Development of Real-time Clinical Data Visualization Tools through User-Centered Software Design

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Introduction

Shock accounts for 10% of all ICU admissions, 20-30% of hospital deaths and 15.4 billion in annual health care costs. Patients who have experienced trauma and require resuscitation from a surgical procedure, or other life-threatening conditions can progress quickly from a physiological state of compensation to overt clinical shock with only minor changes in traditional vital signs. Consequently, identifying and predicting patients' advancement through these stages is paramount for optimal clinical intervention.

Current medical monitoring technologies focus on mean, time-averaged values that are only visualized for short periods of time (seconds/minutes), hindering trend identification and prediction. Visualization of longer segments of clinical data is touted as a viable solution to this problem. However, it remains elusive as there is often a substantial disconnect between software usability and the healthcare professional's information needs. Moreover, when new solutions deploy, they are often cumbersome, inconvenient, or do not enhance real-world clinical decision-making.

Study Aim

Aim: To construct a novel data visualization model developed from real-time ICU patient information, with input from ICU healthcare professionals to guide our agile/user-centered design process.

Hypothesis: By applying a user centered design process to visualize continuous physiologic information, ICU health care providers can better detect a patient at risk for progression into shock.

Approach

Visualization and Summary of Trends in Raw Data

- We will develop software that identifies statistically significant trends in critical raw measures such as blood pressure in real-time compared to baseline when possible.
- Depending on the nature of the observation and a review of literature, we will define a functional model to determine trends in this raw data.
- We will use relevant, peer-reviewed and recent literature to define these models, and will utilize skills gathered from previous research to implement this approach.

Analysis and Prediction

- We will combine clinical data to identify these states by time point and use data from distressed states to predict clinical outcome in hours 8 & 9
- We will use R's *forecast()* package in combination with functions mined from literature to define predictive models for raw, real-time data.
- Analysis needing more computing power will be implemented on the Tusker computing cluster with the Holland Computing center using Python, MPI/OpenMPI, and R.

Visualization and Interpretation of Results

- Results will be summarized using descriptive statistics and sensitivity, accuracy, and specificity of models for each raw data variable will be defined and visualized with the intermediate graphics package *ggplot2()* in R.
- We will store and implement temporal network-based representations of our models using Neo4j.
- We will also incorporate the utilization of Tableau visualization software into our analysis.

Presentation and Feedback of Visualization

- We will conduct focus groups to determine physicians' level of interest in the visualized physiological trend data for clinical decision-making.
- Physicians will be recruited for the focus group from the Division of Cardiovascular Medicine and the Department of Anesthesiology.
- We will display developed prototypes, showing the visualized data and document physician's attitudes, feelings, and reactions to the presented data.
- The data gathered will provide information to enhance and refine the data visualizations.

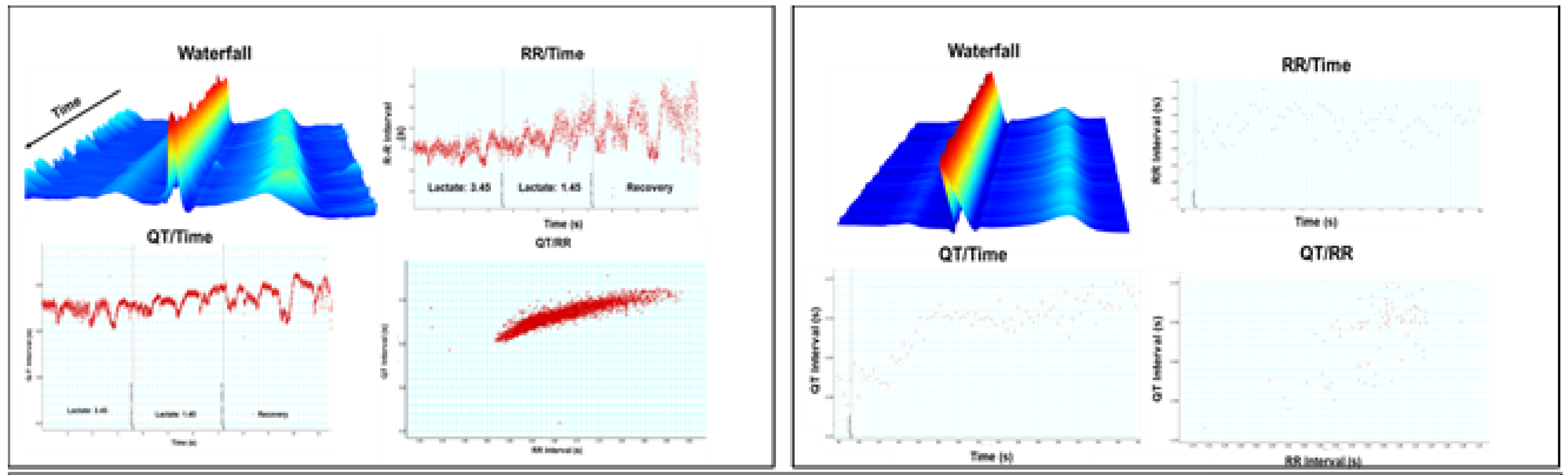
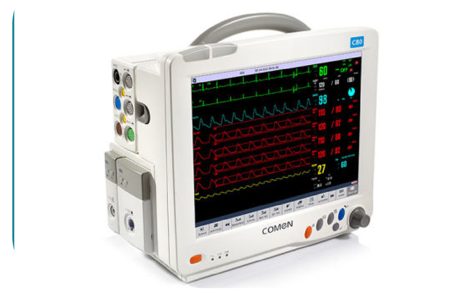


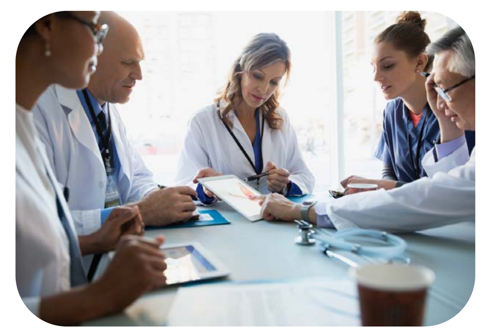
Figure 1. **Left:** 3 hours of visualized continuous ECG data collected from an ICU patient recovering from shock.
Right: 10 minutes of visualized ECG data collected from a healthy human subject. The same analysis techniques are used on both datasets for both figures. Note the lack of visible trend information from the 10 minute dataset.

Innovation



De-identified, clinical and raw physiological waveform database collected from ICU patients that experience elevated blood lactate levels, which is the gold standard for identifying shock.

The ability to visualize longitudinal physiological data by converting raw data into trend data



Utilization of focus groups to guide agile/user centered software design

An interdisciplinary team that can contribute the diverse expertise of several distinct but related disciplines

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