A New Look at Vital Signs

Jay Pandit, MD, Director of Digital Medicine
Assistant Professor of Molecular Medicine, SRTI
Road Map

- Introduction
- Temperature
- Heart Rate
- Respiratory Rate
- Blood Pressure
- Remote Monitoring
- Future Outlook
- Final Case
Temperature

“Calor, Dolor, Rubor, Tumor” – 98.6°F or 37°C
Temperature

Physiology


Temperature Measurement

1867
Liquid Expansion

1960–80
Non-contact

2012
Intelligent

Present
Continuous

Jane

- 35-year-old female with hx of asthma living in NYC. She wants to know what her risk of getting a viral infection is by returning back to work in person.

- 98.6°F
Potential


Heart Rate

60 – 100 beats per minute
Heart Rate Measurement

- Sensing (1707)
- Visualizing (1895)
- Personalizing (1938)
- Democratizing (Present)

Heart Rate Measurement

Measurement at Scripps Research
Jane

- 35-year-old female with hx of asthma wants to know why her heart rate is not back to normal after Covid infection 2 months ago.

- HR 80bpm, 98.6°F
Potential

**DETECT**

- **Feeling sick?**
  - If you're feeling sick, start tracking your symptoms

- **DETECT-AHEAD: New study available**
  - You're invited to help us test new technologies

- **Baseline Survey**
  - Tell us about your respiratory illness history and your demographics

- **Add COVID-19 Test Result**
  - Add the results of a swab test, saliva test, or blood test

- **2/2 Vaccine Doses Received**
  - First dose on 04/2021
  - Second dose on 05/2021

- **Edit vaccine information**

[Image: detect.scripps.edu]

**Change in RHR for COVID-19-positive vs COVID-19-negative individuals**

- **COVID-19 status**
  - Negative
  - Positive

<table>
<thead>
<tr>
<th>Change in RHR, mean (95% CI), beats/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2</td>
</tr>
<tr>
<td>-1</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

-10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

**Time since symptom onset, d**

---

**References**


Heart Rate Potential

- Heart Rate Variability

Heart Rate Variability

754 ms  628 ms  845 ms  730 ms  710 ms

https://ouraring.com/blog/what-is-heart-rate-variability/
Respiratory Rate

12-16 breaths per minute
Respiratory Rate

Physiology

**ACTIONS:**
Medullary chemoreceptors detect a decrease in blood pH (often caused by an increase in blood CO₂), causing an increase in breathing.

**REACTIONS:**
Effectors Respond.
Increased breathing decreases blood CO₂.

**ACTIONS:**
Medullary chemoreceptors detect an increase in blood pH (often caused by a decrease in blood CO₂), causing a decrease in breathing.

**REACTIONS:**
Effectors Respond.
Decreased breathing increases blood CO₂.

Respiratory Rate Measurement

- Listening
- Observing
- Accelerometry
- Acoustics


Jane

- 35-year-old female with asthma, Covid positive 6 months ago, vaccinated and now getting short of breath again.

- 98.6°F, HR 80, RR 16
Acoustic Signaling

Potential

Compound Sound

Talking
Coughing
Snoring
Breathing
Blood Pressure

120/80mmHg
**Blood Pressure**

**Physiology**

**LEFT VENTRICULE**
- **SYSTOLE**
  - Isovolumic Contraction
  - Ventricular Ejection
- **DIASTOLE**
  - Isovolumic Relaxation
  - Ventricular Filling

**AORTA**
- **SYSTOLE**
  - Ventricular Ejection

---

Blood Pressure Measurement

- Primary modifiable RF
- 2nd reason for OV
- >1B adults
- ~50% remain uncontrolled
- Cuff based
Blood Pressure

Optical Sensor Measurement

\[ PWV = \frac{\Delta L}{\Delta t} \]

- Common carotid artery
- Thoracic aorta
- Abdominal aorta
- Femoral artery
- Iliac artery


**Blood Pressure**

**Problem**

Assumptions
- Distance
- Conversion Equations

Pre-ejection period
- Electrical to mechanical

Balmer, J et al. Pre-ejection period, the reason why the electrocardiogram q wave is an unreliable indicator of pulse wave initialization. Physiol Meas. 2018 Sept 24;39(9):09505.

Blood Pressure

Solution: Differential Pulse Arrival Time

Blood Pressure

DPAT Validation

CLINICAL RESULTS DEMONSTRATE DPAT ACCURATELY ESTIMATES BLOOD PRESSURE IN COMPARISON TO CONTROL

Study Demographics: n=12, Ages 25-50, Gender: M/F, Normotensive & Hypertensive Subjects
Blood Pressure

DPAT Validation

![Graph showing Differential Pulse Arrival Time (sec) over time (minutes) with sleep and wake phases indicated.](https://via.placeholder.com/150)
Blood Pressure

Alignment of tech push and clinical pull

- **2015**: SPRINT Trial
- **2017**: HTN Guidelines
- **Mar 2019**: Clinical Pull
- **Present**: BP Wearable

### Table 6. Categories of BP in Adults*

<table>
<thead>
<tr>
<th>BP Category</th>
<th>SBP</th>
<th>DBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&lt;120 mm Hg</td>
<td>&lt;80 mm Hg</td>
</tr>
<tr>
<td>Elevated</td>
<td>120–129 mm Hg</td>
<td>&lt;80 mm Hg</td>
</tr>
<tr>
<td>Hypertension</td>
<td>130–139 mm Hg or 80–89 mm Hg</td>
<td></td>
</tr>
<tr>
<td>Stage 1</td>
<td>&gt;140 mm Hg or &gt;90 mm Hg</td>
<td></td>
</tr>
<tr>
<td>Stage 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*A = American*
Remote Vitals Monitoring
RPM Diagnostics

Multi-modal, skin conforming, time synchronized wireless measurements of key data streams linked to physiological variables of interest:

Informed Wireless Device Locations

Direct Measurements
- ECG
- SCG
- PPG

Extractable Quantities
- STI
- PWV
- HR
- SpO2
- BP
- SVR
- EF

Raw Data and Gold Standard

Multi-Device Time Correlation for PAT, PTT and BP

Data from the Remote Patient Monitoring Study led by Dr. Pandit, Dr. Ahmad and the Rogers Group.
Sensor Capabilities

Parameters Measured by Consumer Digital Health Devices by Type

100% = 384 sensors

Source: IQVIA AppScript Device Database, Mar 2021; IQVIA Institute, Jun 2021
Notes: Chart includes data from 384 sensors. Total exceeds 384 due to multiple measures being tracked by a single sensor. Specific measurement devices include vitals measurement.
Report: Digital Health Trends 2021: Innovation, Evidence, Regulation, and Adoption. IQVIA Institute for Human Data Science, July 2021
Challenges

- Data security and privacy
- User Interface
- Digital Infrastructure
- Reimbursement
- Value and IP
- Digital Biomarkers
- Inclusion, Continued Engagement, Ground Truths
- Standardization
- Regulation
- Patient
- Provider
- Hospital
- Payor
- Developer
- Pharma
- Research
- RPM
Our Efforts

**DETECT**
- Feeling sick? If you're feeling sick, start tracking your symptoms.
- DETECT-AHEAD: New study available
- Baseline Survey: Tell us about your respiratory disease history and your demographics
- Add COVID-19 Test Result: Add the results of a swab test, saliva test, or blood test
- 2/5 Vaccine Doses Received: First dose on 6/20/2021, Second dose on 9/20/2021

**PowerMom**
- Welcome Jane,
- You are in your 1st Trimester
- Due Date: Dec 17th, 2021
- 14 weeks and 6 days left
- Update Pregnancy Status

**PROGRESS**
- Current points: 460pts
- 74 points to text revised
- Collect Blood Sample: 100 points, 16 min
- Collect Saliva Sample: 165 points, 16 min
- Collect Microbiome Sample: 225 points, 20 min
- Return Samples: 90 points, 10 min

**REFRESH**
- Good morning
- Tasks:
  - Sleep Apnea Screening
  - Insomnia Screening
- Results:
  - You results will show here once you've completed the above tasks

**Infectious Diseases**
- detect.scripps.edu

**Maternal Health**
- powermom.scripps.edu

**Precision Nutrition**
- progress.scripps.edu

**Sleep Medicine**
- refresh.scripps.edu

**Precision Medicine**
- go.joinallofus.org
Future Outlook
What’s Next?

- Biofluids with vitals
- Multimodal Integration
- Expanding access
- From active to passive
- From post processing to real time
- From unregulated to regulated
Road Map

- Introduction
- Temperature
- Heart Rate
- Respiratory Rate
- Blood Pressure
- Remote Monitoring
- Future Outlook
- Final Case
Final Case –

• 38-year-old male cardiologist with hx of brain cancer s/p surgery, chemotherapy, and radiation.

• Gets MRIs every 3-4 months for screening because not enough data on risk factors of tumor recurrence.

• Precision health enabled by digital health technology with large longitudinal datasets might hold this answer.

Thank you


- Northwestern BCVI: Clyde Yancy, Sanjiv Shah, John Rogers, Patrick McCarthy, Faraz Ahmad, Andreas Tzavelis, Anjan Tiberwala, Stefanie Miller, Julie Petersen, Sean Connell, Kyle Miller, Andrew Wu, Sonia Kim and the rest of the BCVI and Northwestern team. Stanford and UCSF colleagues and mentors.

- “If you want to go fast, go alone, if you want to go far, go together.” – African Proverb

- Digitaltrials.scripps.edu
Upcoming Lecture

The hunt for regenerative medicines

Michael Bollong PhD
Assistant Professor, Department of Chemistry

Wednesday, June 29, 2022 | 1:00 pm PT/4:00 pm ET

Register now at:
frontrow.scripps.edu