TriageAssist

Problem #3

Team 11

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Problem/Solution/Rationale

The problem we were presented with encompasses the issues surrounding the inadequacies of current triage systems in America, which struggle with inefficiencies and limitations, impacting the quantity of individuals they can assist and the precision in prioritizing patient care. The existing triage systems often particularly suffer from prolonged waiting times due to manual assessments and limited diagnostic capabilities, leading to delays in identifying critical cases. Furthermore, the lack of integration between vital sign monitoring and triage algorithms hampers quick decision-making, impacting patient outcomes and resource allocation; because of these shortcomings we decided to look into increasing the effectiveness of triage through increasing the diagnostic capabilities of a device based system. Our solution involves the development of a portable system capable of detecting crucial vital signs—body temperature, blood pressure, capillary refill time, blood oxygen levels, heart rate, and cardiac electrical activity—which will then be amalgamated using a modified Emergency Service Index Triage algorithm, drawing inspiration from the design principles of Automated External Defibrillators (AEDs) employed by lifeguards. With this innovative approach, our aim is to significantly enhance the classification of patients compared to existing triage systems, ensuring more effective and efficient patient prioritization.

Design Components and Principles of Operation

The device we have designed to address this issue involves an easily-operated color-coded triage sensor system that can be seen in Figure 1. By depressing a button and attaching three color-coded sensor pads to specific locations illustrated in provided diagrams, users can promptly assess a patient's status and promptly facilitate the necessary medical attention. This system utilizes five distinct sensors to collect six vital signs, amalgamating the data to run through a triage algorithm. This algorithm categorizes a patient into one of four severity levels and the device both reads out this information to the user and exports all of its data to the hospital it is registered under, expediting and streamlining the triage process.

Central to the system's functionality are an assortment of various vital sign monitoring sensors. The first is the heat flux sensor – gSKIN®-XM (greenTEG, Rümlang Switzerland, XM 26-27 9C) [1], chosen for its noninvasive and accurate core temperature measurement within 0.25°C. The second sensor, the green light pulse oximeter sensor [2], combined with an algorithm accounting for melanin variations, demonstrates improved accuracy across diverse skin tones and conditions compared to traditional red light pulse oximeters [3]. The third set, visible in Figure 2 (a contact pressure sensor) and Figure 3 (a PPG sensor), is combined in a way depicted in Figure 4. We selected this configuration specifically for its capacity to accurately measure capillary refill time and, consequently, the patient's blood pressure when positioned against the first metatarsal [4]. The final sensor, AD8232 (Analog Devices Inc., Norwood MA, AD8232) [5], was chosen for its real-time cardiac activity data detection for swift assessment.

Operationally, the system operates within a structured workflow. Upon sensor pad placement, the system prompts users through voice and text to confirm accurate positioning, ensuring precise data acquisition. The integration of data from the sensors utilizes a triage algorithm for rapid patient prioritization based on comprehensive vital sign assessments, each with plausible reasoning guiding the triage levels. For instance, absence of or weak cardiac activity or blood oxygen < 70% [6] triggers an emergency categorization due to its indication of critical cardiac issues or potential cardiac arrest. Moreover, having two or more vital signs outside specified ranges (heart rate > 90 bpm [6], blood oxygen < 89% [6], capillary refill time > 1.83 s [4]) denotes a high priority urgency level, as these conditions individually or in combination often signify distress or impending deterioration [6][7]. One vital sign in these ranges signifies an urgent level, prompting attention due to the potential for developing complications. Conversely, none of the vital signs falling within the given range indicates a routine or low priority, signifying stability or mild distress. These criteria solidify the classification levels, empowering our portable triage system to revolutionize critical care scenarios by significantly enhancing diagnostic capabilities and prioritization accuracy, ultimately optimizing patient care delivery.

Design Requirements

- ➔ The device should have a good battery life of at least 8 hours of continuous usage.
- ➔ The device should weigh under 10 pounds for the ease of transport.
- ➔ The device must have at least 2 medical sensors in order to precisely evaluate the health condition of the patient.
- ➔ The device should take less than a minute in order to get all the data from the sensors and inform the users about the triage level of the patients.
- ➔ The device should take less than 30 seconds to set up and ready to be used.

Design Justification

Our portable triage system is meticulously designed to overcome the shortcomings of existing systems by integrating advanced medical sensors for accurate vital sign assessment. The combination of a heat flux sensor, green light pulse oximeter sensor, contact pressure sensor, PPG sensor, and AD8232 sensor ensures precise data collection for core temperature, blood oxygen levels, capillary refill time, blood pressure, heart rate, and cardiac activity. This comprehensive information is seamlessly processed through a modified Emergency Service Index Triage algorithm, resulting in swift and accurate patient classification. The device's streamlined workflow, prompt data acquisition, and ability to export data to hospitals contribute to its effectiveness. By meeting stringent design requirements for quick setup, rapid data acquisition, and portability, our system not only addresses current triage system limitations but also sets a new standard for accuracy in patient prioritization, optimizing critical care scenarios.

Design Goals

- ➔ Device should be able to send all data to their hospital database efficiently through Starlink satellites from anywhere in the world.
- ➔ Devices can do all the testing in less amount of time and with more accuracy.
- ➔ It has to be portable and secure enough to be carried to any location in any circumstances.
- ➔ The device should have 5 sensors in order to do all the testing and reports, which will ensure the wellbeing of the patient very efficiently.

Safety & Efficacy

In our group's development process, we have placed a strong emphasis on user safety and the efficacy of our portal system. One of the ways we achieve this is through our design, as mentioned earlier. Our solution draws inspiration from Automated External Defibrillators (AEDs). The sensors, measuring six vital signs—body temperature, blood pressure, capillary refill time, blood oxygen levels, heart rate, and cardiac electrical activity—are divided among three pads. Each pad can be seen on a general diagram illustrating the correct placement on the desired patient, and a verbal prompt guides users on precise placement as well. All these elements contribute to a higher efficacy for the device, making it user-friendly in setup. Notably, some of our design goals were to enable the system to be set up in 30 seconds and take only one minute for data collection, further affirming the top-notch efficacy of the device.

Moreover, as previously stated, the collected data undergoes meticulous processing through a modified triage algorithm. The results are audibly communicated and transmitted to the corresponding hospital the device is registered under. This systematic organization of data enhances the device's efficacy by providing clear insights into areas where major assistance is needed for both first responders and anyone requiring information.

Concerning safety, we strongly emphasize personnel cleaning the skin before device application and sanitizing tubes that come into contact with body fluids to prevent cross-contamination among patients. Additionally, safety circuits and capacitors have been integrated within the system to address the possibility of faulty wires. All in all, these actions underscore our commitment to ensuring the system's safety and effectiveness.

Wearability and Feasibility

The feasibility of our proposed triage system rests upon the utilization of portable technology to accurately and efficiently assess vital signs for crucial patient prioritization. Engineered to emulate the design principles of AEDs, this portable system aims to revolutionize patient prioritization by efficiently assessing body temperature, blood pressure, capillary refill time, blood oxygen levels, heart rate, and cardiac electrical activity. While this innovation holds immense promise, there are technical, bioengineering, and biological limitations that warrant careful consideration.

In terms of bioengineering challenges, the intricacies of designing a system that accurately and consistently detect the vital signs pose a significant hurdle. Precision in measuring and interpreting these indicators with a portable framework introduces complexities, potentially leading to inaccuracies or inconsistencies in patient classification, specifically with sensors. Furthermore, developing reliable sensors to capture vital signs within a single unit is a formidable task. From a technical standpoint, ensuring seamless integration of the different sensors as well as secure data transmission and the device’s durability stands as a primary concern. Maintaining connectivity, reliability, and sustained accuracy given various environmental conditions is also a considerable technical challenge. In terms of biological limitations, the compatibility of the system with various patient profiles and different medical conditions is a complex challenge. There could be potential discrepancies in readings due to the physiological variations in individuals, and factors like skin type affecting the adherence of sensors. Despite these multifaceted limitations, the implementation and successful development of our triage system offers plenty of advantages. Enhanced patient classification, accelerated emergency responses, and optimized resource allocation are potential outcomes, underscoring the impact this innovation could have on global healthcare delivery systems.

Bibliography

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Figures

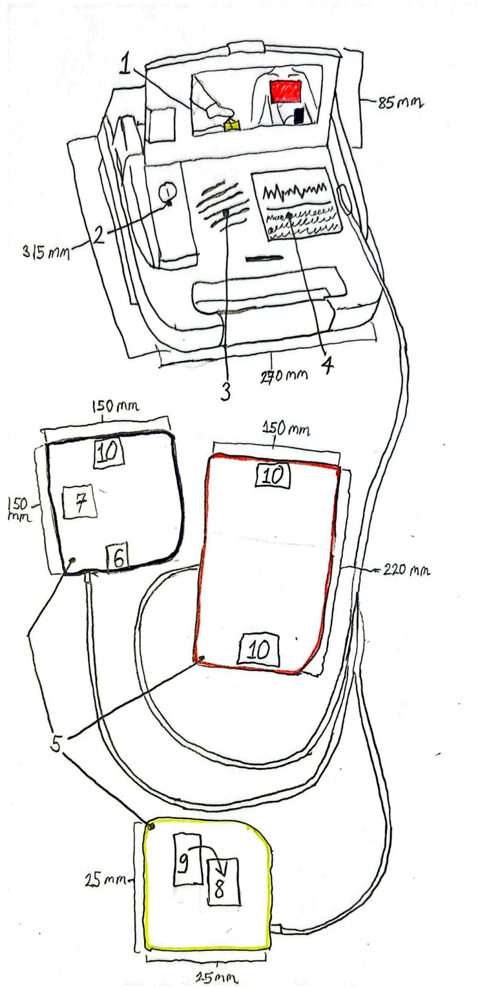

Figure 1: Sensor pad placement diagrams (1) indicate pad identification through color-coding. The power button (2) is located to the left. A voice prompt (3) and text prompt (4) confirm sensor pad (5) placement and display triage information. The ECG signal from the AD8232 sensor is shown. Additionally, the locations of the gSKIN®-XM sensor (6), green light pulse oximeter sensor (7), contact pressure sensor (8), PPG sensor (9), and the three AD8232 sensors (10) on their respective pads are displayed.

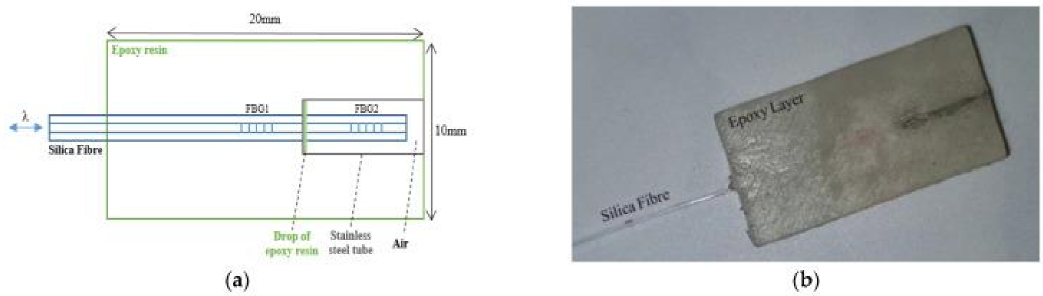

Figure 2: (a) Contact pressure sensor schematic, and (b) photograph of the final constructed sensor. [4]

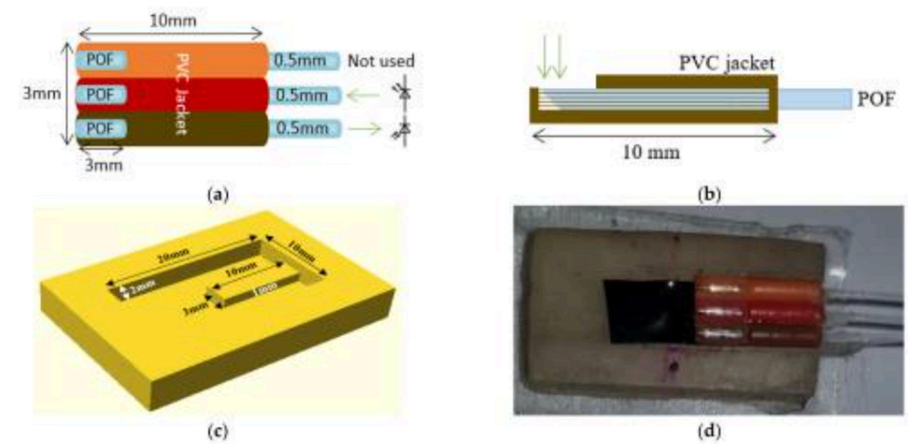

Figure 3: "(a) PPG sensor for measuring changes in blood volume. The POF brown (receives light) and POF red (transmits light) channels are only used in this application. (b) Side view of PPG sensor. (c) 3D mold for embedding the PPG sensor in an epoxy layer. (d) Photograph of the PPG sensor integrated within the epoxy layer used for CRT measurements." [4]

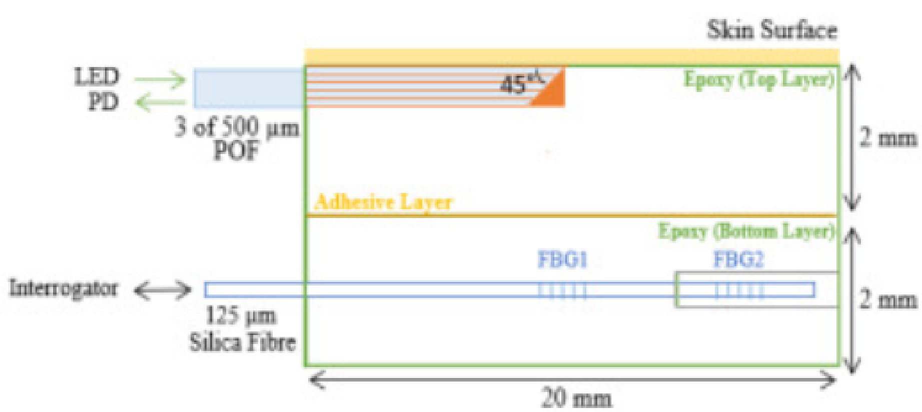

Figure 4. "Side view schematic of the combined sensor of the CRT measurements (PPG and contact pressure) (Figure ? and ??) (LED—light emitting diode, POF—plastic optical fibre, FBG—fibre Bragg grating, PD—photodiode)" [4]