Does Size and Location of the Vital Signs Monitor Matter?  
A Study of Two Trauma Centers

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Abstract

We report the results of an observational study in which we compared how the size and location of the vital signs monitor impact teamwork at two trauma centers. Our observations focused on three factors: information exchange, situational awareness, and ergonomic issues. We found that the smaller display was difficult to view and required more team communication and workarounds, such as periodic verbal reports. The larger and closer display, although accessible to more team members, did not uniformly improve team’s situational awareness because vital signals were not verbalized and the monitor was often ignored. We suggest introducing multiple larger and closer displays, while keeping the practice of periodic verbal reporting.

Introduction

Previous research has shown multiple benefits of having large information displays in collaborative work environments. Large-scale displays enhance awareness of other team members’ activities, are viewable from a greater distance, and allow several users to view and interact with them simultaneously. It is not surprising then that large information displays are becoming increasingly ubiquitous in medical settings such as operating rooms and hospital wards as a means of promoting awareness, supporting coordination and facilitating information exchange.

While large information displays have been used to support highly strained cognitive activities in time- and safety-critical settings, these technologies have not been applied to trauma resuscitation. Unlike other high-risk domains, trauma resuscitation lacks technologies that aid teamwork and promote situational awareness. Trauma bay instruments, such as the vital signs monitor, are output-only displays and do not support interactive sharing of information. Rather than being supported by informational artifacts, decision-making relies on working memory, knowledge and judgment. Team members must remember to view monitors presenting patient data to observe changes and trends in these values.

Our research seeks to identify design requirements for large information displays in trauma resuscitation. Because of the safety-critical nature of trauma resuscitation, it is difficult to experiment with prototypes or different arrangements of equipment. In our current study, we exploited the fact that the size and location of the vital signs monitors already differ at two trauma centers to which we have access. We compared the effect of these manipulations on teamwork at both locations. Our focus was on how placement and size of the vital signs monitor influence information exchange and situational awareness in the trauma bay. We hope that these insights will inform future interventions and the design of novel display systems for the trauma bay.

Background

Integrating technological devices into a confined space of the trauma bay can be difficult. There are several important issues that need to be addressed including how the display integrates into the physical environment, how much physical volume it requires, the optimal location for the display and the type and format of the displayed information.

Studies of both computerized and non-computerized public displays in hospitals have mostly focused on displays as an interactive, collaborative medium. Little research, however, exists on the use of output-only displays, such as vital signs monitors and how they influence co-located collaboration in fast-paced clinical settings. From previous research, we know that greater screen size offers more screen estate and allows more people to gather around and view the display. Also, displays within physical reach promote interaction and facilitate gesturing, which in turn improves explicit communication among the workers. Some researchers have already considered introducing information displays in the trauma bay. It is, however, essential to know what features of the displays are most likely to improve trauma teamwork before significant changes are made.

Vital signs monitor is currently the only electronic display in the trauma bay at most hospitals. It is
central to patient care and team performance as it displays critical patient information including:

- Blood pressure and ECG waveforms
- Pulse oximetry: heart rate (pulse) and oxygen saturation (SpO₂), and
- Respiratory rate

Critical decisions are made based on vital signs information. Blood pressure values indicate whether the patient is hypotensive or hypertensive, providing insight into the type of injury and potentially needed treatments. For example, hypotension suggests intravascular volume loss from hemorrhage and the need for fluid administration. Low oxygen saturation suggests hypoventilation or other problems with oxygen delivery and the need for administering oxygen. It is important to monitor vital signs throughout the resuscitation to ensure that the patient is stable. Abnormal values prompt the team to reassess the patient and intervene accordingly. For these reasons, having vital signs data displayed at all times, clearly visible, and known not only to decision makers but to the whole team is essential.

**Research Sites and Methods**

To examine how display factors such as size and location influence teamwork practices in a high-risk setting of the trauma bay, we compared data from two ethnographic studies conducted at two Level-1 trauma centers.

Trauma injuries include a wide range of mechanisms, such as motor vehicle crashes, falls, burns, and gunshot and stabbing wounds. Trauma patients are treated in the trauma bay, a designated room within the hospital’s emergency department (ED). Trauma team composition is similar at most Level-1 trauma centers in the US. A team typically consists of an attending surgeon, a team leader (a surgery fellow or a fourth year resident), a physician doer (a first or second year resident), an orthopedic surgeon, an anesthesiologist, a respiratory technician, a primary nurse, a pharmacist, a technician, and a nurse recorder. Other specialists may be called depending on the patient and injury types. Upon arrival of the patient, the trauma team gathers rapidly around the patient’s stretcher, positioned in the center of the room. Each member has a specific initial position within the room, based on his or her role. Patient management follows the steps of the ATLS protocol and consists of a rapid primary survey, resuscitation of vital functions, detailed secondary survey and the initiation of definitive care.

**Trauma Center One**

Our first research site was a Level-1 trauma center situated in an urban, teaching hospital in the US Northeast region (from now on referred to as TC1, Figure 1(a)). This center mainly treats adults, caring for over 1,200 patients a year. The trauma room dimensions are 4 m × 7 m. The vital signs monitor is mounted on the wall at the back of the room, in the left corner. The monitor has a 12”-color display.

At TC1, the team leader (usually a third year resident), stands at the head of the bed, while the physician doer (a junior resident), orthopedic resident, primary nurse, and critical care technician assume bedside positions. The anesthesiologist and respiratory therapist stand next to the team leader, on the left side. The attending physician is positioned at the foot of the bed, while the nurse recorder stands behind a portable table located in the lower right corner of the room. This initial positioning of the trauma team reconfigures according to the work demands during the resuscitation event.
Trauma Center Two

Our second research site was a pediatric emergency department of an urban, Level 1 pediatric trauma center in the mid-Atlantic region (from now on referred to as TC2). The center treats about 1,200 injured children each year. The room at TC2 is slightly bigger and measures 6.5 m × 7.5 m (Figure 1(b)). The vital signs monitor is sitting on a boom arm and is connected to a 19”-color display for an expandable view. The display is positioned close to the patient’s stretcher, on the left side.

The structure of the trauma team at TC2 differs slightly from that of TC1, mostly because of the presence of additional pediatric specialists. Some differences are also observed in team members’ positioning. The team leader is positioned at the foot of the bed. Physician doer stands on the left side, while the anesthesiologist and a respiratory technician stand at the head of the bed. The nurse recorder is positioned at the foot of the bed.

Methods

Data at both sites were collected using standard ethnographic techniques including observation and interviewing. For each study, we spent over 100 hours observing the work of trauma teams. In addition to observation, we also videotaped live resuscitation events. Approvals from institutional ethic committees were obtained at each institution prior to initiating the study. At TC1, we observed 60 resuscitation events, 18 of which were videotaped due to the 96-hour limit for video analysis. At TC2, we observed and videotaped 56 resuscitation events.

Observations, interviews, and video reviews yielded detailed field notes and transcripts of the events. Field notes and transcripts were analyzed using the grounded theory approach. We focused on instances that involved the use of the vital signs monitor. The data was analyzed at the paragraph, sentence, and word level to identify themes related to the effects of display size and location on teamwork practices.

Results

The nature of this study is observational and as such, our goal was to identify themes and trends that could be attributed to the size and location of the vital signs monitor at the two trauma centers. The results are presented as general observations concerning information exchange, situational awareness and ergonomic issues.

Information Exchange

We observed frequent questions about vital signs and other critical patient parameters at TC1. The vital sign monitor at TC1 is small and positioned to be out of the way. While its current location allows team members to move freely around the patient’s stretcher, its position makes it difficult to view. To work around this problem, a critical care technician is assigned to read the vital signs monitor periodically and announce the readings for others. Although this workaround somewhat helps, it also introduces a work practice that is unreliable. For example, we observed that technicians forgot to report vital signs, which prompted other team members, such as primary nurse to take over the technician’s role and report values (while neglecting their other duties). Even when the vital signs were called out, most of the time only one or two vital signs were reported. Reports mostly included blood pressure and heart rate, but rarely oxygen saturation. In a discussion following an observed event, the recorder expressed frustration with the lack of anticipatory reporting, which made the documentation work difficult and prompted unnecessary requests for information. The following vignette highlights this problem and how the recorder dealt with it:

Technician glances at the monitor and reports to the team: “120 over 70!”
Nurse recorder writes the value down in the flowsheet. A few second later, she asks the technician: “Heart rate?”
Technician: “111”
Nurse recorder: “What’s the... repeat hear rate?”
Technician: “111”
Nurse recorder writes the hear rate down and immediately asks again: “Saturation 100%?”
Technician: “Yes”

This example also points to another problem we have observed. Although the team members are collocated and can hear each other, the ambient noise impairs speech intelligibility. The nurse recorder is positioned in the lower right corner of the room, diagonally from the vital signs monitor. While out of the way, this outlying position often prevented the recorder from both seeing the monitor and hearing or understanding the technician reports. To address this problem, recorders either asked for information repeat or moved closer to the monitor to see the values.

In contrast to TC1, the vital signs monitor setup at TC2 contributed to fewer information exchanges related to patient vital signs. The display is considerably bigger and located closer to the team’s working area (Figure 1(b)). Similarly to TC1, a clinical care technician is responsible for connecting the patient to the vital signs instruments and monitoring their operation. We observed, however, that technicians reported only the first set of vitals. To obtain subsequent vital signs values, most team
members looked up to the display either in a quick glance or through a series of glances. Being positioned at the foot of the bed, the nurse recorder could also view the display and gather needed information without verbalizing it. While this display positioning might have decreased the amount of redundant questions and reports, it also made some team members less aware of the current vital signs values. For example, anesthesiologists and respiratory therapists standing at the head of the bed could not view the display because it was oriented the opposite way, toward the rest of the team. The following statement given by an anesthesiologist during a video review session highlights this problem:

“I am always trying to see vital signs and sometimes that’s hard, but it’s important to get the feeling of what the vitals are.”

Similarly, physician doers who are involved in hands-on patient evaluation had difficulty seeing the display due to their location. They often ignored the vital signs display until explicitly reminded by the team leader or attending to check the vitals.

**Situational Awareness**

Display size and location of the vital signs monitors at both trauma centers affected teams’ awareness of the problems with measuring vital signs, and thus the activities of technicians responsible for monitoring their functioning. At TC1, the team relied on technicians’ periodical verbal reports, instead of team members glancing at the monitor. When the reports became irregular, team members started inquiring about the vital signs. In other words, it was not the display that enhanced the awareness of technician’s activities, but his own verbal reports. Because fewer eyes were viewing the display, smaller display size also made technicians solely responsible for monitoring the functioning of the vital signs instruments and recognizing abnormal values.

In contrast, because most team members at TC2 could view the vital signs display, monitoring of the instruments and watching for abnormal values was spread across the team. The bigger display at TC2 also enhanced the awareness of technician’s activities. When blood pressure values disappeared or did not show up for a long time, it was a signal to the team that the technician was having difficulties with setting-up the blood pressure instrument.

**Ergonomic Issues**

The positioning of the vital signs monitor at TC1 made it difficult for the recorder to obtain values. Nurse recorders often had to leave their duties and check vitals on their own or request readouts. In addition to this ergonomic issue, we also observed that the monitor positioning at TC1 required the team leader to turn away from the patient to read the vital signs. This inconvenience made the team leader obtain information through inquiries rather than through direct observation. Consider the following conversation between the team leader (TL) and the primary nurse (PNR); BP stands for blood pressure:

TL: “Are you running fluids wide open?”
PNR: “Yeah.”
TL: Alright, we can slow it down. BP is how high?
PNR first glances at the vital signs monitor, then responds: “147 over 76.”
TL: “You can shut one off, and the other one and then we’ll wait before chest x-rays.”

At TC2, team members who had difficulties with viewing the vital signs monitor included anesthesiologists and physician doers. Because anesthesiologists stand at the head of the bed, they did not have clear views of the display and thus, had difficulties in obtaining vital signs values. Similarly, physician doers were turned away from the monitor and often ignored it during patient evaluation. Another problem is that the monitor, being too close to the patient stretcher, made it inconvenient for the physician doer to move around and examine patient’s head. They either had to move away the monitor or bend to avoid hitting their head.

**Discussion**

The following summary highlights pertinent results and discusses design implications.

**Information Exchange:** The larger display at TC2 had positive impact on information exchange. It reduced the number of redundant questions about vital signs and obviated the need for verbal reports. In addition, several team members benefited from the larger display. The team leader had a clear view of the monitor and rarely inquired about vital signs; the nurse recorder was able to document vital signs without moving closer or asking for readouts.

**Situational Awareness:** Situational awareness improved with the larger display in some aspects but also weakened in others. For example, the larger and closer display enabled more people to view it and detect problems with obtaining vital signs measurements. It also enhanced the awareness of technicians’ activities. On the other hand, the display at TC2 remained inconveniently positioned for some team members, including the anesthesiologist and physician doer. Moreover, their awareness of vital
signs weakened because they lacked both a clear view of the monitor and technician’s verbal reports.

The larger display in close proximity also improved observing changes and trends in vital signs. To observe trends or detect changes, team members at TC1 needed to memorize previous verbal reports and recall them for comparison with new values. At TC2, this task changed into pattern recognition because team members could view the display on their own.

Ergonomic Issues: The display position at TC2 was ergonomically better for the recorder and team leader, compared to TC1. However, some team members found that the display interfered with their activity and had to navigate around the display.

Implications for Design

The team’s main locus of attention is and should continue to be the patient. This observation implies that visual sources beyond the patient cannot and should not be depended upon to transmit information reliably. They may be ignored when out of sight or may act as a distraction when in sight.

Our results suggest two potential improvements:

First, a single vital signs display appears to be insufficient. The team members’ positions and the need to remain focused on the patient require multiple displays around the room. Their location should allow for important information to be displayed in a way that does not require frequent changes in eye-accommodation. These displays could be either wall-mounted flat-panel displays or ceiling-mounted over-the-table displays (a module with four flat-panel displays just about at eye level).

Second, we believe that improving the display alone is not enough to enhance situational awareness in the fast-paced setting of the trauma bay. Larger screen size and close proximity facilitated access to information for some team members, but weakened awareness of vital signs for others. We suggest introducing larger and closer displays, while keeping the practice of periodic verbal reporting. As our data showed, verbal reports are helpful because team members can hear them while focusing on their work.

Conclusions

We focused on identifying themes and trends in trauma teamwork related to differing size and location of the vital sign monitors. Given the complexity of trauma resuscitation and some organizational differences that we have observed, it is difficult to examine these factors in isolation. Nevertheless, we believe that our ethnographic analysis successfully identifies the effects of display size and location on information exchange and situational awareness in the trauma bay. Our findings offer insights into the strengths and weaknesses of these display factors and are relevant for future systems design for trauma resuscitation and other dynamic, safety-critical settings.

References