

## INTRODUCTION

- 1.7 million people are hospitalized annually for sepsis in the United States. [1]
- Resuscitation strategy guided by peripheral perfusion (CRT) leads to better patient outcomes than lactate testing. [2]
- Manual CRT measurement is not accurate or reproducible.

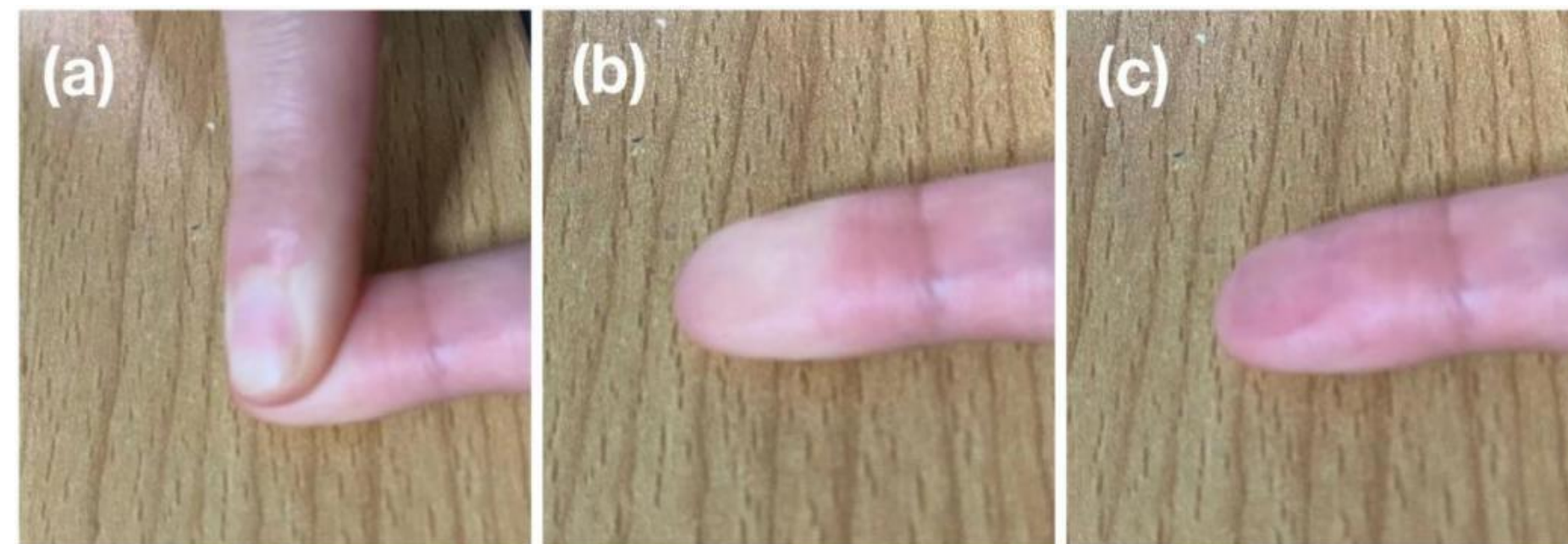


Figure 1: Manual CRT measurement demonstration. A) Apply pressure until blanching. B) Remove pressure. C) Count seconds until color restores. [3]

Our team aims to find a way to quantify capillary refill time for providers monitoring treatment response in septic shock patients in order to rapidly identify changes in patient condition and reduce cost associated with serial serum lactate testing.

## METHODS

Table 1: Device objectives.

Design Objectives	Functional Objectives
<ul style="list-style-type: none"> <li>Accurately and easily measure CRT.</li> <li>Operate wirelessly and independently.</li> <li>Holistic, reusable, and compact design.</li> <li>Display CRT results and measurement history.</li> </ul>	<ul style="list-style-type: none"> <li>Apply sufficient pressure to blanch nail bed without harm.</li> <li>Use light sensor to measure transmittance change from blanching to reperfusion.</li> <li>Digitize CRT process and measurements in real time using microcontroller and battery and store measurements.</li> <li>Provide accurate CRT measurements regardless of external factors.</li> </ul>

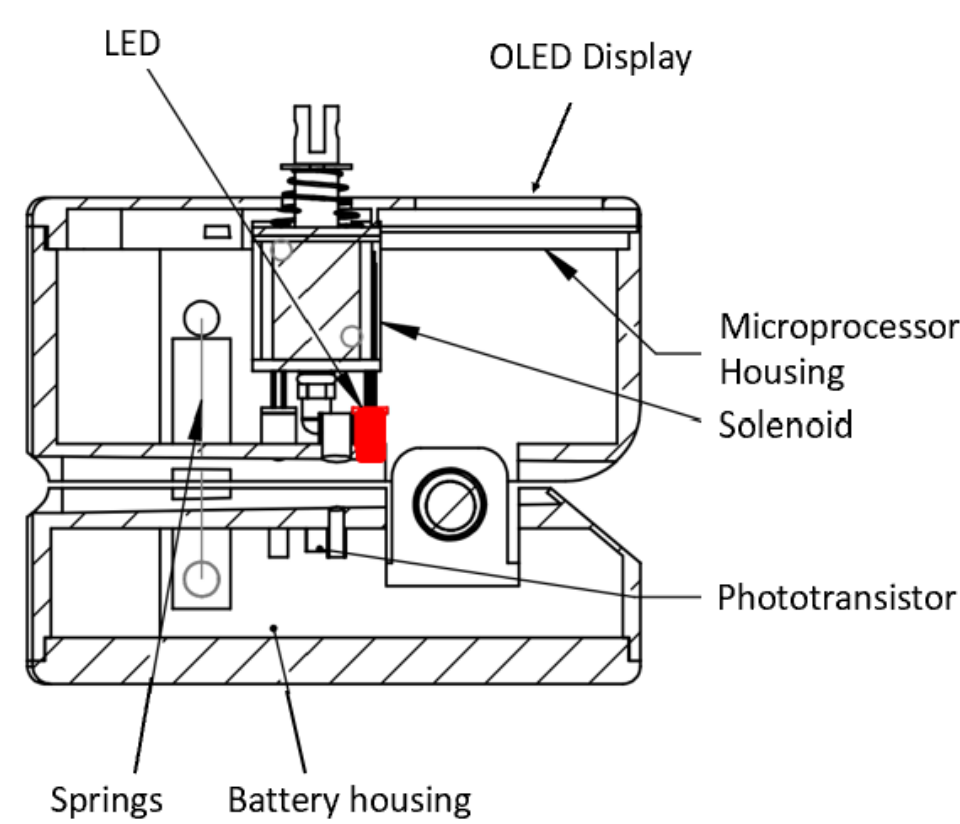


Figure 2: Device setup.

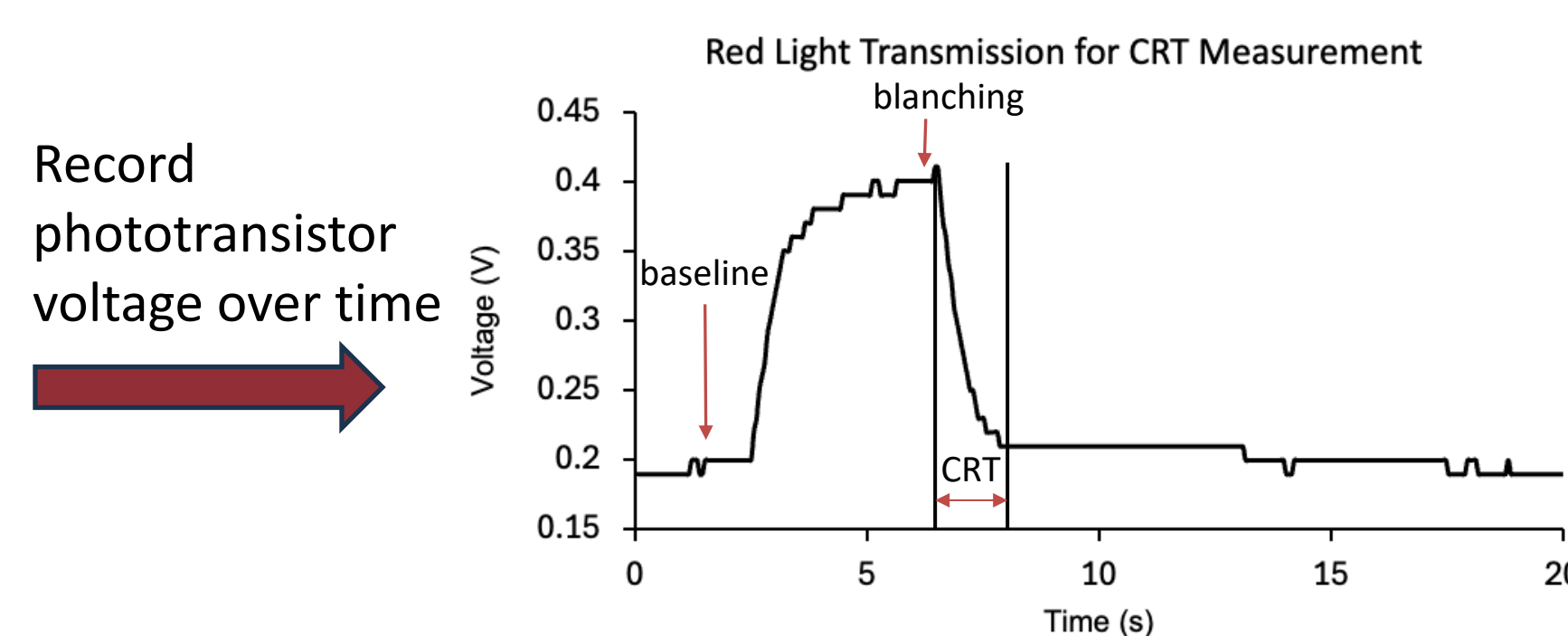


Figure 3: Example CRT measurement (voltage over time).

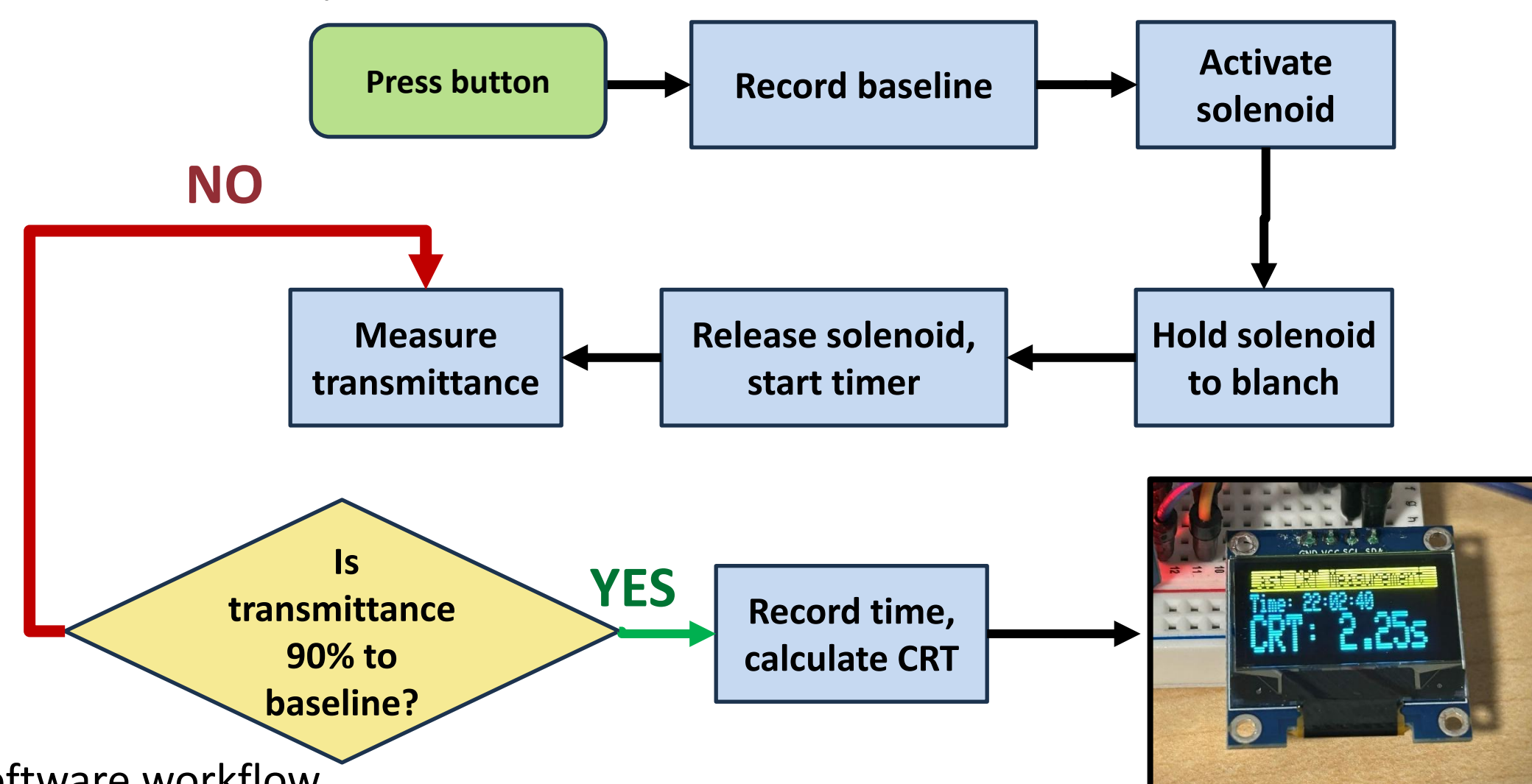


Figure 4: Software workflow.

## RESULTS

### Monitor Lasts 4.5 Hours on Battery Power

Table 2: Device power requirements.

Duty Cycle	50% Duty Cycle with 162 sec maximum ON time for single pulse
Wattage	18 Watts @ 20C (max watts dissipated by solenoid)
AWG (American Wire Gauge)	27 awg, 405 # of turns
Resistance	Resistance: 5.04 ohms @ 20C
Nominal VDC (Volts Direct Current)	Nom. VDC: 1. 100% Duty Cycle: 6.7 V 2. 50% Duty Cycle: 9.4 V

$$\text{Current Draw (I)} = V/R = 6.7 \text{ V} / 5.04 \Omega = 1.329 \text{ A}$$

$$\text{Current Draw (I)} = V/R = 9.4 \text{ V} / 5.04 \Omega = 1.865 \text{ A}$$

$$\text{Power Capacity} = 7.4 \text{ V} \times 5.2 \text{ Ah} = 38.48 \text{ Wh}$$

$$\text{Runtime} = \frac{38.48 \text{ Wh}}{1.329 \times 6.7} = 4.32 \text{ hours}$$

### Solenoid Requires More Power to Blanch Fingers

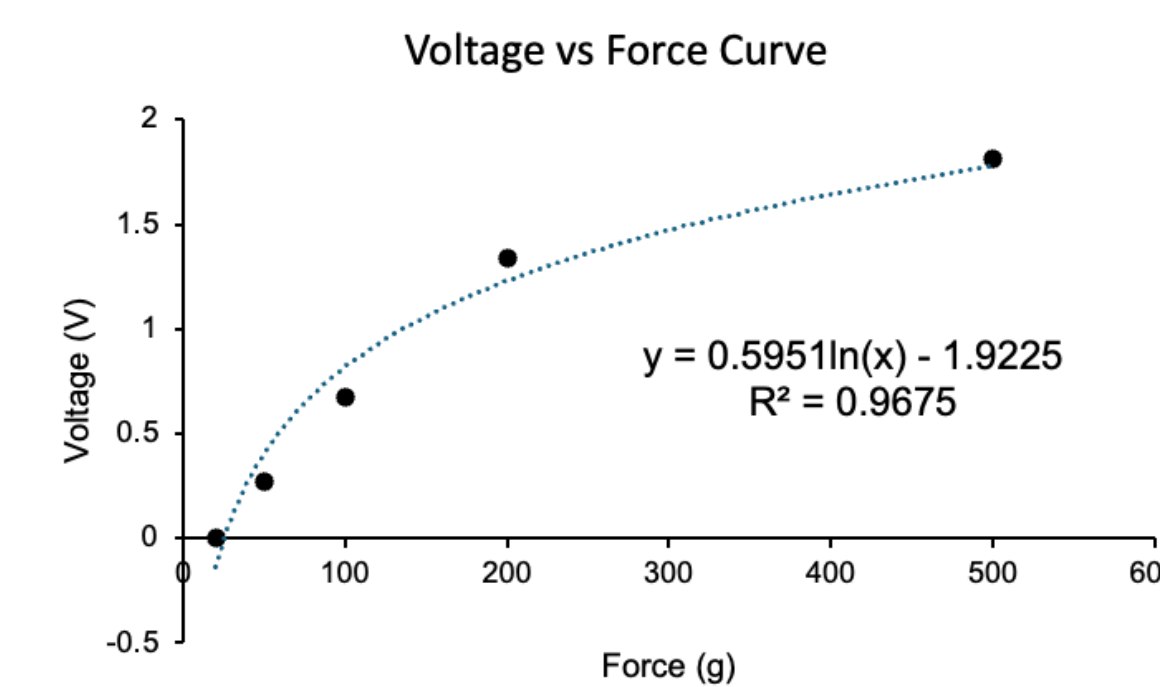


Figure 6: Force vs Voltage curve for our Force Sensitive Resistor (FSR) to extrapolate solenoid forces.

Table 3: Solenoid FSR extrapolated force.

Label	Force (g)
Solenoid 1	64.4
Solenoid 2	236.7
Force Required for Blanching	300-700

### Monitor Distinguishes Between Low and High Peripheral Perfusion

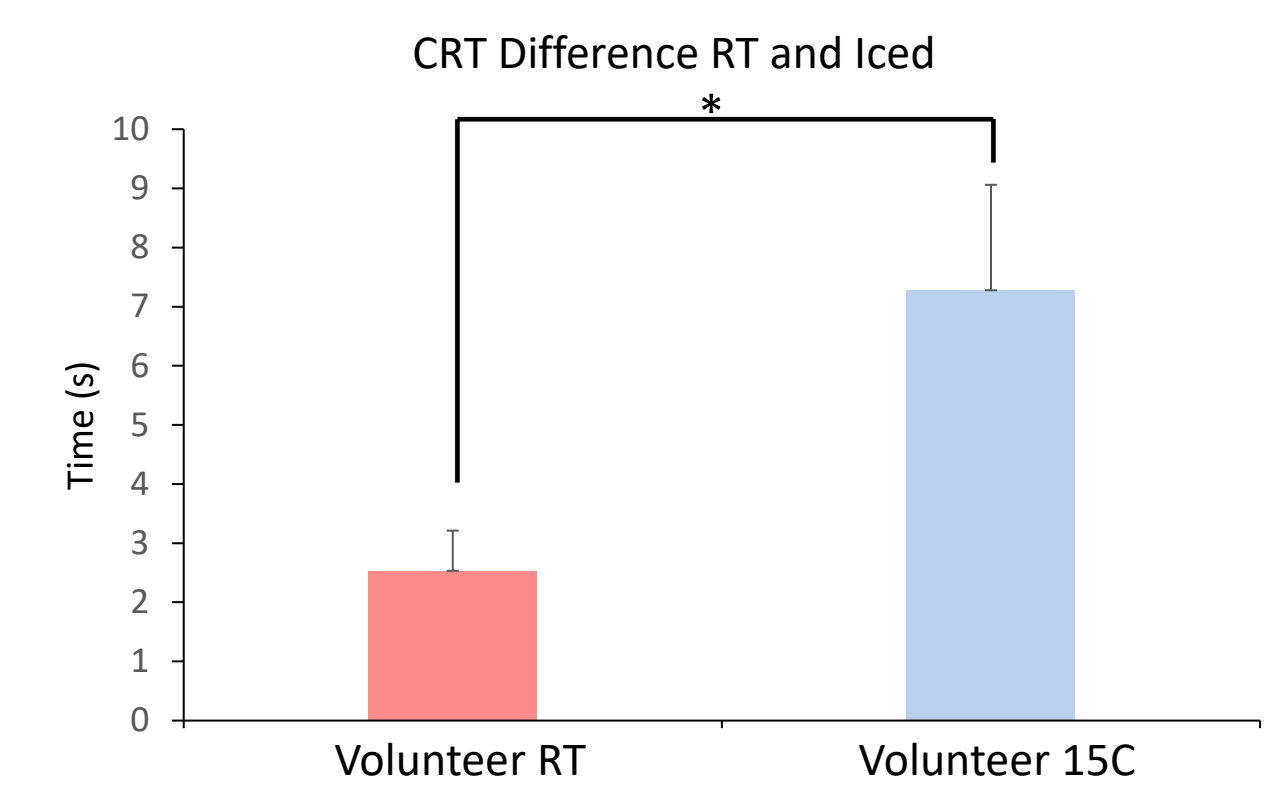


Figure 7: Volunteer CRT with Normal (RT) and Reduced (15C) Peripheral Perfusion, \* indicates p = 0.004.

### Software Correctly Identifies CRT

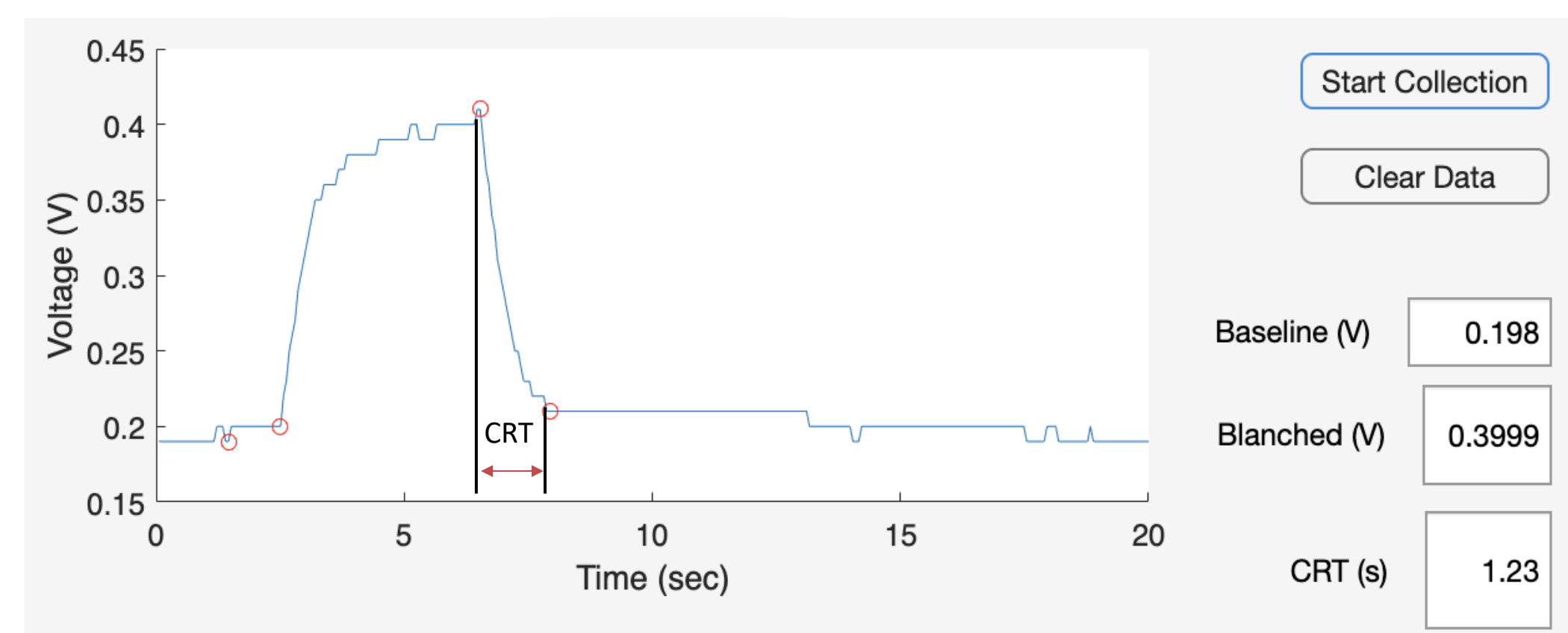


Figure 8: MATLAB app software demonstration.

### Testing Prototype Housing Evolution

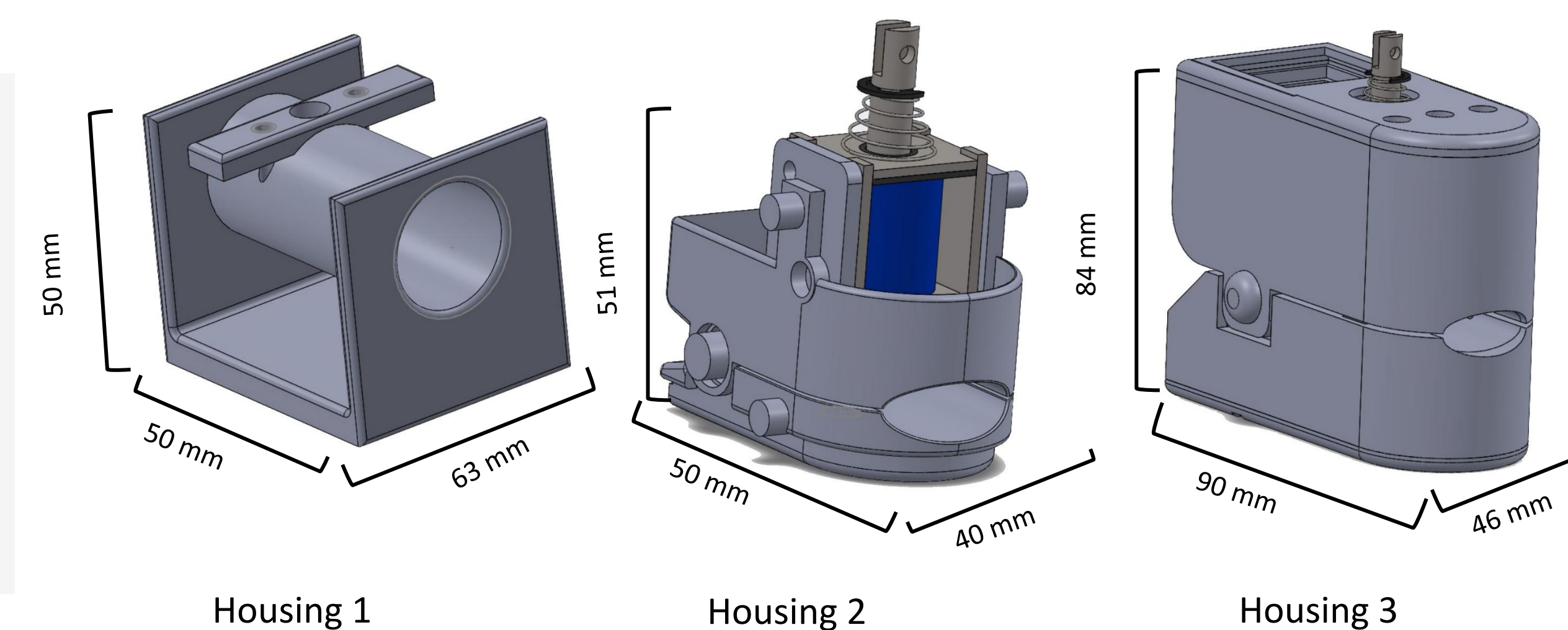


Figure 9: Prototype housing CAD models.

## CONCLUSIONS AND FUTURE WORK

- Functions on battery power for 4.5 hours.
- Software accurately identifies CRT.
- Housing fits variety of finger sizes and types.
- Monitor can distinguish between low and high peripheral perfusion.



Figure 10: Current prototype.

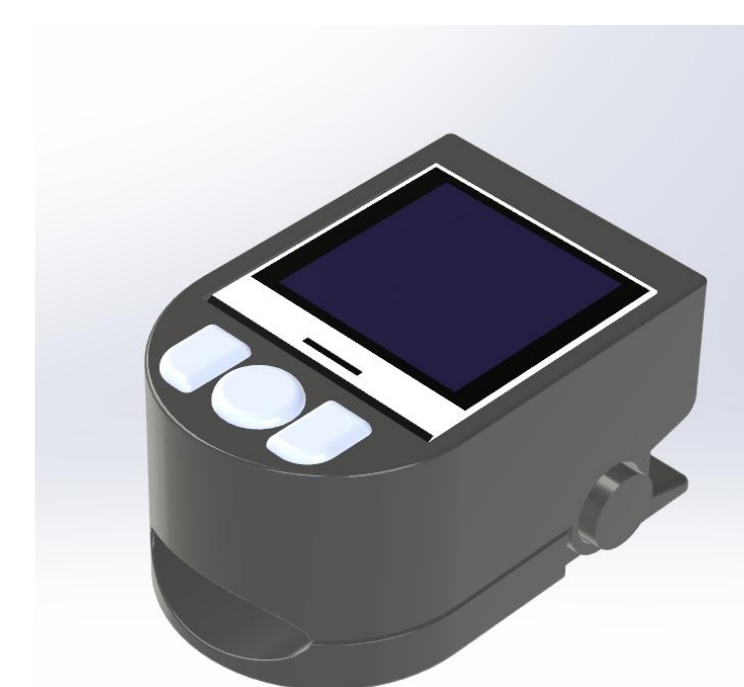


Figure 11: Looks-like prototype CAD.

### Future Work:

- Reduce size and streamline appearance for usability.
- Test monitor with broader range of volunteers.
- Compare CRT monitor measurements with physician manual CRT and lactate measurement.

## BIOETHICAL IMPLICATIONS

- Reduces cost of care associated with lactate testing.
- Provides consistent, real time peripheral perfusion assessment.
- More testing is needed to ensure accuracy for patients with different skin tones, finger sizes, and finger conditions.

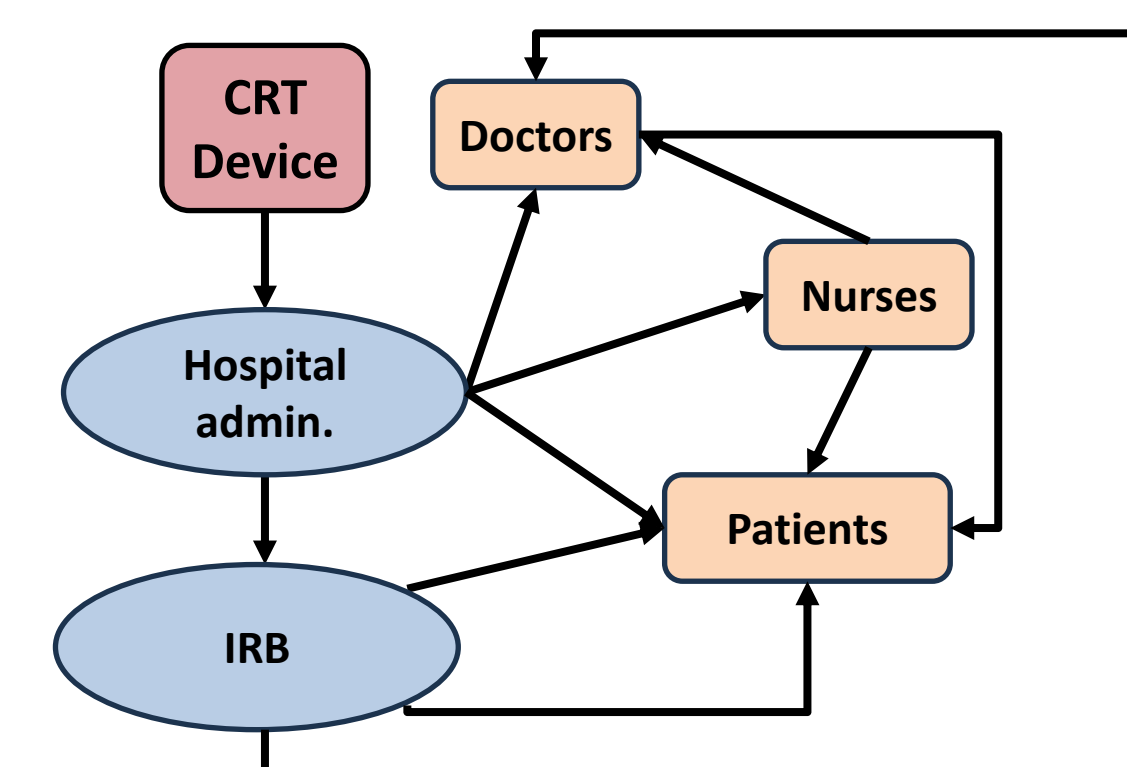


Figure 12: CRT monitor systems map.

## REFERENCES AND ACKNOWLEDGEMENTS

- [1] "About Sepsis." Centers for Disease Control and Prevention, Centers for Disease Control and Prevention, www.cdc.gov/sepsis/about/?CDC\_AAref\_Val=https%3A%2F%2Fwww.cdc.gov%2Fsepsis%2Fwhat-is-sepsis.html.
- [2] Hernández G, Ospina-Tascón GA, Damiani LP, et al. Effect of a Resuscitation Strategy Targeting Peripheral Perfusion Status vs Serum Lactate Levels on 28-Day Mortality Among Patients With Septic Shock: The ANDROMEDA-SHOCK Randomized Clinical Trial. JAMA. 2019;321(7):654-664. doi:10.1001/jama.2019.0071
- [3] Ziyu Ma, Lan Lin, Shuicai Wu, Yixiong Chen and Shen Sun. 2023. Can Capillary Refill Time (CRT) measurement be a reliable clinical test?. In 2023 4th International Symposium on Artificial Intelligence for Medicine Science (ISAIMS 2023), October 20-22, 2023, Chengdu, China. ACM, New York, NY, USA, 9 Pages. https://doi.org/10.1145/3644116.3644302

We are grateful to Dr. Mohammad Abdulelah for his time and clinical guidance, and Dr. Ian White for his technical expertise and advice.