Preliminary Data Collection for Collaborative Emergency Department Crowd Management using Wearable Devices

Victoire Metuge[1], Maria Valero[1,*], Liang Zhao[1], Valentina Nino[2], and David Claudio[3]

[1]*Information Technology Department. Kennesaw State University. Georgia, USA*
[2]*Mechanical & Industrial Engineering Department. Montana State University-Bozeman. Montana, USA*
[3]*Mechanical Engineering Department. University of Massachusetts, Lowell. Massachusetts, USA*
[*]*Corresponding author*

***Abstract*—Emergency department (ED) visits have risen to more than 60% since 1997, with more than 90% of U.S EDs being over-stretched due to overcrowding which has only been compounded by the recent pandemic. Consequences for ED overcrowding range from less severe effects such as patient inconvenience to more severe outcomes such as patient fatality. Research shows poor crowd management at the ED does not only affect patients but takes a toll on ED staff as well. To attempt to address this issue, our study researches how patient vitals collected and transmitted in real time to ED staff can help manage patients in the ED using a triage system that orders vitals in an urgent priority listing. We gathered data from participants using non-invasive wearable devices (CareTaker4 & Oximeter) to collect vital signs information such as heart rate, respiratory rate, blood pressure, and oxygen levels. We aim to use the data to feed a mathematical model that will create a priority algorithm that can sort patients in an ED according to the urgency of their vital signs and transmit the data in real time to health personnel. This way, the patients can be moved automatically in the list as they deteriorate while waiting. We were able to plot the data to show which patients' health are deteriorating quickly and that would require immediate attention. This will be instrumental by helping ED staff attend to pressing cases faster and help control crowds according to medical urgency instead of a first come first serve basis which is not always effective.**

***Index Terms*—Emergency Department, Crowd Management, Wearable Devices, Mathematical Model, Priority List.**

I. Introduction

Overcrowding in hospitals has been the norm for years with Emergency Departments bearing the brunt of those crowds [1]. This happens when the facility is hindered by a large number of patients waiting to be attended to by a health personnel [2]. ED have continued to be overstretched which have only gotten worse with the recent pandemic as average wait times have increased 28% since 2009 to about 4.5hrs [3]. These long wait times due to overcrowding have real consequences that range from minor patient inconveniences to serious outcomes such as death ranging between 20% - 30% [2]. There is constantly ongoing research to provide solutions to ED overcrowding which have mostly being recommendations on various aspects such input-output, additional resources, demand management, operation research and a few others [2] but very few are focused on the root cause which is crowd control. Every patient in the ED always feels their situation is more urgent than the next person's and would be comfortable doing away with the first-come-first-serve system if that meant their urgent case is resolved first. To that end, we are researching how vital signs data (heart rate, respiratory rate, oxygen level and blood pressure) collected using non-invasive wearable devices (CareTaker4 & Oximeter) and transmitted in real time to health personnel can reduce overcrowding as a deteriorating patient climbs the lists in terms of urgency [4]. In a sense, this will be a triage tool for the ED done using only the data fed into a mathematical model that creates a priority listing of patients according to real time data.

This paper aims to detail the methods of data collection and materials used, the process of data conversion and transmission and recommendations based on the results.

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II. Methods and Materials

A. Subjects

Participants were informed of the study via a flyer which contained detailed information about how data will be collected, and the materials used. They were incentivized with a $20 gift card which enabled us to have a sample size of about 30 participants. The criteria for eligibility included participants between the ages of 18 and 65, no restriction on medical conditions and pregnant women were allowed to participate as well. The study was conducted under IRB approval (IRB-FY22-363) in a lab facility at the Marietta KSU campus and all safety protocols were observed in accordance with the CDC guidelines for Covid-19.

B. Materials

The CareTaker 4 (CT4) device was used to gather all the data used in this study. CT4 is an FDA approved non-invasive wearable device which consist of a compact wrist-

worn device with an on-board display [5]. A disposable finger cuff is connected to the CT4 via a tube which inflates to low pressure when in use. The CT4 operates through a low power Bluetooth and AES 128-bit encrypted data stream and serves as a 'wearable hub' for collecting data on other Bluetooth devices such as Oximeters, thermometers, weight scales, etc. The device communicates with a companion CT4 android application which can be integrated on Android, Windows and Linux platforms using software development kits [6]

Through the wrist cuff, a finger sensor, and pulse decomposition analysis technology, the CT4 is able to provide continuous hemodynamic monitoring of various vital signs for transmission in real time to a central monitoring system as needed [6]. Some of the vital sings the CT4 measures include blood pressure, heart rate, respiration rate, oxygen levels, temperature, and Mean Arterial Pressure (MAP) which are all collected non-invasively and with little to no pressure on the site of application [6]. The CT4 and oximeter device are shown in Figure 1.

Figure 1: Care Tacker 4. (Left) Device. (Right) Oximeter

C. Data Collection Process

Once participants arrived the research lab at their scheduled appointment time, they filled a survey to provide demographic data and to confirm they did not have any Covid-19 symptoms. All safety protocols were followed both by the participants and the research administrators. Then the participant was seated and made comfortable, the CT4 was wrapped on their wrist, turned on and synced with the companion android application on a Samsung tablet. If no errors flagged on the app about the device, the start button was then clicked on the App to start calibrating the data. The vitals recorded include blood pressure, heart rate and respiratory rate. Then the oximeter was turned on and added on the index finger and the SPO2 button pressed on the app to record oxygen levels. The oximeter was kept on for five minutes and taken off while the rest of the data was collected for a duration of 20 minutes. See Figure 2 for device setup and data calibration in the android app. After the participants vitals were recorded, Covid-19 protocols were followed again to ensure proper hygiene both for participants and research admin and cleaning of equipment. Examples of CT4 on the hand of a subject and the Android App are shown in Figure 2.

Remark 1

Although the CT4 is effective in collecting the data required, the data can sometimes be of low quality for a few reasons,

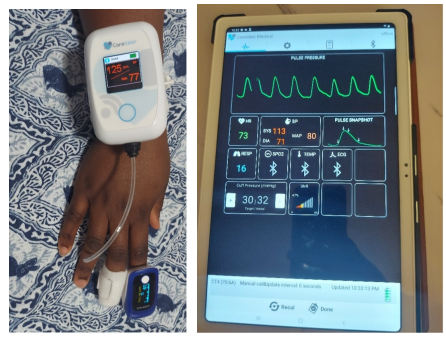

Figure 2: Care Tacker 4 during data collection. (Left) Device on the hand of a subject. (Right) Data collection application.

which include uneven pressure on the finger cuff, excessive movement of the finger finger cuff or CT4 device, and incorrectly wearing the finger cuff/CT4. The remedy to this is the existing fix by way of message display on the CT4 of the suggested error and correction [5].

III. Data Analysis and Visualization

A. Data Analysis

The CT4 records the data and stores it in two forms – as a hemodynamic summary report in *PDF* format and also a detailed *EXCEL* report file. The *PDF* report shows individual vital signs plotted against time in a graph, there is also a table of the data statistics, an event log, and a vitals survey. One of the hemodynamic report is shown in Figure 3.

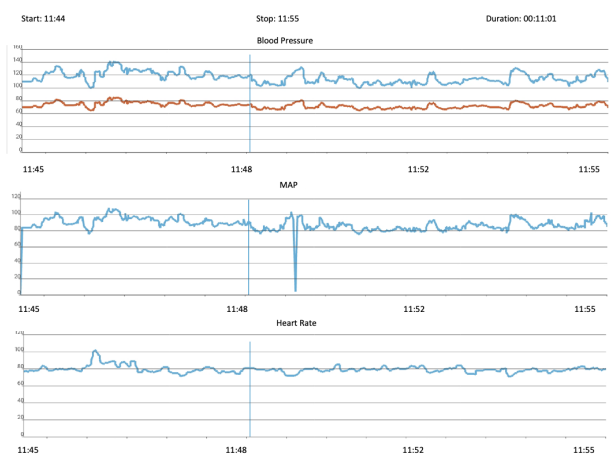

Figure 3: Hemodynamic Report

B. Data Visualization

Because the study is still in early stages, the data set is very limited. The data sets plotted in Figure 4 uses data from five people and is used to demonstrate what we expect to be able to achieve in this study. Figure 5 shows the vital signs of one participant collected for a duration of 20 minutes per required time. The blood pressure (systolic/diastolic) for this participant hovers around the normal rates of 120/80mmHg with random fluctuations as more data is gathered. Their heart rate also falls within normal range of between 60 to 100 beats per minute.

The normal respiratory rate is between 12 and 16 breaths per minute and normal oxygen levels are above 95% which this participant is right at recommended levels. The oxygen levels show inconsistency in comparison to other vitals for the same timeframe because the oximeter is connected mid-point during data collection and only stays on for about 5 minutes.

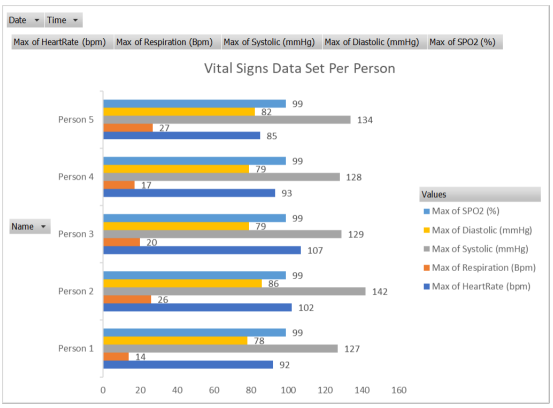

Figure 4: Bar Chart showing data sets for five different people

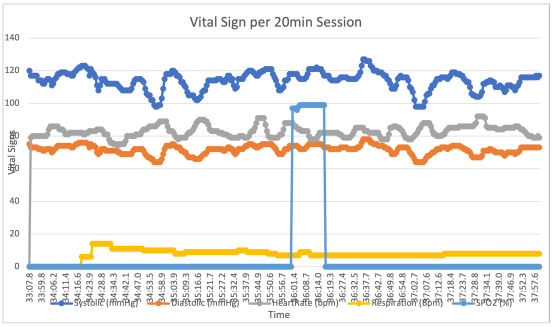

Figure 5: Line graph of participant data for 20 minutes session

IV. Results and Recommendations

Figure 4 shows data sets collected from 5 different people with the max values of each vital sign marked per participant. According to research, while all vital signs are important predictors of patient status, a combination of heart rate and respiration rate deteriorating signals urgency [7]. Taking into consideration only the max value of each vital sign per participant in a period of time and using heart rate and respiratory as best signals for urgency, that would move person 2 and 3 on the priority list of those that should be attended to immediately. Figure 6 shows a similar result to graph 2 plotted differently and although the same data set is used, the range is reduced for better visuals. Going by the logic from before, on this graph, person 4 will move up the priority list of urgency as their heart rate is above normal range at 107 and their respiratory rate is below average at 7 breaths per minute. With the study itself, we expect to get about more data sets from participants and aim to deduce the mathematical model [8] that will enable us to generate the triage. The expectation is that data collected in a time window like this will fluctuate which has both pros and cons for the study. Pro in terms of mimicking an ED

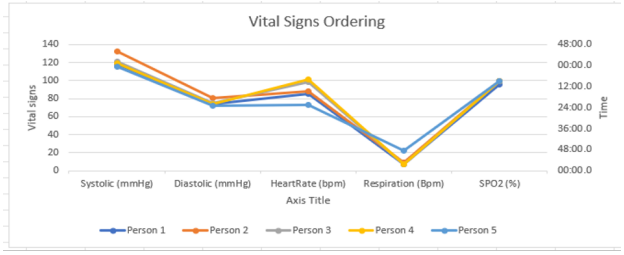

Figure 6: Line graph of participant vital signs

scenario in which patient vitals are constantly changing as they are monitored but cons because the data is not all recorded at the same time as different participant will have different appointments. Also, for this study, there is no simulation in a real ED to determine how the study translates in the real world for the time being. Currently, for the purpose of the study, CT4 only measures blood pressure, respiratory rate, heart rate and oxygen levels and no temperature. The mathematical model that is in development, must include temperature and reason of visit to the ED.

V. Conclusion

This is a preliminary report with limited data and basic charts to simulate what the study expects to achieve. As the research advances and more progress is made to include other vital signs and simulation in a real environment, the end goal is to be able to create an algorithm with a mathematical model using data in real time to create a priority listing of patients according to deteriorating vital signs. This would create so much needed relief in the ED both for patients and ED staff – boosting ED staff morale and increasing patient confidence in the system while reducing patient mortality.

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