Safety Innovations

Healthcare Alarm Safety—What We Can Learn from Military Alarm Management Strategies

Editor's Note: *This paper was originally published earlier this year under the auspices of the AAMI Foundation's Healthcare Technology Safety Institute (HTSI).* The Safety Innovations *series is a collection of white papers, reports, and guides from HTSI. This particular paper was written by Julie Scott Allen, of Drinker Biddle & Reath, based on interviews with Daniel McFarlane, Sc.D., a researcher with Lockheed Martin (LM) Advanced Technology Laboratories. In this paper, McFarlane describes how hospital systems might improve their alarm management strategies by considering innovative alerting systems utilized by the Navy to improve warfighter awareness and capabilities.*

Description

In an effort to help nurses and other health professionals make better decisions in response to patient alarms, AAMI sought the insight of Lockheed Martin researcher Daniel McFarlane, ScD, to consider how hospital systems could improve their alarm management strategies by examining the strengths of military alarm management protocols and systems. With a mixed background in informatics, cognitive systems, and communications, McFarlane provides a perspective from outside the healthcare field with recommendations for consideration by healthcare providers and systems.

Introduction

Deep within the center of a naval warship is a military combat information center that utilizes both human and computer-based intelligence to understand its surroundings and to identify nearby objects, decide if they are friendly, neutral, or hostile, and determine whether they require a response from the warship. Military decisions on identifying objects and labeling them as potential or actual threats must be done in real-time so only necessary action is taken. If decisions made by military combat information center personnel are not accurate, the consequences are significant at best or severe at worst, with potential international implications. The process for making these decisions is far from easy. Operators within the combat information center carefully watch complex screens, scrutinizing every movement in the outside situation looking for any sign of concern. At the same time, alarms announced with buzzers are firing off to alert personnel to any recognized pattern of change that was predecided to merit human attention. This includes a mix of alarm types, and deciphering the importance of each is often relative to the changing situation. These alarms must all be interpreted by operators simultaneously. As an example of what this requires, warship operators during the first Gulf War were receiving extremely frequent alarms; one class of operator, for example, received a new alarm every 11.5 seconds on average. Turning a deaf ear to alarms is not an option for the military operators, as some alarms have life or death consequences.

Over the years, defense researchers have spent significant time and resources examining how to maximize a warfighter's performance as they monitor screens of information and deal with a multitude of automated notification systems and alert interruptions. The military recognized years ago that while automated notification systems provide constant warnings, they do not necessarily result in the needed recognition by operations personnel. Research from the defense research community has shown that people have cognitive limitations that affect their ability to cope with alert-based interrup-

tions. Ultimately, individual decision quality is significantly reduced as a consequence of these limitations. For the military, dealing with the risks associated with human error led to the development of a new solution and way of thinking about alarm management. The solution was found in the use of software that helps maximize human performance, regardless of the type or multitude of alarm interruptions. Interactive software provides "negotiation-based coordination" services that empower operators to quickly understand the importance of every alarm relative to the current situation, and triage their own attention to focus on what is most important.

Applying Defense Logic To the Healthcare Setting

In the healthcare setting, alarm management can be as crucial to making life and death decisions as it is in the warship. Nurses and the expanded healthcare team are expected to appropriately respond to alarms, using judgment while listening to alarms that fire off on a frequent basis. For a nurse working a 12+ hour shift, these alarms eventually may fade into background noise, and even when they are recognized, most alarms give no direct actionable information that provides immediate support for decision making. Dr. Daniel McFarlane of Lockheed Martin's Advanced Technology Laboratory in Arlington, VA understands this scenario more than most. With over 25 years invested in the study of human attention theory on how people manage and focus their attention to make decisions, he sees an immense opportunity to learn from defense-related research and practices and to change how hospital systems manage alarms and ultimately save lives.

In 2012, after learning of Lockheed Martin's efforts to improve systems integration in healthcare and of the company's experience with military alarm safety management, AAMI asked McFarlane to serve as a subject matter expert and to utilize his work in human attention theory to provide recommendations on how the healthcare industry could improve its current alarm management systems. He made site visits to hospital and clinical care settings and participated in standards workshops to learn more about current hospital-based efforts and best practices in alarm management. Site visits included spending time at Johns Hopkins Medical Center, Massachusetts General Hospital, Davita outpatient clinics, Palomar Medical Center, and Cedars Sinai Hospital. McFarlane reviewed how various healthcare settings managed alarms, examining everything from cardiac and neonatal hospital units to post-operation settings and outpatient dialysis units. What he discovered was that the approaches being used across the hospital industry and in other outpatient settings continued to present repetitive challenges—challenges the broad healthcare community has faced for years: ignored alarm signals, lengthy practitioner response rates to the alarms, and provider confusion over the importance of the alarms. Having worked with the military to improve alarm management and introduce software options to support decision making, he began to see that military-type solutions could provide hospitals a similar level of support, but to implement such a system(s) in the healthcare sector would require a shift in the mindset of care providers and a change in how medical devices ultimately work.

Drawing on his experience, McFarlane approached the task of helping to advise on alarm management with one primary question in mind: What does a healthcare worker need to know, and when do they need to know it in order to make a good decision? Once that question could be answered, he sought to focus on two specific efforts: 1) identifying which patient a nurse should be attending to now, and 2) determining what actions a nurse must take at this time.

Health System Observations

McFarlane observed several limitations in how medical devices function when producing alarms. Such limitations included the following:

- Alarm configuration settings on devices are limited to simple ranges, and most clinicians tend to rely on factory-default alarm settings rather than making adjustments.
- Alarm signals do not include sufficient metadata about the nature of the alarm to help a nurse determine its importance.
- There is no cross-device integration, as

Success to Alarm Management:

First, answer the question: What does a healthcare worker need to know and when do they need to know it in order to make a good decision? Then, respond by doing the following:

- Identify which patient a nurse should be attending to now; and
- Determine what actions a nurse must take at this time.

Problem #1: The design of current alarm signal delivery is not focused on helping the nurses triage time across multiple patients.

Proposed Solution: Hospitals need to advise device manufacturers and the standards development organizations that specify device behavior in these areas that devices need to be designed to provide content (about a patient) to assist nurse decision making and multitasking.

Proposed Method for Addressing the Problem: Design a new research method for evaluating a medical device for how it helps the "front line workers" (e.g., nurses), and then test it in a high-fidelity patient simulation setting so that nurses can determine what works and what does not work for them.

devices do not "talk" to each other. A ventilator from one manufacturer will likely not communicate data across a network with a physiological monitor from another vendor.
- Alarms on devices connected to a patient are not connected to clinical information systems that can provide specific medical information a nurse can access while considering the reason behind a patient alarm.

Problem #2: Many medical devices are built by a number of different vendors and cannot relate or talk to each other.

Proposed Solution: Establish standard interfaces for medical devices that facilitate integration.

Proposed Method for Addressing the Problem: Consider a new model for provisioning hospitals by buying hospital "systems" from an integrator. If enough hospitals adopted this model, the integrator would have sufficient market power to motivate vendors to conform to interface standards.

As a result of these limitations, nurses largely do not trust that alarms are valid or useful, and they stop relying on the systems and their notification. This frequently results in a slower review and response time to patient alarms, at times having dire consequences for the patient.

Utilizing his training, McFarlane sought to dissect the problems he observed and to match alerts "in the hospital" to actionable data that are fed to the personnel responsible. He began to see distinct behavioral variances between the military warship setting and the hospital/clinical setting with advantages and disadvantages in relation to alarm management. For example, he realized that unlike a military command officer who observes a computer screen full of remote unseen objects and relies on alarms to sound off concerns that must be analyzed, a nurse walks into a command post already "armed" with more intelligence about the targets (patients) in question. A nurse has the benefit of patient medical charts and background information, distinguishing patients from one another, a distinct advantage over a military officer who knows very little about the targets being observed. Similar to the military setting, however, the nurse is without any definitive information on the true status of what the alarms represent when they sound.

Another distinct difference between the warship and the hospital is that the warship allows for stationary work, while the hospital requires mobile work. In the warship, the military operators are focused only on observing the screen and the images and the alarms being presented in front of them. In the hospital setting, nurses and other health professionals are anything but static; moving around a hospital wing or department nonstop, their days are focused on managing multiple patient-related tasks simultaneously.

"One of the first things I noticed during my site visits to hospitals and health clinics is that existing hospital alarm systems are not targeted at helping the care provider—the nurse¬—on the front lines who has direct patient care decision-making responsibilities. Current alarm systems don't even allow nurses to get to the meta-level task of understanding which patient they should be attending to first." His observation was that medical devices provide an audio or visual sign that an issue and potentially a problem exists, but they do not directly provide the nurse with any other information that could be used to prioritize their responses. For some hospital systems, nurses are provided pagers or other mobile devices as secondary notification that a patient alarm signal has been made, but most pager notification system provide no other direct, actionable intelligence to the nurse to aid in decision making or a response. For example, secondary notification systems sending alarms about a patient's heart rate threshold crossing event, could additionally include information about the patient's other vital states.

"The lack of actionable intelligence from alarm signals makes it impossible for nurses to effectively triage their multitasking among multiple patients," said McFarlane. "The testing of new medical alarm designs seems to be often focused on whether it affects patient mortality rates. I think a more useful metric would be do these alarm designs provide a nurse the information needed to make a good decision about when to provide what care to patients." To address this issue, McFarlane believes it would be useful to include nurses as stakeholders to help guide alarm safety research and development (R&D). McFarlane believes that identifying ways to help nurses improve in triaging their time would result in improved care for all patients.

McFarlane recommends that such an R&D effort should seek to "walk in a nurse's shoes" and understand that nurses are typically assigned to two or more patients at the same time, all in different rooms. As a nurse's job requires frequent movement throughout a hospital wing, they are often blind to recent changes in their patients'

status. This situation too frequently results in missed opportunities to provide needed patient care, despite the presence of medical device alarm systems. According to McFarlane, "current alarm generation functions do not align with the multitasking needed to triage attention across multiple patients. Instead, each alarm feature considers only local conditions on separate sensors on separate instruments for separate patients. The result is an overwhelming rate of alarm signals from multiple devices associated with multiple patients that do not carry the context of information needed for nurses to understand the signals relative to their responsibility to triage their efforts." He argues that an R&D effort must recognize the limitations of the nurses' current work environment and seek to establish new mechanisms that address nurses' needs given the mobility of their practice.

Advising Healthcare Device Manufacturers

One of the primary challenges in relation to medical devices and alarm management, according to McFarlane, is that devices are built by a multitude of vendors. The alarms all sound similar even though the purpose of the alarms are all different, and perhaps most significant, the medical devices made by different manufacturers cannot talk to each other.

"As an engineer, I've learned that there can be a fatal error in how a machine is constructed. That error is due to false assumptions about how a machine will be used." In McFarlane's observations, medical devices are too often being designed as if the nurse is always standing at the bedside and can review the patient as soon as a device issues an alarm or visual signal. In his opinion, this is simply a false premise. "A good nonmilitary example of a "system" is the automobile," according to McFarlane. "Car makers do not make most of the various different car components; they instead do the integration work of bringing together technologies made by many vendors. Similarly, each hospital buys their technical components directly from many different primary manufacturers and then does their own custom integration. Because no single hospital has the market power to motivate the many vendors to conform to standard interfaces, each hospital is faced with a very difficult integration effort. Talented engineers bring all the pieces together, but the result is not a well-designed "system" and does not directly support the high-level workflow needs of the nurses and other end-users."

The Future for Alarm Management

For McFarlane, the conclusion to the challenge behind alarm management can be summed up as follows: "Current alarm generation functions do not align with the multitasking needed to triage attention across multiple patients. Instead, each alarm feature considers only local conditions for a single sensor for a single patient." The end result—a fire hose of alarm signal data that does not carry the context of information nurses need for understanding how to utilize the alarms to triage across the multiple patients they are responsible for at any one time.

Alarm research needs to look at three distinct areas related to how alerts issued

Problem #3: Nurses are mobile and medical devices are static.

Proposed Solution: Get the information interface for a medical device to where the provider is located as she/he moves around the hospital.

Proposed Method for Addressing the Problem: Use current technological resources to deliver intelligent information on medical device alarms through such processes as smart phone or other electronic technology and applications.

from medical devices can support patient care decision making:

- Alert generation: The design of how medical instruments detect specified alarm conditions and then generate alarm signals.
- Alert mediation: How raw alarm events are managed to support end-users' workflow needs. This can include implementation of a policy about how alarms should be managed and routed to which end-users. For example, an alarm delivery escalation policy can define a chain of people to forward an alarm to if the primary recipient does not acknowledge it within a specified time.
- Alert presentation: How the alarm signal is delivered to end-users. This includes the visual and audio announcements of alarms to end-users. Critical alarms about a patient's breathing difficulty could be announced with different sounds than alarms about device batteries needing to be changed before the end of the day.

Change the Look, Feel, And Scope of the Devices

Alert mediation is an important R&D focus for improving the utility of alarms for end-users. Lessons from military "systems" thinking can be leveraged to inform a new design that combines raw device-based alarm signals with additional data to support a nurse's decision making in response to a patient alarm. According to McFarlane, "in current operations, there is a high rate of alarm signals generated, but the majority of these signals do not reflect clinically-significant events. The main problem is that these alarms are not being delivered to their nursing consumers with enough contextual metadata to provide an understanding of their meaning or relative importance. Computer networked data analytics are capable of dealing with the current high rates of streaming data and applying algorithms that can assess that data."

McFarlane advocates for research that considers how to link alarms to patient data through a secure computer network connected to a centralized server. When an alarm is generated, alarm mediation technology could package the delivery of that alarm with additional context information about the patient, such as the patient's medication status. This would enable health personnel to potentially understand the relative importance of that alarm signal and decide how to fit a response to the alarm into their multitasking.

Once the alarm can be turned into something actionable, after being paired with patient information, the next challenge is how to deliver it to the nurse. According to McFarlane, "to be successful in ensuring the nurse gets the right information at the right time to respond, the R&D effort must also consider how to address the fact that a nurse is mobile and does not work only at the bedside. Researchers must consider how to get this actionable information seamlessly into the hands of the nurse. Through the use of mobile technology—devices and apps—information can be made available in a matter of minutes." ■