Point-of-Care Monitoring System For Early Sepsis Detection

Kevin Adams, Brian Chan, Allison Cong, Krysia Olszewska
2016 SIMR Bioengineering Bootcamp, Stanford University

Introduction

Sepsis, the inflammatory cascade response to a blood infection, is a leading cause of mortality worldwide. The infection of the bloodstream itself, sepsis, triggers an overblown immune response. Symptoms include an increase in heart rate, respiratory rate, body temperature, and blood lactate concentration, as well as hypotension. These symptoms can lead to multiple organ dysfunction syndrome (MODS), the defining feature of severe sepsis. With extended hypotension, patients enter septic shock, which drastically increases mortality rate to 80%.

Although empirical antibiotics and IV fluids are initially administered, the infection cannot be properly treated without identifying the pathogen. The current gold standard for this is blood culturing, where doctors culture and test blood samples for evidence of infection, impaired oxygen availability, and other vital indicators. Complete testing can take up to 5 days. However, death may occur within 3 to 4 days; thus, early detection of sepsis symptoms is crucial for effective treatment.

Need Statement

A way to quickly and accurately diagnose sepsis at home in sepsis-vulnerable patients to enable clinical personnel to determine the risk of pathogenic infection and be able to administer specific treatment more immediately.

Need Specifications

<table>
<thead>
<tr>
<th>Must Have</th>
<th>Nice to have</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measures heart rate (HR), respiratory rate (RR), and body temperature</td>
<td>Adjustable</td>
</tr>
<tr>
<td>Obtains data quickly</td>
<td>Lightweight</td>
</tr>
<tr>
<td>Comfortable</td>
<td>Aesthetic</td>
</tr>
<tr>
<td>Non-invasive</td>
<td>–</td>
</tr>
<tr>
<td>User-Friendly (band &amp; app)</td>
<td>–</td>
</tr>
<tr>
<td>Accurate</td>
<td>–</td>
</tr>
</tbody>
</table>

Materials

- 3D-printed casings
- Spandex material
- Adafruit FLORA
- Adafruit FLORA Bluefruit LE
- TMP36 Temperature Sensor
- Pulse Sensor
- Green LED as Respiratory Rate sensor
- Velcro
- Conductive Thread

Concept Analysis

Wearable

- Vital Signs
- Vital signs data
- Temperature (°F), Heart rate (bpm), Respiratory Rate (breathe per min)
- Sensors
- Vital signs data
- Bluetooth Transmission

Application

- Bluetooth Receiver
- Vital signs data
- Computer
- Heart rate, respiratory rate, body temperature, blood pressure, lactate concentration

User Interface

- Push Notification System
- Patient
- Prediction of sepsis vs infection (%) vs time analysis
- Graph and visual representation of data
- Abnormal activity detection option
- Guardian
- Prediction of sepsis vs infection (%) vs time analysis
- Doctor or hospital
- Symptom test
- Baseline vital values

Prototyping

An early layout of the battery, sensors, microcontroller, and Bluetooth module.

The 3-D printed casing, D-ring, sensors, and wiring being compiled.

Mobile App:

- Line graph of vital signs over time
- Searchable database that allows users to check vital signs data from any previous time
- Notification system alerts patients, guardians, and clinicians of any imminent risks of sepsis.
- Symptoms test to confirm pathogenic infection

Conclusions

By analyzing vital signs and detecting the possible onset of sepsis, our point-of-care device expedites the treatment process by allowing clinicians to start the blood culturing process and administer appropriate treatment earlier. We have developed a works-like physical prototype of our device, along with a looks-like respiratory rate sensor and a version of the accompanying mobile application. Our prototype can serve as a convenient way for sepsis-vulnerable patients to constantly monitor their condition.

In the future, we aim to send data to a working mobile app via Bluetooth transmission, and to noninvasively monitor other strong indicators of sepsis, such as changes in a patient’s blood pressure, respiratory rate, and blood lactate levels.

Acknowledgements

We would like to acknowledge Ross Venook for providing our workspace, Arjun Aditham, Derek Croote, Ben Kotopka, Mandy Li, Elaine Ng, Colleen Rhoades, Heather Rogan, and Alexa Wnorowski for their insightful advice, and the TA’s of the PRL for their help and materials. Special thanks to Dr. Daniel Rogen and Dr. Lisa Snieh for sharing their knowledge on sepsis. Finally, a big thank you to the Amgen Foundation for supporting the SIMR Program.

References

5. Caplan, Surviving the first hours in sepsis: getting the basics right (an intensivist’s perspective). JAMA. 2016