TRENDS IN INTENSIVE CARE INFORMATION VISUALIZATION

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Abstract – Monitoring of a critical care patient admitted to the intensive care unit generates substantial data. However, much of this information is largely discarded, as they are simply too large to be processed by a human. To understand patterns and meaning in the data, information visualization methods have been adopted in the electronic medical records. In this paper we identify the history and trends of medical information visualization, and provide some direction to advance the field of medical information visualization.

I. INTRODUCTION
Physiological data are derived from sensors attached to the patient. These sensors generate a continuous flow of information, which is of immense value for evidence-based decision making in the critical care unit [1]. Only a fraction of this data is aggregated, and transcribed at hourly or twice-hourly rates to the electronic medical record. The remaining portion of this data, however, is lost once it is deleted from the monitor’s internal memory. The intensive care environment is frequently referred also as the data-intense environment, where clinicians are required to maintain high vigilance and high situational awareness in order to react rapidly to the detection of adverse medical events [2]. The availability of substantial data volume presents several challenges which have been extensively studied in several domains, themes of related subjects include: information-overload, human-errors in transcribing, misinformation resulting from indirect communication, and the perception of physical and mental workload related to information comprehension and decision making [3]. Endsley, 1995 introduces situational awareness as three states of knowledge, wherein the consumer sources, synthesizes and finally imposed contextual meaning to predict information with respect to their surroundings [4]. Endsley argues although an individual may have perceived an event, they may not be actively aware of its significance or implications. Clinical researchers have long held the belief that existing methods of information display is internally taxing [5]. This internal requirement has been attributed to cases of medical errors, associated with the transfer of misinformation and persistent information overload [6]. Alternative methods of representing critical physiological information have been actively studied to reduce the internal processing requirement. With advances in the development of graphical user interfaces (GUIs), and improved accessibility of physiological data from medical hardware, several visual techniques have been produced to improve communication at the bed-side.

II. HISTORY OF MEDICAL GUI
As medicine became ever more complex clinicians saw the need to identify alternatives to the paper chart. The early-1990’s saw growing interest in converting large-volumes of paper patient charts to ‘virtual’ records [7]. These records were largely text-dominant, and contributed negatively to information overload. GUI-based medical records became popular by the mid-1990’s, intensive care unit systems were starting to integrate graphical electrocardiogram tracing [8]. These GUI systems were, somewhat disappointingly, the representation of text on a Windows-Icon-Mouse-Pointer format. Hence, even those GUI-based systems were significantly populated with text. There was also an attempt to make patient charts available ubiquitously over the internet; the motivation was to quickly visualize a patient’s laboratory reports while away from the bedside [9]. With the advent of hemodynamic monitoring technology in the early 1970s, displays were able to produce real-time visuals of patients’ immediate health status [10]. To this day however, that method of visualizing physiological data remains largely unchanged. Many continue to follow the single-sensor, single-indicator paradigm where each sensor is provided its independent display space. Much of the sampled data is represented as wave-form or aggregated numeric, and the former frequently exposed to artificial smoothing to constrain to restrictive screen sizes. Human consumption of all data points are infeasible, and exceed the capabilities of the human working memory.

III. TRENDS IN INTENSIVE CARE
Two less formal reviews and one systematic review were published in the last decade observing positive impact of graphical representations in the critical care setting. Sanderson et al., 2005 provides a forward looking analysis in the representation of physiological displays for anaesthesiology [11]. Drews and Westenskow., 2006, reviews several graphical displays to display graphical "metaphors" for rapid translation of
physiological event knowledge for anaesthesiologists [12]. Finally, the only available systematic review was published in 2007 by Gorges and Staggers in which an extensive systematic protocol is followed to review studies and report key findings of each study [10]. There are still many unanswered questions about graphical displays that have limited their adoption at the bedside. These reviews do not provide insight into limitations and a pathway for the future of graphical displays in medicine.

IV. DISCUSSION

GUIs have been attempted by several authors, and several studies have shown their potential to improve clinical care. While largely positive results have been released, there are still concerns as to efficacy. Most studies include diagnosis accuracy as a method to compare GUIs against standard practise; however, as to be expected, when provided relatively limited training time, and rapid exposure of new variables, diagnostic accuracy scores on studies ranged tremendously across all domains [13]. This method of training does not account for habituation and familiarity with traditional medical displays by clinicians. Detection was another area in which there were positive, but largely statistical differences. Many prototypes improved detection by enough seconds as to ascertain their statistical significance, however it has yet to be proven whether these statistical significances are relevant in the clinical domain [10]. Very few studies have tested their model against the general population to validate human factor efficacies, Effken and colleagues [14] are among the few who have attempted to measure these factors. However, Effken does not include any clinicians in the experiment, thereby eliminating influence from familiarization. Liu and colleagues [15] use medical students in their experiment to evaluate their prototypes, however they omit training altogether in their experiment. Better data collection tools are needed, for instance, Jungk and colleagues use eye tracking mechanisms to identify areas in the GUI where the user was heavily invested [16]. Tools that measure visual load, degree of attention, cognitive mapping of visual variables, degree of familiarization, and identification of the system status and error would provide additional insight into aspects of the graphical display that are effective for a complex, potentially stressful intensive care environment. Future studies should focus on clinical validation as a means to identify real-life relevance. Clinical experiments are difficult in lieu of several considerations and their limitations. However, one study by Wachter, et al. 2005, demonstrates that observational studies although somewhat intrusive may produce some significant qualitative results. These studies need to be expanded, and clinical trials must ultimately demonstrate their efficacy.

V. CONCLUSION

Graphical displays show promise; however, they are plagued with user-preference and interaction challenges. Several studies continue to show positive influence of graphical representations when they are used in simulated studies. However, many of these studies have not used standardized metrics across studies to test distinct controlled variables, or provide evidence of what features of the graphical displays afford greater comprehension to the consumer. Questions remain as to the efficacy of the representations in real clinical practice, wherein, the availability of all data instruments required by the advance representations may be limited. There are also questions of the graphical representation failing to maintain interpretable coherence when provided incorrect data.

VI. REFERENCES