Managing Mechanical Ventilator Alarms with Middleware

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About the Author



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in New Britain, CT. Email: cdills@ hfsc.org Alarm fatigue is a major issue facing hospitals today. The ECRI Institute defines alarm fatigue as an event that "occurs when staff members are exposed to an excessive number of alarms, which can desensitize them to alarms and result in sensory overload."1 Research suggests that 75% to 99% of clinical alarms are false² and typically categorized as a technical rather than a physiologic alarm. Many other alarms are considered nonactionable in that they do not require an immediate response. Contributing to the complexity of this issue is the variability in the types of alarms generated. Three types of alarms are generated with hospital monitoring devices: dysrhythmia alarms, parameter violation alarms, and technical alarms.¹ The Joint Commission sentinel event database reports that 98 alarm events occurred between 2009 and 2012, 80 of which resulted in patient death.3 ECRI identified missed ventilator alarms as the third-highest potential health technology hazard for 2017.4

The current article focuses on parameter violation alarms and technical alarms. In addition to helping to alleviate sensory overload, the process described could reduce the number of lives lost due to alarm desensitization.

The progression of mechanical ventilator technology has kept pace with other medical technologies. Accompanying this progress have been exponential additions to how these devices monitor themselves and the patients connected to them. The result is a proliferation of ventilator alarms associated with more than 100 different conditions. These alarms were intended to promote and enhance patient safety. However, the volume and sheer number of alarms bombarding clinical staff and patients made responding to them in a timely fashion nearly impossible, particularly for many institutions with large populations of ventilator patients. The Association for the Advancement of Medical Instrumentation and the Food and Drug Administration convened a workgroup of clinical practitioners, vendors, and researchers to address this specific issue, and the group identified actionable versus nonactionable alarms for the ventilator patient.⁵

Identifying the Issue of Clinical Alarms

The Hospital for Special Care (HSC) in New Britain, CT, identified clinical alarms as a major concern more than 10 years ago. HSC manages approximately 100 mechanically ventilated patients each day, among a population that includes infant, pediatric, and adult patients suffering from a wide range of pathologies. We estimated that approximately 19,000 ventilator alarms occurred each day within the facility. Staff identified the negative effects of incessant ventilator alarms as a concern.

Respiratory therapists and nurses are responsible for numerous patient care responsibilities in addition to answering ventilator alarms. We needed to find a way to address this very important safety issue. We recognized the need to leverage both technology and the expertise of interdisciplinary leadership. In the several decades prior to August of 2006, all HSC ventilators were plugged into the nurse call system, which meant that every alarm condition was audible overhead. Our primary goals included ensuring that actionable alarms were answered in a timely fashion and reducing the number of overhead alarms, which contributed to ambient noise and subsequently to alarm fatigue.

We were fortunate to receive organizational backing from hospital administration and pulmonary medicine, expertise from clinical staff, and additional support from the departments of information technology, clinical engineering, safety and risk, and respiratory management.

We identified middleware as the best route in addressing this challenge. As utilized for alarm management, middleware works as an electronic monitoring system, which interfaces with medical devices and continuously collects data and monitors for breaches in set alarm parameter settings. Middleware then alerts caregivers to potential life-threatening conditions. Middleware affords the ability to customize alarms and to send notifications to a secondary device (e.g., a pager, smartphone, laptop, desktop computer, and/or electronic message board). However, middleware's invaluable contribution to clinical care is the ability to distinguish between actionable and nonactionable alarm conditions. HSC's respiratory therapists tailor alarm settings to the patient's condition based on American Association for Respiratory Care best practices, but this does not eliminate the plethora of alarms that can and still do occur.

Implementing the Middleware

We focused on high inspiratory pressure (HIP) limit and high respiratory rate (HRR), which are our most frequently occurring alarm conditions. A recent 90-day data review of 86 of our ventilators at HSC revealed 520,309 HIP alarms, which accounts for nearly one-third of all alarms elicited. Our second most frequently occurring alarm is HRR. Combined, these two alarms account for more than 50% of all ventilator alarms. Our clinicians at the bedside readily agreed that most of these alarms were nonactionable and precipitated by patient actions such as coughing, swallowing, attempting to speak, or repositioning. Typically, these alarms self-clear before someone responds but not before audible alarming by the device (i.e., the ventilator) occurs. By using middleware, we filtered out those alarm conditions as a level one priority (Table 1).

The interdisciplinary team identified the alarm conditions critical to patient safety: patient disconnect, low exhaled minute

volume (Low Ve), low inspiratory pressure (LIP), and no data. Patient disconnect indicates that the patient disconnected from the ventilator circuit or that the ventilator circuit disconnected from the ventilator. In either case, the ventilator cannot ventilate the patient. Low Ve tells clinicians that the amount of air exhaled by the patient returning to the ventilator has ceased or decreased to an unacceptable level. That may indicate that the patient's spontaneous respirations have ceased or are too shallow or that there is a leak in the system. LIP indicates a potential leak in the system that is great enough to prevent the ventilator from providing an adequate breath to the patient. No data indicate a loss of connectivity with the middleware. Although these critical alarm conditions clearly indicate that the patient is not being ventilated, they account for less than 40% of all alarms.

If the patient presents with a clinical issue and the alarm condition persists beyond a few breaths, a level one priority alarm is actuated because Low Ve can result from a high respiratory rate or the limiting of the delivery of the breath by reaching a pressure limit. Respiratory therapists can also set "smart alarms" through the middleware to alert them to alarm conditions for patients whose clinical condition warrants a heightened level of concern. This facilitates prompt intervention prior to the development of a critical situation that would affect patient safety.

We implemented middleware on one unit at a time, beginning with the pediatric unit because of its physical layout. HSC's pediatric unit is located in the oldest part of the 75-year-old building. The physical layout posed some unique challenges. The unit is broken into four segregated teams. Two teams are open but divided wards. A third team is located down a corridor with private and semiprivate rooms. The fourth team is a three-bed enclosed unit. Additionally, there is a one-bed isolation room. This configuration made it difficult for the staff to oversee more than one area of the unit at any given time. The middleware system proved effective at managing this problem, and we encountered very few issues during and immediately following implementation. We were able to proceed with implementing the middleware to the other units in short order.

Results

We realized an immediate 80% reduction in the number of nonactionable ventilator alarms following implementation of the middleware. Although we only examined ventilator alarms, this correlates with a scientific statement by the American Heart Association, which estimated that 85% to 95% of clinical alarms

Ventilators (Audited)	Days (Audited)	Total Alarms (Audited)	HIP Alarms No. (%)	HRR Alarms No. (%)	Total Low Ve No. (%)	Total LIP No. (%)	Total Patient Disconnect No. (%)	No Data (Loss of Connectivity) Technical Alarm (%)
86	90	1,680,198	520,309 (31)	370,883 (22)	341,053 (20)	298,324 (18)	145 (0.00001)	0.0003

 Table 1. Ventilator alarm audit at 90 days. Abbreviations used: HIP, high inspiratory pressure; HRR, high respiratory rate; LIP, low inspiratory pressure;

 Ve, exhaled minute volume.

do not require intervention.⁶ The units sound significantly quieter today due to the noted absence of every ventilator alarm blaring overhead. When an actionable alarm occurs, the respiratory therapist is notified via pager with a message indicating the patient's name, the room number, and the alarm condition. The message puts a face to the alarm, and the clinicians know that an immediate response is required. A secondary page alerts coworkers in the event that the primary caregiver's response is delayed. Reducing the number of alarms informs practitioners which ventilator alarms require immediate attention, resulting in improved response times, productivity, and efficiency.

We are currently examining response times to actionable ventilator alarms. During a 5-month period, we audited 490 level-one priority alarms. Although no established standard specifies alarm response times, we set our time limit to 60 seconds and our compliance threshold at 90%. Our average response time was 17 seconds, and compliance was above threshold at 99% (Table 2).

Conclusion and Future Directions

The human factor is inseparable from this complex and risky area of healthcare. Monitoring systems perform only as well as the practitioners who use them. We routinely audit alarm parameters established by the respiratory therapists on the ventilators because the middleware is rendered ineffective if the alarm parameters are not set within established guidelines and policy. When managing these devices and systems, it is essential to understand your patient population, organizational and unit-based culture, and the competency of your staff. We continue to assess and act on concerns relative to these factors as patient populations, unit-based leadership, and technology continue to change. In the 13 years since HSC implemented a middleware system, we have not encountered a single adverse ventilator event related to monitoring and alarm response.

Patient safety represented the primary driver of this initiative, and we successfully met phase I and II of The Joint Commission's National Patient Safety Goal (NPSG) on Alarm Safety (NPSG.06.01.01),⁷ as well as the four associated elements of performance, through our use of middleware. Staff and patients have reported a considerable reduction in alarm fatigue following middleware implementation. This is largely the result of the reduction in the number of audible overhead alarms and our practitioners utilizing their skills more efficiently.

We are phasing in a new fleet of ventilators with enhanced technology and are experiencing a dramatic drop in our most frequently occurring alarm conditions. Our next frontier is examining the significance of the decrease in those alarms. Although they do not go through our middleware, they still alarm at the bedside and are a major contributor to alarm fatigue, particularly that of the patient, which is at the heart of this most important issue facing hospitals today.

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Unit (Type)	No. Level-One Priority Alarm Conditions (Audited)	No. Alarms Answered in <60 s	Compliance (%)	Average Alarm Response Time (s)
A (adult)	150	146	97	18
B (adult)	150	146	97	18
C (pediatric)	74	74	100	16
D (adult)	116	116	100	16
Total compliance (%)		_	99	17

Table 2. Response to actionable alarms at 150 days