



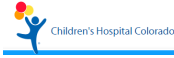
<https://www.jama.com/newsroom/2018/12/18/long-term-irregular-heart-rhythm-notification-available-online-on-apple-watch/>

"But my watch said.....":

Interpreting wearable data in the pediatric population





Johannes von Alvensleben, MD
Associate Professor of Pediatrics
Director, Arrhythmia and Electrophysiology Service




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Disclosures


None



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Outline

- Increase familiarity with common wearables and the underlying technology
- Review the representative literature on wearables and electrophysiologic interpretation
- Understand the accuracy and limitations of data provided from wearables used in the pediatric population



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Clinical Case

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16 y.o. girl presenting for well child visit

Complaint: intermittent heart racing
 Seems to be associated with periods of stress (e.g. finals week)
 Mother wonders if it is anxiety but thought they would bring it up just in case
 Patient and family are provided reassurance and asked to check back in if symptoms continue during winter break

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F/u MyChart message

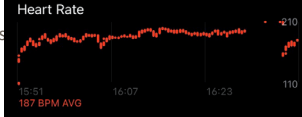
- Patient was on a workout and heart suddenly felt "fluttery and fast"
- Palpitations stopped after 10 minutes
- Attached a snapshot of the workout episode

Workouts Thu, Mar 11

Avg. Cadence	Avg. Heart Rate
168SPM	187BPM
Avg. Pace	
8'46"/MI	

Splits

Heart Rate



15:51 187 BPM AVG 16:07 16:23 110


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Do you trust the data?



<https://www.apple.com/newsroom/2018/12/12/cap-app-and-ir-regular-heart-rhythm-notification-available-today-on-apple-watch/>

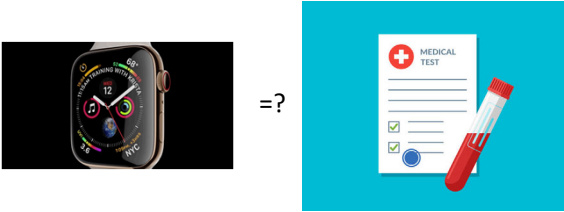
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Do you trust the data?



<https://www.apple.com/newsroom/2018/12/12/cap-app-and-ir-regular-heart-rhythm-notification-available-today-on-apple-watch/>

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Wearable technology: via Wikipedia

Wearable technology (i.e. **wearables**) are smart electronic devices that are worn close to and/or on the surface of the skin, where they detect, analyze, and transmit information concerning body signals such as vital signs, and/or ambient data and which allow in some cases immediate biofeedback to the wearer.

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Wearable Technologies

1550 1975 2022

https://en.wikipedia.org/wiki/Nuremberg_eggs http://www.vintagecalculators.com/html/puhsr_calculator_watch.html <https://ttechcrunch2011.files.wordpress.com/2011/06/wearables.jpg>

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<https://www.beaconlens.com/intersection-of-health-care-and-technology/>

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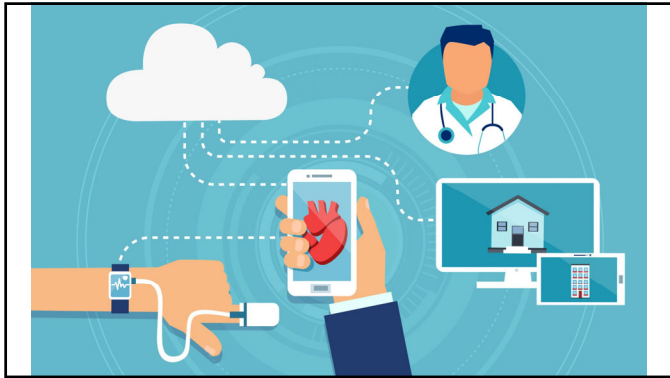
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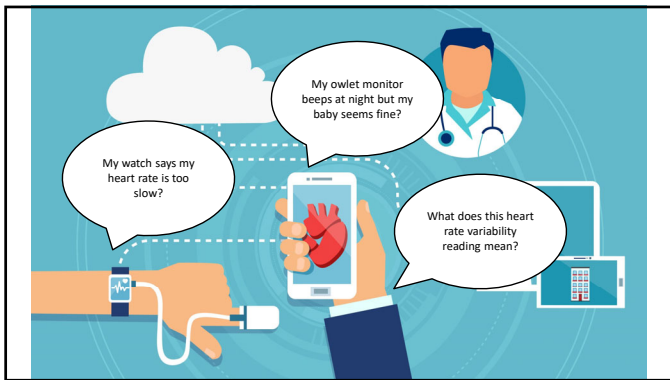
Medical Device Consumer Electronic

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The Big Three

fitbit
Good healthy habits and fun
run as a family with a Fitbit
Activity Tracker!

The Smart Sock
can help you
heart rate and
oxygen level

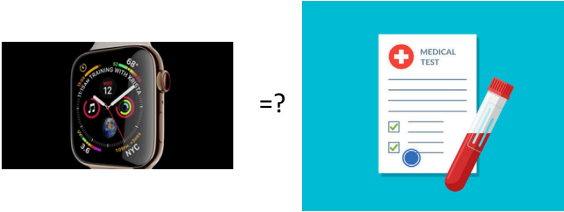
<https://www.apple.com/newsroom/2018/12/12/cap-app-and-ir-regular-heart-rhythm-notification-coming-today-on-apple-watch/>

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Do you trust the data?



<https://www.apple.com/newsroom/2018/12/12/cap-app-and-ir-regular-heart-rhythm-notification-coming-today-on-apple-watch/>

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BRIEF REPORTS | JUNE 28 2022

Characteristics of Emergency Room and Hospital Encounters Resulting From Consumer Home Monitors

Sansanee Craig, MD, MSc; Irit R. Rasooly, MD, MSCE; Andrew S. Kern-Goldberger, MD; Brooke Luo, MD; Mark V. Mal, MD, MHS; Jonathan M. Beus, MD, MS; J. Grey Faulkenberry, MD, MPH; Canita Brent, MPH; Daniel Herchline, MD, MEd; Naveen Muthu, MD; Christopher P. Bonafide, MD, MSCE

Address correspondence to Sansanee Craig, MD, Department of Biomedical and Health Informatics, Children's Hospital of Philadelphia, Roberts Center for Pediatric Research, 15th Floor, 2716 South St, Philadelphia, PA 19146. E-mail: craigs4@chop.edu

Hosp Pediatr (2022) 12 (7): e239–e244.
<https://doi.org.proxy.hsl.ucdenver.edu/10.1542/hpeds.2021-006438>

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BRIEF REPORTS | JUNE 28 2022

Characteristics of Emergency Room and Hospital Encounters Resulting From Consumer Home Monitors

Methods: Queried encounters across two institutions to assess for presentation to ED for use of "Consumer-Health Monitors"

36 encounters

- Leading discharge diagnoses were **viral infection (13, 36%) gastroesophageal reflux (8, 22%) and false positive alarm (6, 17%)**
- Median encounter duration was **20 hours (IQR: 3 hours to 2 days; max 10.5 days)**
- Median cost of encounters was **\$2188 (IQR: \$255 to \$7632; max \$84 928)**

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Smartwatches as wearable technology


Smartwatches are increasing in popularity and availability

Apple Watch accounted for more than 50% of the smartwatch sales in 2019

Sales outpaced the entire Swiss Watch industry

Increasingly marketed to teens and children

Apple extends the Apple Watch experience to the entire family

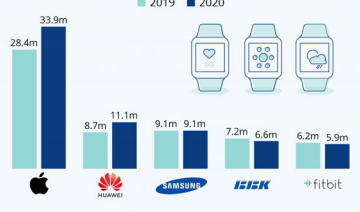


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Apple Several Ticks Ahead in the Smartwatch Market

Estimated global smartwatch shipments by the top 5 vendors



Vendor	2019 Shipments	2020 Shipments
Apple	28.4m	33.9m
Huawei	8.7m	11.1m
Samsung	9.1m	9.1m
LG	7.2m	6.6m
fitbit	6.2m	5.9m

Source: Counterpoint Research

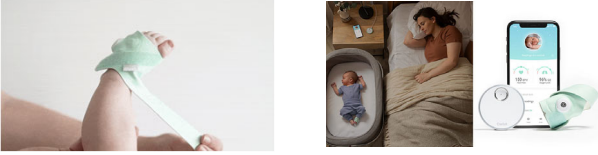
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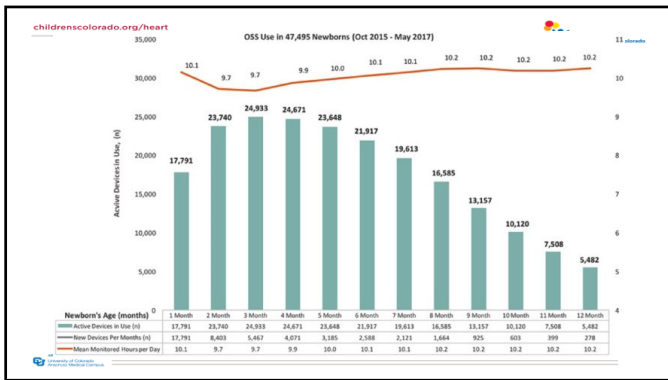


Owlet Smart Sock




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How do they work?



Heart rate monitoring

Photoplethysmography

Green LED/infrared LEDs transmitted

Some light absorbed, some reflected

Degree of absorption varies with blood flow in subcutaneous vascular beds

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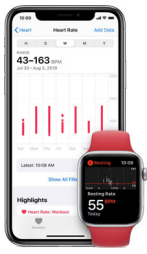
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Heart Rate Monitoring

Heart rate sampled variably depending on activity and mode

Data can be viewed as individual values or graphic trends

Reported accurate range of 30-210 bpm



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How do they work?

Pulse oximeter embedded sock

- Blue-tooth connection to a "base station"
- Transmits pulse ox and "Heart Rate" information that is available on demand

Photoplethysmography



The Smart Sock tracks baby's heart rate and oxygen level

Collects and trends data via WiFi (Bluetooth) to the Owlet app and the Base Station

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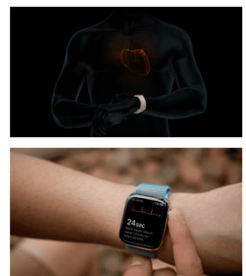

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ECG recording

Certain manufactures have ability to record a single lead ECG strip

- Electrodes on back of watch and crown
- Single lead ECG with closure of the circuit

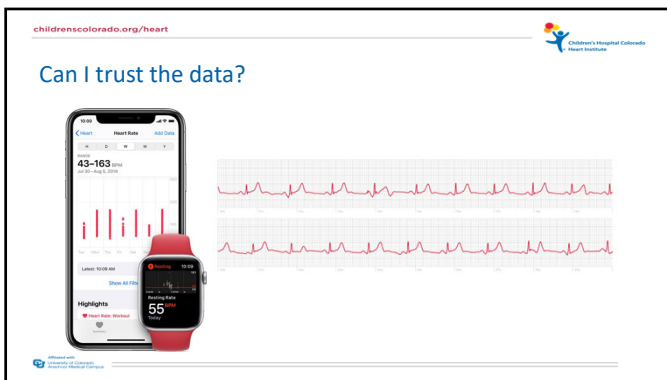
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<https://www.heart.org/stories/2019/07/22/apple-watch-series-4-ecg-app-available-canada/>

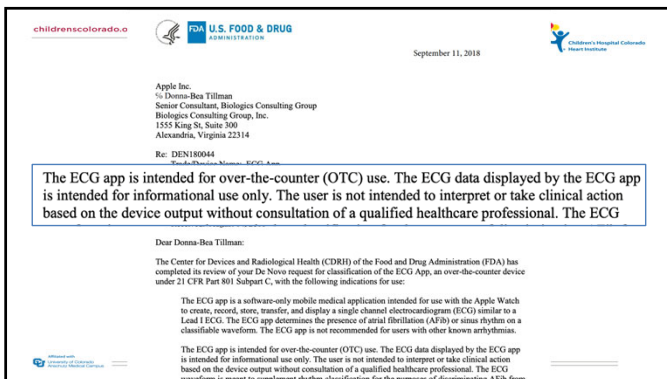
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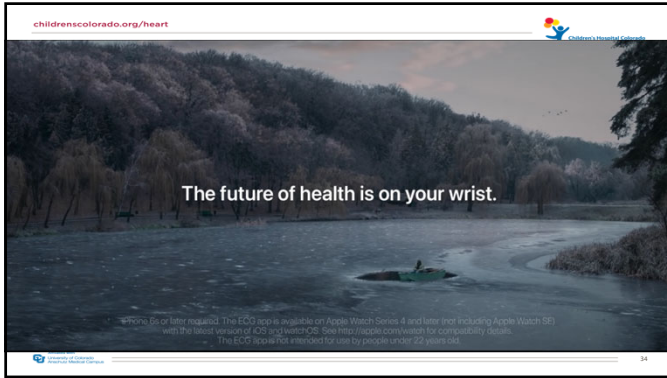
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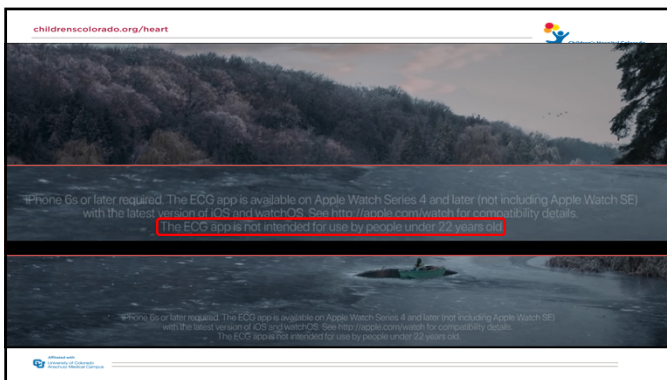
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Literature: Smartwatch HR Accuracy

Accuracy of Wrist-Worn Heart Rate Monitors
JAMA Cardiol. 2017;2(1):104-106. Wang R, et al.
 Prospective study of 50 healthy adults, comparing heart rate accuracy among various commercial heart rate monitors and ECG during exercise.

Device	Agreement With Electrocardiogram Concordance Correlation Coefficients (95% CI)
Polar H7	.90 (.887-.913)
Apple Watch	.81 (.804-.829)
Mio Fuse	.81 (.802-.828)
Fitbit Charge HR	.84 (.791-.872)
Basis Peak	.83 (.779-.865)

Assessing Accuracy of Wrist-Worn Wearable Devices in Measurement of Paroxysmal Supraventricular Tachycardia Heart Rate
Korean Circ J. 2019;49(5):437-445. Hwang J, et al.
 Prospective study of 51 adult patients with history of paroxysmal SVT wearing wrist based heart monitors during EP studies.

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AVNRT captured by Apple Watch Series 4: Can the Apple watch be used as an event monitor?

Hani Siddeek MD¹ | Kaylee Fisher² | Sandra McMakin³ | John L. Bass MD¹ | Daniel Cortez MD^{1,4}

¹Department of Pediatrics, University of Minnesota/Masonic Children's Hospital, Minneapolis, MN, USA
²Park Center, Minneapolis, MN, USA
³Fairview Health Systems, Minneapolis, MN, USA
⁴Clinical Sciences, Lund University, Lund, Sweden

Abstract
 Wrist-worn devices are popular for heart rate monitoring, including use of photoplethysmography. The Apple Watch series 4 can identify atrial fibrillation. We describe a case of identification re-entrant supraventricular tachycardia not identified by outpatient rhythm monitoring, however, was identified by the Apple Watch series 4, which lead to electrophysiology study and successful ablation of atrioventricular nodal re-entrant tachycardia.

KEYWORDS
 ablation, Apple Watch, AVNRT

Correspondence
 Daniel Cortez, Department of Pediatric Cardiology, University of Minnesota/Masonic Children's Hospital, Lund University, 2450 Riverside Avenue, Minneapolis, MN 55454, USA. Email: dcortez@umn.edu

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Owlet Smart Sock Accuracy

Internal Study 1

Registered in clinical trials, but data not published in peer-reviewed Journal

SpO2 Accuracy Comparison of Smart Sock V. 2 SpO2 to Arterial Blood CO-Oximetry

- 10 participants
- Age: 8-65 years
- Mean weight: 159 lbs
- Primary Outcome: Accuracy Root Mean Square (ARMS) 3% or Lower for range 70-100% between OSS and reference SpO2
 ARMS is the standard measurement for pulse oximetry
- 226 samples
- ARMS = 2.4%

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Research Letter FREE

August 21, 2018

Accuracy of Pulse Oximetry-Based Home Baby Monitors

Christopher P. Bonafide, MD, MSc¹, A. Russell Localio, PhD², Daria F. Ferro, MD³, et al

Author Affiliations | Article Information

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³Department of Biomedical and Health Informatics, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania
⁴Health Devices Group, ECRI Institute, Plymouth Meeting, Pennsylvania
⁵Division of Neonatology, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania

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chil THE JOURNAL OF PEDIATRICS • www.jpeds.com ORIGINAL ARTICLES

Detection of Tachyarrhythmias in a Large Cohort of Infants Using Direct-to-Consumer Heart Rate Monitoring

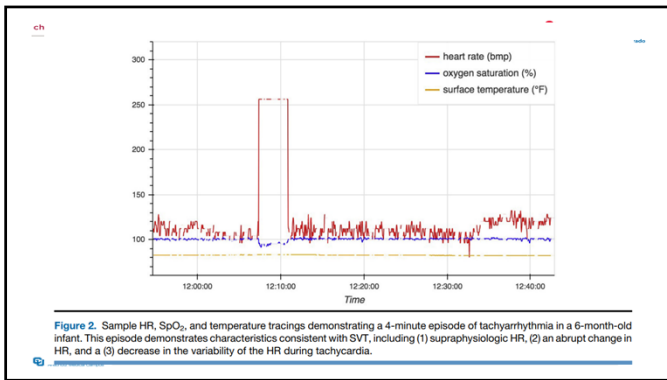
Scott Anjewierden, BS¹, Jeffrey Humpherys, PhD², Martin J. LaPage, MD³, S. Yukiko Asaki, MD⁴, and Peter F. Aziz, MD⁵

OWlet internal data set for 2017-2019 queried for HR >240 bpm for >60 seconds

- 100,949 infants monitored for >200 million total hours
- 5070 episodes of arrhythmia in 2508 infants
- Cumulative incidence of 2.5% over first year of life (> reported incidence of clinical diagnosis)
- Median age = 36 days
- Median length = 7.3 minutes

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Accuracy and Diagnostic Performance of the Apple Watch Cardiac Features in Pediatric Patients

Dustin Nash MD¹, Omar Shehab MD, Andrea Jones MD, Maully J. Shah MBBS^{1*}, Christopher Janson MD^{1*}

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Methods: Heart Rate Measurements

Inpatients on Telemetry	EPS	EST

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Methods: Heart Rate Measurements

AW and Gold Standard time-stamp differences were recorded to the second for each patient to allow for time synchronization

Apple Watch

Heart Rate: 196 BPM

Date: Apr 30, 2021 at 4:02:55 PM

Source: CHOP-AW's Apple Watch

Date Added to Health: Apr 30, 2021 at 4:02:59 PM

9:25:24

9:25:46

R-R

P-R 7.6 mm 0.304 sec 187 bpm

EKG 194

194 bpm 100-200 ms T2 REFERENCE 44% REFERENCE

Modality Avg

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Methods: ECGs on infants

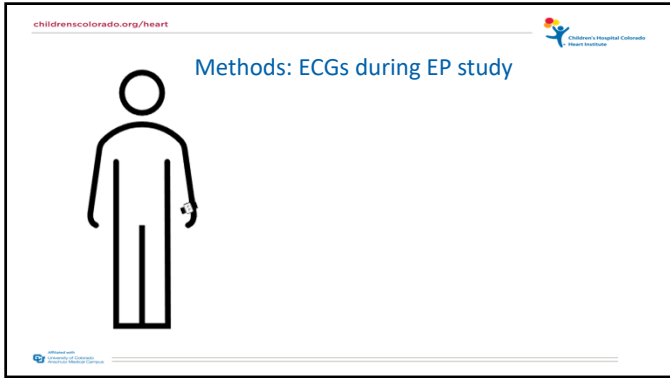
Heart Rate Over 120 - 128 BPM Average

This ECG was not checked for AFib because your heart rate was over 120 bpm. If you repeatedly get this result or you're not feeling well, you should talk to your doctor.

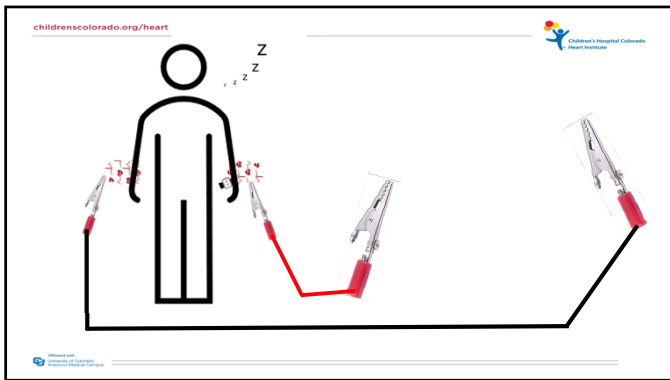
28 mmHg, 95 bpm, SpO2 95%, RR 128 bpm, PR 128 bpm - The hardware is similar to a LEAD ECG. For more information, see instructions for use.

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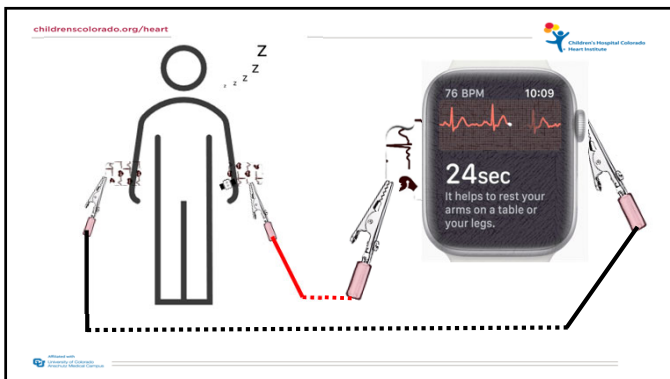
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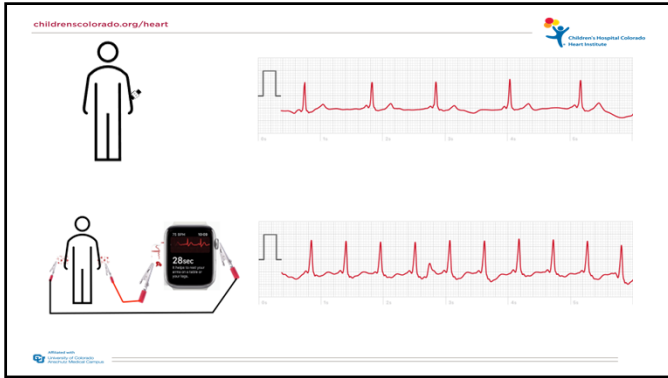
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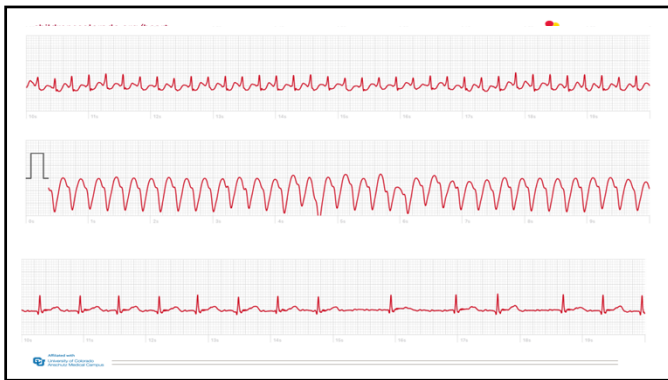
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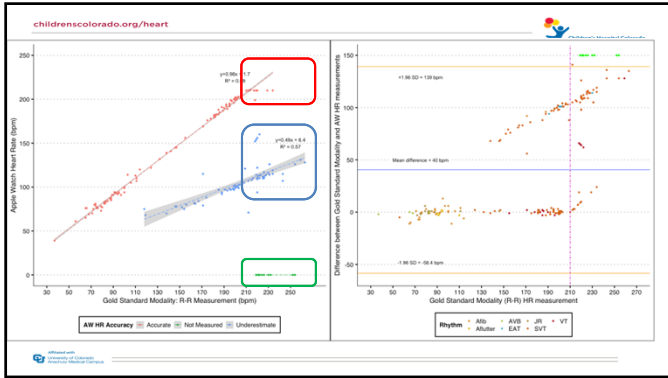
ECG Review

Smartwatch ECGs were reviewed by blinded electrophysiologists

- Determined sinus vs. non-sinus rhythm
- Ranked confidence in using the information for diagnostic decision making

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The Hemodynamic Effects of Induced Supraventricular Tachycardia in Man

BRUCE N. GOLDFREY, M.D., JOHN A. KASTOR, M.D., AND KENNETH L. KERSHBAUM, M.D.
 Published: 1 Nov 1976. 1976;54:783-789

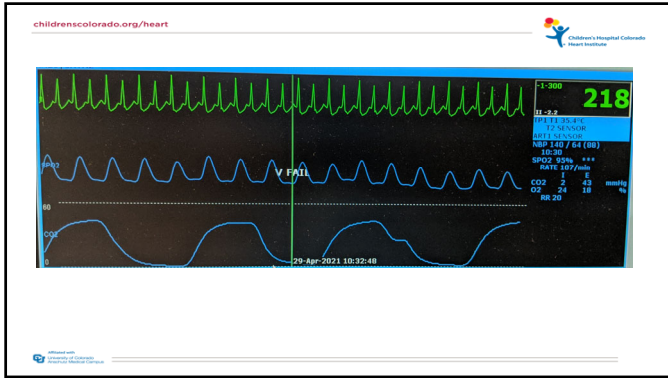
8 patients with documented SVT

- Catheter in the PA & brachial artery art line
- SVT induced by rapid atrial pacing
- 8/8 had **pulsus alternans** in SVT

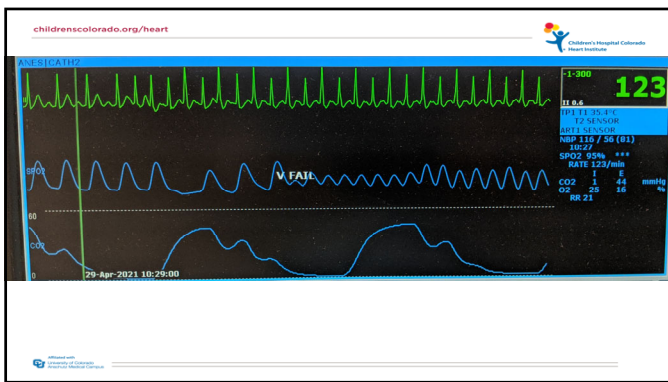
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Heart Rate Evaluation

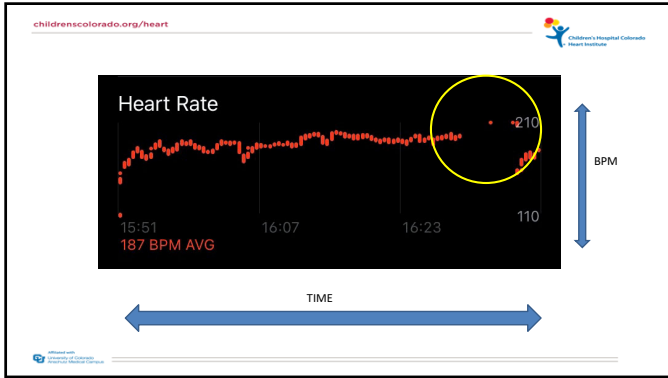
Excellent agreement for HR <210 between AW and GSM

Values >210 have poor agreement and are not dependably captured

Heart rate measurements in arrhythmias are unreliable

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ECG Review by Electrophysiologists

56 smartwatch ECGs reviewed by 3 electrophysiologists

Determination of sinus vs. non-sinus rhythm

- 92.5% agreement
- Kappa 0.85 +/- 0.13
- Sensitivity of 90.3% - 93.5%
- Specificity of 95.5%-96.0%

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Accuracy of Apple Watch Cardiac Features in Pediatric Patients

80 patients including in 3 clinical settings

Excellent agreement for HR <210 between AW and gold standard monitoring


Values >210 have poor agreement and are not dependably captured

Heart rate measurements in arrhythmias are unreliable

High sensitivity and specificity in the determination of sinus vs. non-sinus rhythm

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Wearable Data in Pediatrics

Often function well in normal vital sign ranges
If asked if the data is reliable, this can be shared with parents

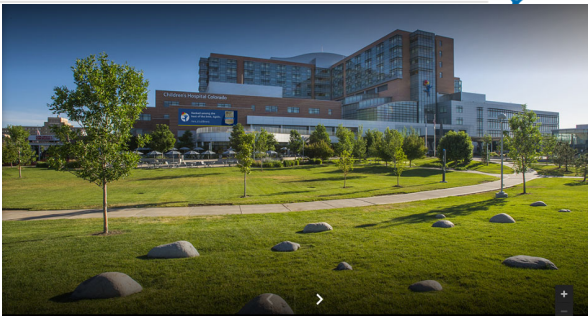

Consumer technologies are rarely validated at clinical extremes
False negatives and false positives are seen with higher frequency outside of the normal range

Clinical diagnoses can be made with the data
Tend to be specific with unknown sensitivity

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