they meet the current ICMJE criteria for authorship.

Patient Consent

All patients provided written informed consent (and assent, as appropriate).

Ethics Statement

The authors designed the study and gathered and analyzed the data according to the Helsinki Declaration guidelines on human research. The research protocol used in this study was reviewed and approved by the institutional review board.

Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.cvdhj.2022.07.003.

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