Improving Telemetry Alarm Management at UMass Memorial Healthcare Center

A Major Qualifying Project Report Submitted to the Faculty of

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Report Submitted to:

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Abstract

"Alarm fatigue" is a top priority in many hospitals because it can cause dangerous, potentially life-threatening situations. This project focuses on the causes of and responses to the high numbers of telemetrically initiated alarms in a cardiac care unit at the UMass Memorial Medical Center. Lean methods tailored for hospitals are utilized to assess current state conditions, identify root causes, propose target conditions, and develop and effect an implementation plan. After implementation, the unit experienced a 13% reduction in total paged alarms over the post-design change period compared with the data preceding implementation of target state design. There was a 38% reduction in the number of the two specific telemetry paged alarm types targeted in this project over the sample period.

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Client Statement

The client is a cardiac telemetry unit, called 3 East, at the University campus of the UMass Memorial Medical Center (UMMHC). The problem is the lack of response to alarms received in the telemetry unit due in part to the number of alarms, but also due to various system design features. The system being studied consists of 3 East's telemetry hardware and software, the nurses, PCAs, nurse educator, and nurse manager who work in the unit and who monitor a maximum of 24 patients through telemetry, and the policies and procedures for responding to telemetry alarms. The objective of this MQP is to redesign this system using lean methods so that all "$Sp0_2$ no sensor" and "ECG leads off" alarms are handled in a clinically acceptable period of time. Background information is provided below about the client, the problem, and the approach taken to address the problem.

The Client

The UMass Memorial Medical Center, located in Worcester, Massachusetts, is a three-campus, nonprofit healthcare network which serves as the teaching hospital for the University of Massachusetts Medical School. In 2012, for the second consecutive year, UMass has been rated the number one hospital in Worcester County by U.S. News Best Regional Hospital rankings. The 700 bed hospital system, the largest in Central and Western Massachusetts, treats thousands of patients daily and is "committed to improving the health of the people of our diverse communities of Central New England through culturally sensitive excellence in clinical care, service, teaching and research" (http://www.umassmemorial.org/clinton-hospital/about-clinton-hospital/mission-vision-and-values).

The University Campus houses 417 licensed acute care beds with clinical focuses on radiation therapy, cancer care, neurology, trauma care, psychiatry, surgery, and advanced cardiovascular care in the Cardiac Care Laboratory. The Children's Medical Center, a pediatric specialty center, is located at this campus as well, and has Central Massachusetts' only pediatric ICU. This campus is also home to LifeFlight, the first air based ambulance in New England, as well as the region's only Level I trauma center. Every year over 110,000 patients are treated in the Duddie Mass Emergency and Trauma Center. In 2010 the campus opened an Ambulatory Care Center that offers care through clinics and translational research programs. More information is available at the following link: http://www.cdc.gov/nchs/data/series/sr_10/sr10_255.pdf

Because so many of the patients reside in either acute care or in Intensive Care Units (ICU), constant monitoring of patients' medical conditions is necessary. Many patients in acute care are monitored through telemetry by recommendation of a physician, and all ICU patients are watched through bedside units. All employees of the medical center seek to provide the best patient care possible, and because of this, the existing alarming model is in place.

The Problem

A major problem with the current system is that the sheer number of alarms is so large that nurses, who are responsible for responding to the alarms, have become overwhelmed by the volume of noise. On the patient care floors there is constant noise that has led to a condition known as "alarm fatigue." The medical center's mission is to provide the best possible experience for the patients, and noise is the number one complaint of admitted patients.

The primary goal of this project is to reduce the number of nuisance and false alarms in order to restore the urgency initially intended to be created by the alarm. To do so, research into the current alarm system, including investigation of parameters, policies, work flow, and limitations of the equipment, was conducted.

This project specifically addressed the problem of high volume and long response times to telemetrically generated ECG (electrocardiograph) and SpO_2 (pulse oximeter*)* alarms and their contribution to subsequent high volume of alarms caused by alarm repeat. Alarms are paged to both nurses and personal care assistants (PCAs) within the cardiac unit (3 East floor in this study) with no specific individuals accountable for response to the alarm. In addition, there was not a known way to silence the alarms from within the patients' rooms meaning that alarms would still be generated even when the patient was being attended to by a nurse or PCA. Although personnel could be responding to a patient whose telemetry pack had generated an alarm, they would still need to return to the patient information center (PIC) to silence the alarm. As a result, unnecessary or redundant alarms are generated and sometimes alarms are not addressed in a timely manner.

Boundary/Scope

The focus for this project was located at the 3 East cardiac floor of the University Campus of UMass Memorial Health Care and involved a maximum of 24 telemetry packs and the associated nurses, PCAs, nurse educator, and nurse manager. The specific types of alarms that were studied were ECG "leads off" and SpO_2 "no signal". Discussion among members of an executive steering committee that was formed to address the problem resulted in a determination that the project should involve only telemetry units and there would be no change of physiologic parameters allowed. Management participated in the selection of the particular unit, 3 East on the University campus, which was

selected because Mary Buttitta, the Nurse Manager of the unit, expressed interest in involving her staff with the project.

The Approach

The approach used in this project is lean methods based on a process known as the A3 report format, which is shown in Appendix A. Root cause analysis (RCA), which focuses on identifying all elements that contribute to the problem, is a component of the A3 report process. The client also incorporates the plan-do-study-act (PDSA) method as part of their A3 report format. Using these tools and processes, including working with the front line staff, an understanding of flaws with the system and current practices was developed. Input from Philips, the manufacturer and creator of the alarm system, telemetry units, and bedside units was used to further understand underlying contributors to alarm fatigue.

Chapter 2: Background Literature

This chapter provides background and context on technology and the terminology associated with the project. Topics covered include telemetry, an overview of alarm fatigue with associated hazards and patient satisfaction issues, and an explanation of how Lean Methods have been integrated into the healthcare industry. Case studies are included which provide background into how two institutions addressed alarm systems management.

Telemetry

Telemetry is used in intermediate care units which include cardiac, surgical, neurological, and respiratory care units. In these intermediate care units the goal is to provide optimal care while requiring less expensive technology and lower nurse-to-patient ratio than in the ICU units. Prior to the development of telemetry, any and all patients who required monitoring had to be admitted to ICUs. The mobility of telemetry packs is important for post-surgical patients in intermediate care units who, for the most part, tend to be relatively mobile so constant portable monitoring is necessary. The physiological purpose of telemetry units is to monitor the electrocardiograms (ECG) and the saturation of peripheral oxygen (SpO_2) in the body. ECG signals and SpO_2 values are captured and transmitted via the telemetry pack. This data is then processed and displayed on the central monitor operation system, otherwise known as the patient information center (PIC). The PIC generates alarms and recordings which are used to notify and inform clinicians of changes in the patient's conditions.

Constant monitoring of ECG signals and SpO_2 values is crucial. SpO_2 levels are measured with pulse oximeter devices that are connected by a cable to telemetry packs; the device is a sensor that can be placed on any thin, translucent part of a patient's body. Typically sensors are placed on fingertips or

earlobes, with two light-emitting diodes (LEDS) one with a wavelength of 660nm and the other 905-940nm, that shine through the skin to a photodiode. The absorption of the wavelength differs between oxyhemoglobin (Hb02) and deoxyhemoglobin (Hb) and their ratio can be calculated from the absorption ratio of the two LED lights. From the following formula SpO_2 is calculated.

$$S_pO_2 = \frac{HbO_2}{HbO_2 + Hb}$$

Knowledge of a patient's SpO_2 level is important because it provides a "fifth vital sign", in addition to blood pressure, temperature, pulse, and respiratory rate. An SpO_2 of greater than 95% is generally considered to be normal. When saturation level decreases below 92% this suggests hypoxemia. Patients with known respiratory illness or breathing difficulty may need to be put on oxygen supplementation if their SpO_2 rate falls below 92%. Pulse oximetry is valuable in triaging potentially hypoxic patients to determine which patients should have arterial blood gas measurement. Alarms are triggered from the telemetry pack when SpO_2 rate falls below the set parameters of the system or when a signal is no longer being read.

ECG signals have similar value to SpO_2 alarms with respect to patient monitoring ability**.** An ECG is a measurement over time of the net electrical activity of the heart muscle, as recorded at the body surface by electrodes attached to the skin, and is measured in several directions simultaneously. By interpreting the electrical currents of the heart throughout a series of heartbeats, from several angles, much can be determined about the functioning of a patient's heart. For recording data, graph paper is dragged past a marker hooked to the measurement device of the electrical current at a fixed rate leaving a graph of the net electrical current between two electrodes. (Pullen, 2011)

Willem Einthoven, born in 1860, was a physician, mathematician, physiologist, and also the first person to transmit ECG signals over a telephone line. Known as the "Father of Electrocardiography," he developed the string galvanometer that enabled producing the first high-quality images and identified wave forms and described the mathematical relationship between leads I, II and III (Hannibal, 2011). This is known as Einthoven's triangle and was the basis for the three electrode system used more than 30 years until the development of the twelve lead ECG. The trend in the last decade has been to use continuous monitoring of the 12 lead ECG with reduced lead sets so that ischemic (insufficient blood supply) patterns can be identified quickly (Hannibal, 2011).

Alarm Fatigue

Alarms on medical devices are intended to alert caregivers of hazardous conditions and potential problems, but when subject to too many alarms the caregiver may become a victim of alarm fatigue. This can result in errors due to omission, distraction, or inattention to alarms and patients in need. The definition of alarm fatigue has not yet become standardized, but at the Clinical Alarm Summit hosted by the Association for the Advancement of Medical Instrumentation (AAMI) in 2011, representatives from AAMI, the U.S. Food and Drug Administration (FDA), the Joint Commission (TJC), the American College of Clinical Engineering (ACCE), and the Emergency Care Research Institution (ECRI) conversed together to address the multiple interpretations. The most common definition of alarm fatigue is when a caregiver is overwhelmed with 350 or more alarms per patient per day (Welch, 2012).

Another aspect of alarm fatigue is what it means relative to patients who are unable to rest because of the magnitude of the alarm signals within audible range. It is also considered alarm fatigue when true life-threatening alarm events are not addressed because caregivers do not respond. This

happens when a caregiver is unable to distinguish a critical or high priority alarm over the noise of competing alarms.

In 2012 ECRI published a Top 10 Health Technology Hazards list, upon which alarm hazards was ranked number one (Welch, 2012). The article summarized a variety of factors that result in alarm-related adverse incidents. For example, when caregivers become overwhelmed with the number and sounds produced by alarms their chances of being desensitized increases and they are more likely to have a delay in their response to the alarms. Alarm desensitization is a result of high false alarm rate, lack of alarm standardization, and the number of medical devices that produce alarms. Studies have shown that 80-99% of alarms are false and/or clinically insignificant. Many devices generate false alarms, which causes distraction and interferes with clinicians performing critical tasks. In some cases staff may attempt to reduce the number of alarms by improperly adjusting alarm limits or reducing the volume of the alarms. Such actions may cause the conditions and events not to be properly captured or alarms to be ignored because they were unable to be heard. When caregivers are unable to distinguish the source or level of urgency of an alarm they may also not be able to respond in a timely manner.

Alarm-related incidents may also occur when the alarms have not been restored to the active setting after patients have been put on standby. Other causes of incidents include: alarms not being properly relayed to ancillary notification systems potentially resulting in a failure to notify staff, lack of alarm-notification and response protocols, and failure to promptly correct leads-off alarms or other frequent nuisance alarms caused by “artifact.” Artifact is the term for inaccurate analysis of the ECG, resulting in false alarms caused by noise in the signal being sent by electrodes. Causes of artifact or

noise include: increased resistance to electrode conductivity resulting from buildup of skin oils, dried or smeared electrode gel, or wrong brand of electrode for telemetry device. Other causes are poor electrode contact with the skin due to poor preparation, sweating, pulling on the cables, or muscle movement. (Wheaton Franciscan Healthcare Self-Learning Packet – Telemetry Monitoring)

The 2012 ECRI article also highlights recommendations for addressing alarm hazards, with the central theme being a recommendation for an in-depth assessment of an organization as a whole as well as each individual care area. This is because trying to fix isolated problems in one area may cause more problems in different areas. It is important to establish protocols for the alarm-system settings that are customized for the specific care unit based on the types of conditions being monitored. Protocols for caregivers to tailor alarm limits to individual patients should also be put into place to ensure staff are notified of any clinically significant alarms. Alarm notifications and response protocols that ensure each alarm will be recognized and responded to by the appropriate caregiver should also be established. It should be clear who is responsible for recognizing and responding to which alarms.

The solution to reducing alarm fatigue is through alarm management which involves the proactive focus on the culture, staff responsibilities, technology, policies, procedures, processes, and other factors and tasks that are required to created efficient alarm verification, notification, response, and documentation. Alarm management policies are important in defining alarm accountability as well.

Attention to reduction of alarm fatigue through alarm management has been of interest for a number of years. In 2006 the Health Care Technology Foundation (HTF) conducted a survey of clinical alarm issues with responses from nurses and other staff in hospitals with acute care. In 2011

they conducted the same survey again with 3,454 complete responses. More than three quarters of the responders held eleven or more years' experience in the healthcare industry.

One question asked participants to rank nine issues concerning alarms, with a ranking of 1 as most important and 9 as least important. As shown in Figure1, one third (33.3%) of the responses indicated frequent false alarms as the number one issue. The 2011 version of the

35. Please rank the following issues below concerning alarms; 1=Most important, 9=Least important. Read ALL ISSUES FIRST, then rank each issue with only one ranking. You will be able to adjust the ranking during the process. Create Chart Download

	1: Most important	2	3	4	5	6	7	8	9: Least important	Rating Average	Response Count
Difficulty in setting alarms properly:	8.8% (246)	9.4% (262)	9.7% (271)	10.1% (280)	12.9% (359)	10.9% (305)	12.0% (334)	11.6% (324)	**14.5% (405)**	1.00	2,786
Difficulty in hearing alarms when they occur:	11.5% (317)	14.1% (387)	13.6% (373)	**14.4% (397)**	11.7% (321)	10.9% (301)	10.1% (278)	9.2% (252)	4.5% (124)	1.00	2,750
Difficulty in identifying the source of an alarm:	7.0% (191)	13.3% (363)	**17.2% (467)**	14.9% (406)	13.6% (370)	12.2% (332)	11.4% (309)	6.7% (181)	3.7% (102)	1.00	2,721
Difficulty in understanding the priority of an alarm:	8.7% (241)	12.9% (357)	14.3% (397)	**16.4% (456)**	14.5% (404)	13.2% (366)	9.2% (256)	6.7% (187)	4.1% (113)	1.00	2,777
Frequent false alarms, which lead to reduced attention or response to alarms when they occur:	**33.3% (964)**	15.4% (447)	11.7% (338)	9.7% (282)	11.4% (330)	6.5% (187)	4.4% (127)	4.6% (134)	2.9% (85)	1.00	2,894
Inadequate staff to respond to alarms as they occur:	**14.5% (416)**	13.8% (394)	9.9% (284)	10.1% (288)	9.6% (275)	11.5% (330)	9.4% (270)	10.4% (298)	10.8% (310)	1.00	2,865
Over reliance on alarms to call attention to patient problems:	10.7% (308)	14.0% (403)	13.9% (400)	10.4% (300)	10.2% (293)	11.5% (333)	**14.8% (426)**	9.1% (263)	5.5% (159)	1.00	2,885
Noise competition from non-clinical alarms and pages:	3.2% (95)	6.3% (187)	7.9% (233)	9.0% (267)	9.1% (270)	10.8% (320)	13.2% (391)	18.7% (554)	**21.8% (646)**	1.00	2,963
Lack of training on alarm systems:	8.6% (269)	7.0% (217)	7.8% (243)	7.6% (237)	8.8% (275)	9.2% (285)	11.4% (356)	16.6% (516)	**22.9% (712)**	1.00	3,110
										answered question	3,307
										skipped question	971

Figure 1: Health Care Technology Foundation Survey 2011

survey included additional questions regarding clinical alarms and changes. The results of one question showed that 18% of hospitals had experienced adverse patient events between 2009 and 2011, with nearly half of the participants unsure if events had occurred. A second new question asked if their institution had developed clinical alarm improvement over the same two years, with results that indicated only 20% had and nearly half were unaware. In the 2011 version of the survey, data were collected to determine the percentage of hospitals that have employed monitor watchers, of which 47% reported they do. Other key statistics regarding nuisance alarms from the 2011 survey

are: 75% of participants agree or strongly agree that nuisance alarms occur frequently, 70% of participants agree or strongly agree that nuisance alarms disrupt patient care, and 78% of participants agree or strongly agree that nuisance alarms reduce trust in alarms and cause caregivers to inappropriately turn off alarms.

The first recommendation made in regards to the results of the survey was to reduce nuisance alarms. All stakeholders including manufactures, clinicians, healthcare leadership, government agencies, and clinical engineering must be involved in a systematic approach to address the complexities of clinical alarm issues. Education regarding adverse events was shown to be lacking as well as knowledge of improvements in alarm safety, leading to a recommendation to improve communication. Also the priority of clinical alarm improvements needs to be raised. Another suggestion was the utilization of monitor watchers as a form of central alarm management.

Between 2005 and 2008 over 550 deaths nationwide were reported through the FDA's Manufacture and User Facility Device Experience (MAUDE) database related to alarms on monitoring devices, with 216 deaths total during 2005-2010 related to alarms on bedside and telemetry monitors alone. The MAUDE database reveals that over a period of four months during 2010 there were 73 alarm-related deaths reported, with 33 having been caused by physiologic monitors. It was not until 2010 that an unfortunate incident spurred national attention to alarm hazards. In January of 2010, a patient at Massachusetts General Hospital suffered an untimely death due to alarm fatigue. The patient was awaiting the implant of a pacemaker when his heart rate began to fall. His bedside monitors' alarming had been silenced the previous night, as a consequence, nurses were not notified of the

patient's plummeting heart rate. After twenty-three minutes, a nurse discovered the unresponsive patient when conducting her routine rounds.

Over the course of 4 years, UMass Memorial Medical Center has had two deaths that were caused by alarm fatigue. The first occurred in 2007 when a patient's alarms indicating the battery needed to be replaced were not answered. The woman suffered from cardiac arrest, but because her monitor had stopped working no alarm was generated and the event went unnoticed. A second case of alarm-related death occurred on 2011 when a patient who was restless and constantly removing sensors had a severe increase in heart and respiratory rate and decrease in blood oxygen level. For approximately an hour the patient's monitor generated alarms until a final critical alarm sounded indicating that he had stopped breathing. The nurse assigned to this patient claimed that she was updating medical records and assumed someone else had been responding to the alarms. When she finally responded to the critical alarm the patient needed cardiopulmonary resuscitation (CPR), but ultimately the patient suffered brain injury due to lack of oxygen and was withdrawn from life support.

Patient satisfaction is also a concern for institutions. The World Health Organization (WHO) recommends noise levels in hospitals not exceed 35 decibels during day-time hours and 30 decibels in the evening, as it can present occupational hazards or hinder patient recovery. A study conducted with 75 pieces of medical equipment illustrated how 54% of the equipment had a fixed alarm sound that exceeded 70 decibels. The multitude of these loud alarms is bothersome to patients especially during the evening. Surveys conducted with patients pre-discharge have shown that one of the top complaints is too much noise.

Case Studies

The following two case studies described here illustrate how lean methods can be used to design solutions to the alarm fatigue problem. The first is a white paper entitled, "Using Data to Drive Alarm System Improvement Efforts" which describes the efforts undertaken at Johns Hopkins to better understand and then to implement change to better manage their alarm systems (Using Data to Drive Alarm System Improvement Efforts - The Johns Hopkins Hospital Experience, 2012).

Johns Hopkins Hospital in Baltimore, MD is a 1050 bed teaching hospital that undertook several major initiatives beginning in 2006 to address hazardous situations related to alarm systems. Prompted by several adverse patient events, a program to improve alarm system management was put into action. With data from this effort, the severity of the alarm fatigue problem became apparent. At one point the alarm data collected averaged 350 alarm conditions per bed per day.

The first challenge faced by the task force established to address the alarm system problem was to learn how to analyze the data. According to Maria Cvach, assistant director of nursing, clinical standards, "It took us two years to figure out how to extract the right data." Andrew Currie, director of clinical engineering, headed up a safety effort working with a "comprehensive unit-based safety program" (CUSP) team and began studying data. They set up a "real-time surveillance system to integrate data feeds at the bedside from multiple medical devices" in an ICU unit based on an in-house system and data from commercial components. Although the number of alarms was huge, patterns of alarm conditions began to emerge which showed that many were clearly false. A patient safety expert teamed with Cvach, Currie and the task force began to tackle the problem on several fronts.

A first goal was to eliminate as many nuisance alarm conditions as possible by focusing on alarm parameters. This led to an investigation of the default setting for alarms. Adjustments were made unit by unit, in all monitored units, to levels that would only signal a call to action. This allowed advisory alarms to be subordinated and present visual signals only instead of auditory alarms that contributed to the noise. By working with unit leadership, they were able to guide staff through a process that evaluated and prioritized alarm conditions, one by one, unit by unit. Profiles were created for different patient types to determine, in conjunction with monitor vendors, how to fine tune the settings. With the metrics that had been established by data analysis, the team was able to compare the results of the modest changes that had been made. An initial 30% reduction in alarm conditions resulting from changes made with unit management participation helped motivate broad buy-in.

In addition, new types of technology were tried, and changes in monitoring practice were evaluated. New electrodes leads were tested. Hallway waveform displays with split screens were tried. In-room monitors allowing caregivers to view other patient's data were tried along with pagers to provide closed-loop communications and escalation of alarm conditions to backup caregivers. A centralized monitor watch program with trained operators to watch waveform units 24 x 7 and alert caregivers was evaluated. This approach was not rolled out hospital-wide due to high expense and lack of conclusive data supporting improved effectiveness versus other methods. According to Cvach, no one technology works well in every unit across the hospital and few of the technologies are perfect."

In conclusion, the initiative has been successful. The hospital has experienced a 43% reduction in high priority alarm conditions over an 18-day period, a 24-74% reduction in alarm conditions in 6 Intensive

Care and Intermediate Care units, and a 47% reduction in total alarm conditions per bed per day in two pilot units. What began as a task force intended for a short time has evolved into a hospital-wide, continuing effort with monthly meeting of the Alarms Management Committee six years later. In 2012 this committee became a medical board subcommittee. A major factor in the success of this initiative was the effort made to share the goal with clinical unit managers once the data was available in a meaningful context. Another key component was investing the time to fully understand all aspects of the alarm condition events in terms of equipment, patient and staff. By taking incremental steps to design and effect change, only after unit management had participated in the decision process, risk of adverse outcomes and resistance to the process were mitigated, if not eliminated. New training programs on alarm systems for staff were also important. While all these indicators point to improvement, there are still too many alarm conditions and a need to develop better multi-parameter, predictive monitoring systems rather than focus on reducing critical (those intended to save a patient from demise) alarm condition numbers.

The second case study entitled, “Plan, Do, Check, Act: Using Action Research to Manage Alarm Systems, Signals, and Responses” details the process undertaken at Beth Israel to address their alarm system challenges (Plan, Do, Check, Act: Using Action Research to Manage Alarm Systems, Signals, and Responses, 2012).

Beth Israel Deaconess Medical Center is a 631-bed teaching hospital of the Harvard Medical School with two campuses in addition to clinical partnerships with other institutions. After two

sentinel events[1] in patient rooms at their Boston Campus, investigation revealed "inconsistent cardiac telemetry alarm system management." Two different types of alarm signals were involved in these specific events: one was physiological (ventricular tachycardia) and the other technical (leads off). For both events there was delayed response to the alarms, the first because the alarm was sounded in a room distant to the central station and was not heard, and the second alarm, leads off, was treated by responders as not very significant because of the high frequency of these types of alarms.

A multidisciplinary team formed to investigate the events quickly identified some simple steps to be taken such as synchronizing all the clocks involved in the monitoring system: devices, displays , and wall clocks. Other measures for improvement were determined after an intense month-long assessment. It was learned that 40 to 50% of patients in general medical and surgery units were being monitored by cardiac telemetry. In one cardiac unit alone "more than 1,200 cardiac auditory alarm signals from the unit's 32 telemetry beside monitors" were generated in a 24-hour period. In addition, there were other devices creating alarm signals that were also adding to the noise.

An evaluation of cardiac alarm technology was undertaken using Failure Mode Effects Analysis (FMEA), now widely used in the healthcare industry. The Institute for Healthcare Improvement defines FMEA as a "systematic proactive method for evaluating a process to identify where and how it might fail and to assess the relative impact of different failures, in order to identify the parts of the process that are in the most need of change."[2] At Beth Israel Deaconess, a thorough step-by-

[1]"Sentinel Event" A term for a 'headliner' event that may cause an unexpected or unanticipated outcome, death or serious physical or psychological injury, or the risk thereof. Source: http://www.health.state.mn.us/patientsafety/toolkit/joint commrcascopehospitals.pdf

[2] http://www.ihi.org/knowledge/Pages/Tools/FailureModesandEffectsAnalysisTool.aspx

step process to reveal potential failures or mistakes and identify possible consequences complements the lean objective of focusing on value to the customer (patient). It was observed that criteria for placing patients on cardiac telemetry monitoring was inconsistent. There was a sense that placing patients on cardiac monitoring was improving their safety when in fact it was not really true. Increasingly sophisticated equipment was being deployed with "more bells and whistles" without evidence that patient safety was improved. The training for cardiac monitoring given nurses was also found to be inconsistent.

One step taken was to standardize default alarm parameter settings on all the devices used in all units while still allowing staff to make individual adjustments for some patients. Additionally, some alarm conditions were eliminated altogether. According to Pat Folcarelli, director of patient safety, "If we look at those 1,200 alarm conditions, a significant percentage of them weren't contributing at all to any clinical significance. We suppressed them from being able to alarm." A second step taken was to change the way staff dealt with alarms. They assigned a nurse or patient care assistant to be the "primary alarm responder" to assure continuous monitoring. This individual's role was to be responsible for resolving technical alarms such as leads off or no signal conditions. The intent was to reduce repeat alarms and help alleviate background noise.

For the long term, Beth Israel established a telemetry task force which now guides decisions concerning "alarm system management standards, guidelines, and equipment upgrades." The team, composed of physicians, clinical engineers, nurses, healthcare quality, facilities, and supply management staff, initiated an upgrade of all cardiac monitoring equipment. Visual marquees are now located in the hallways of all patient units. A comprehensive, multi-year equipment upgrade

program for the medical center is now underway. In 2012, all telemetry monitors, including hardware and software, and central monitoring stations were replaced. The hospital is working with vendors to tailor alarm conditions to its institutional preferences.

As Tricia Bourie, cardiology nurse manager and chair of the telemetry task force stated, "A leads-off technical alarm condition in this institution is treated as urgently as a high-priority physiological alarm condition and yet our equipment still treats it like a low-priority alarm condition." Leads-off alarms are shown on the marquees but the audible alarm signal indicates low priority. They are also paying closer attention to determining when to place monitors on patients so that the opportunity for false or unnecessary alarms is reduced.

Cardiac monitor leads were also evaluated to determine if there was a better ECG electrode product that could be used. After trying different lead products on different floors, a change was made to use new electrodes that would adhere better to patients' skin while still providing comfort.

Training was upgraded to help better manage alarm response in cardiac units. According to Bourie, "There's 24-7 coverage of the monitoring by a trained telemetry technician who can respond to alarm conditions…and actually go to the patient bedside and put leads on, replace batteries, and perhaps be a first responder to a code event." This specialty role, not commonly used in the area, was developed at the hospital.

Results achieved by Beth Israel include: 30% decrease in alarm signals, reduced response time to critical alarm signals (45 seconds down to 10-15 seconds), and a decrease in the response to leads-off alarms from an average of more than 3 minutes to an average of between 1 and 2 minutes. Changes also include annual telemetry competency training for all nurses, defined goals and responsibilities

for alarm signal response, standardized volume levels for auditory signals, and a focus on best practices. Through a focused, consistent, multidisciplinary approach to addressing the alarm fatigue problem, Beth Israel has created a culture of action for auditing their standard of patient care and outcomes with respect to alarm systems management and clinical practice. As Bourie says, “It hasn’t always been this way. We are more consistent with our approach and metrics so we know if we’ve made a difference.” They are now expanding their efforts beyond cardiac alarm systems to include other medical technology with alarms.

The Johns Hopkins and Beth Israel case studies reveal that the entire system of patient monitoring, not just the alarms, requires systematic methods for understanding and identifying factors that contribute to, or cause alarm fatigue. This includes: data capture and analysis, understanding the technologies’ capabilities and limitations, training and responsibilities of personnel, appreciating that requirements differ by department, and that a multi-disciplinary team will likely be required to monitor effectiveness and progress over time. In this project at UMMHC, management decided to focus specifically on two types of nuisance alarms in one department. This low risk approach allows for potential benefits to be identified without causing disruption or distraction to multiple departments.

Lean Methods in Healthcare

In the past decade the healthcare industry has undergone significant changes. Healthcare costs and the need for treatment have increased while the number of staff and the level of patient satisfaction have decreased. Many of the issues in hospitals, including alarm fatigue, are the result of, or are made worse by, inefficient work systems. Healthcare leaders, in particular hospital executives, are applying many processes and techniques, including lean process analysis tools in a variety of ways to

become more efficient.[3] Lean is a method used to identify the errors, or waste in processes, and then correct or remove them. Lean techniques can be used to strike a balance between efficient use of resources and patient satisfaction, and still be fiscally responsible. The various quality improvement initiatives use systematic problem-solving techniques to design sustainable changes for systems. The end goal of applying these principles is to design a system that has only value added activities, "referring to those tasks that cause the product or service to advance to a more complete stage" (Carriera, 2006). All non-value added work should be minimized or eliminated. Any non-value added work wastes resources, including time and money.

The roots of what is now called lean process improvement originated with the Toyota Motor Corporation's Toyota Production System (TPS). In the early 1950s the company began administering Training Within Industry Courses (TWI) to improve quality and productivity while also reducing cost. The renewed importance of these programs came with the boom in the automotive industry when mass production and standardization of parts first became possible. Continued development of these principles and techniques has led to the application of lean principles, not only in manufacturing, but in all processes.

A first step in understanding lean improvement is to "understand value as defined by our customers. In clinical care delivery, external customers include patients, families, payers, and regulators. Internal customers include physicians, nurses, clerks, and others involved in the care process" (Lim, 2006) Within the context of this MQP project, value can be regarded as fewer nuisance alarms for care

[3] For an overview of quality improvement methodologies see The Intersection of Evidence-Based Practice With 5 Quality Improvement Methodologies. Seidl, Kristin L. PhD, RN; Newhouse, Robin P. PhD, RN, NEA-BC, FAAN Journal of Nursing Administration. 42(6):299-304, June 2012.

givers to cope with coupled with reduced possibility of sentinel events for patients as a consequence of alarm fatigue.

Lean management philosophy has ties to other models of quality improvement such as W.E. Deming's total quality improvement (TQM)/continuous quality improvement, and Six Sigma which was developed by Motorola and General Electric (Kim, 2006). Although there are overlapping ideas and techniques, the value stream approach to effect change and eliminate waste within the process of providing products (services) for customers distinguishes lean from the others. Unique to the concept of lean are the ideas of value from the customer's perspective and the discovery and description of waste. Lean uses specific tools to help transform waste into value. A lean approach motivates people to "learn to see" their product or service process flow and thus help to identify examples of waste with the goal of creating products and services with built-in quality and minimized waste (Kim, 2006).

"In a lean organization, everyone is responsible and accountable for integrating lean thinking principles, methodologies, and tools into daily work" (Kimsey, 2010).

Many examples of lean projects are documented in the literature with some institutions having conducted dozens of lean projects over a span of years. For example, in an article entitled "Impact of 5 Years of Lean Six Sigma in a University Medical Center," Gerard Niemeijer, et al document experiences of the Netherlands second largest hospital, the University Medical; Center Groningen (Niemeijer, 2012). In the period from September 2007 through December 2011 this institution conducted 163 official Lean Six Sigma projects. In their experience with the lean projects it was noted that "related problems in different sectors or departments were very similar, with often-similar solutions as well" (Niemeijer, 2012). They also noted that in order for projects to be successful the

scope must be limited to the organizational scope of the champion. Their conclusion notes that engagement of leadership is essential for success of projects.

While lean methods are now routinely applied in diverse settings, implementing lean principles in the hospital environment can prove challenging. Hospitals are composed of individual units; each specialized with a different focus. It is common that not all units will have the same processes because of their various disciplines. This presents a problem for system-wide implementation of any solutions that were successful in one unit. Additional planning and communication between departments, along with commitment to the lean project, may be required to improve efficiency.

Many organizations and companies now have departments specifically dedicated to improving effectiveness and efficiency in processes. The UMMHC has a new department called the Center for Innovation and Transformational Change (CITC) that is focused on the improvement of hospital processes and operations. Staff members in this department implement lean techniques to address various design flaws and inefficiencies in the hospitals' processes. To ensure improvement initiatives are successful a multidisciplinary team that represents all stakeholders is required.

Chapter 3: Methodology

This chapter provides an explanation of the standard documents, processes, and procedures that our client, UMMC, employs to address problems or conditions identified. These steps are used for work on the topic of this project because as part of their mission statement, UMass Memorial Medical Center is committed to "Effecting change through teamwork and system thinking", an example of which is the Process Improvement Charter: Clinical Alarm Management and Distribution (Appendix B). One specific item in this charter is to "Decrease the total number of non-actionable nuisance and false alarms."

This MQP was initiated to fulfill parts of this alarm management charter. UMMC's recently formed Center for Innovation and Transformational Change works with various units at UMMC to adopt industry-accepted methodology to help achieve their goals for (CITC) improved operations. Their selected format, which is what is used in this project, is the A3 report format, (Appendix C) enhanced to include PDSA (plan-do-study-act) components, which consists of an eight step template for addressing a problem. This is a variation of the basic A3 Report format template (Appendix A).

1. The first step is to create an issue statement which is a descriptive title for the report, or what is often referred to as a **problem statement**.
2. The second step is to form a **background** synopsis of the problem. This involves identifying relevant information which relates the problem to be solved to the broader context of the organization and its experience with the issue.
3. The third step involves explanation of **the current condition** and includes an iconic diagram describing how the process works at present including problem identification labeling and data describing the extent of the problem. (Figure 2)
4. The fourth step is a **root cause analysis**. This identifies the cause and effect relationship of elements which lead to the root of the problem. This cause analysis uses a fish bone diagram (Figure 6) which to assign reasons to the four basic elements methods, machine, materials, and man.
5. The fifth component is the **target condition** which proposes countermeasures to the root causes presented (Figure 8) in an iconic diagram describing how the new process will work with the proposed changes implemented. This element of the process identifies the goals the team has established.

6. The sixth element is **the implementation plan** which defines the steps necessary to accomplish the target condition. This includes identifying who will take each action and when.
7. The seventh element is the **follow up plan** which defines how and when the user will verify that the target condition has been met.
8. The eighth and final step is **identifying results** that were achieved as a result of implementation.

The A3 Enhanced PDSA template includes a "Follow-up Actions" component that calls for decision making on the basis of Accept, Adapt or Abandon regarding a system change based on recorded results. Provisions are made for revision of the target model with testing again in the next "Plan-do-study-act" activity.

In the remaining document, the results of applying these eight steps are presented. Specifically, Chapter 4 provides our analysis of how the current system operates by presenting the results of applying steps 1-4. Chapter 5 addresses our design and plan for implementing interventions to improve the operating system by presenting our results from applying steps 5-7. Chapter 6 presents step 8, the results of our new design. Finally, Chapter 7 presents our overall conclusions and recommendations for follow-up actions.

Chapter 4: Analysis of How the Current System Operates

This chapter describes the current manner in which two types of alarms are communicated by telemetry in the 3 East Cardiac Unit and the staff response systems in place. An overview of the setting and procedures is provided along with an explanation of the steps involved in obtaining information, observing the process in place, and meetings conducted to discuss the project. Examples of data collected prior to project start are also presented. A root cause analysis to identify elements contributing to the problem is also included in this section.

Step 3: Current Conditions

The 3 East floor cardiac unit on the University campus is equipped with 28 beds and is staffed as follows: thirty nurses, three unit secretaries, one nurse manager and one nurse educator. Patients are fitted with telemetry packs that monitor a maximum of 24 patients and these units are capable of generating three different signals to report on patient status. These signals are not audible in the rooms but are sent by wireless transmission in a path illustrated in Figure 2.

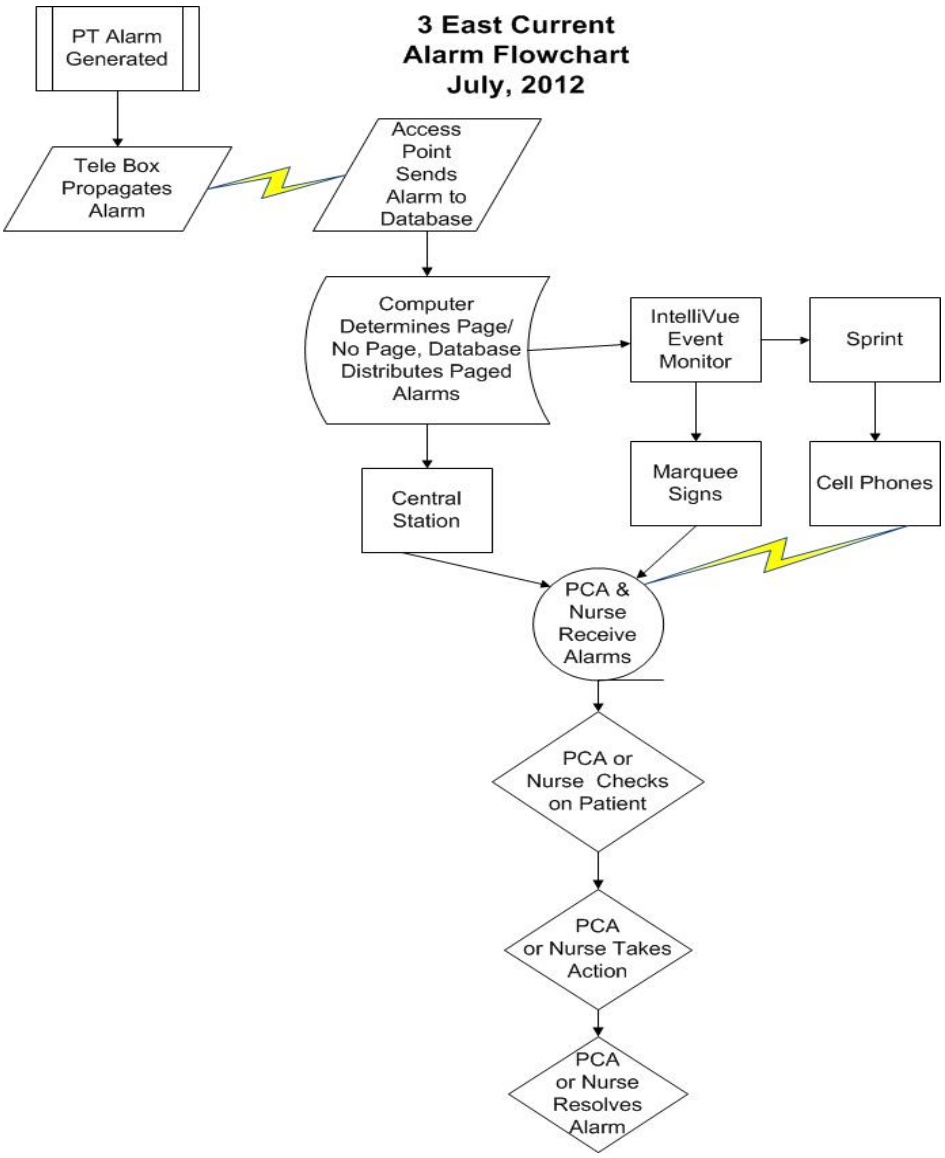

Figure 2: 3 East Cardiac Unit Current State Alarm Flowchart

Of the total number of signals or "alarms" the units send, two conditions, ECG "lead offs" and "no signal" (SpO_2) are the two most numerous and therefor the most challenging to manage. Currently, whenever a lead comes loose from the body or is detached, or the pulse oximeter is removed from its site, an alarm is generated and displayed on the Patient Information Center (PIC) at the central station in the unit. The alarm is also paged to the nurse and PCA assigned to the patient. If after three minutes the alarm condition is not resolved in some way, a reminder alarm will be generated and

sent to the same three locations. Reminder alarms will continue to be generated every three minutes until the alarm has either been silenced at the PIC or the condition has been resolved.

The current process is an open system, meaning there is no one individual responsible for answering the alarm. If a nurse or PCA sees an alarm displayed on the PIC they may assume the patient's assigned nurse or PCA would be addressing the situation. Also because both the nurse and PCA assigned to the patient receive a text notification on their cell phone each could think the other was taking action. Both types of alarms are also green or in-ops alarms so they are on the lowest priority in comparison to the other alarms monitored through the telemetry system.

In the daily activities that nurses and PCAs perform, there may be times when the ECG leads or pulse oximeter are intentionally removed from the patient. Therefore, alarms for these two conditions will be generated even though the nurse purposefully removed them. When a healthcare provider is in the room with a patient, generation of alarms is not necessary because the provider is there to address any situations or observe conditions. Although the provider is with the patient, alarms are still being generated at the central station. This is unnecessary noise and information that will not be used because if they are already tending to this patient, it is unnecessary for an alarm to sound.

Figure 3 illustrates the magnitude of the problem for the University Campus at large represented by paged "reminder" alarms for the two types (ECG Leads off and oximeter No Signal) tracked in this project. For this 3 month period, "reminder" alarms for these two conditions, columns 2 and 4 from the left in Figure 3, totaled 81,769 or nearly 26% of the total of all 317,966 of the top ten telemetry paged alarms.

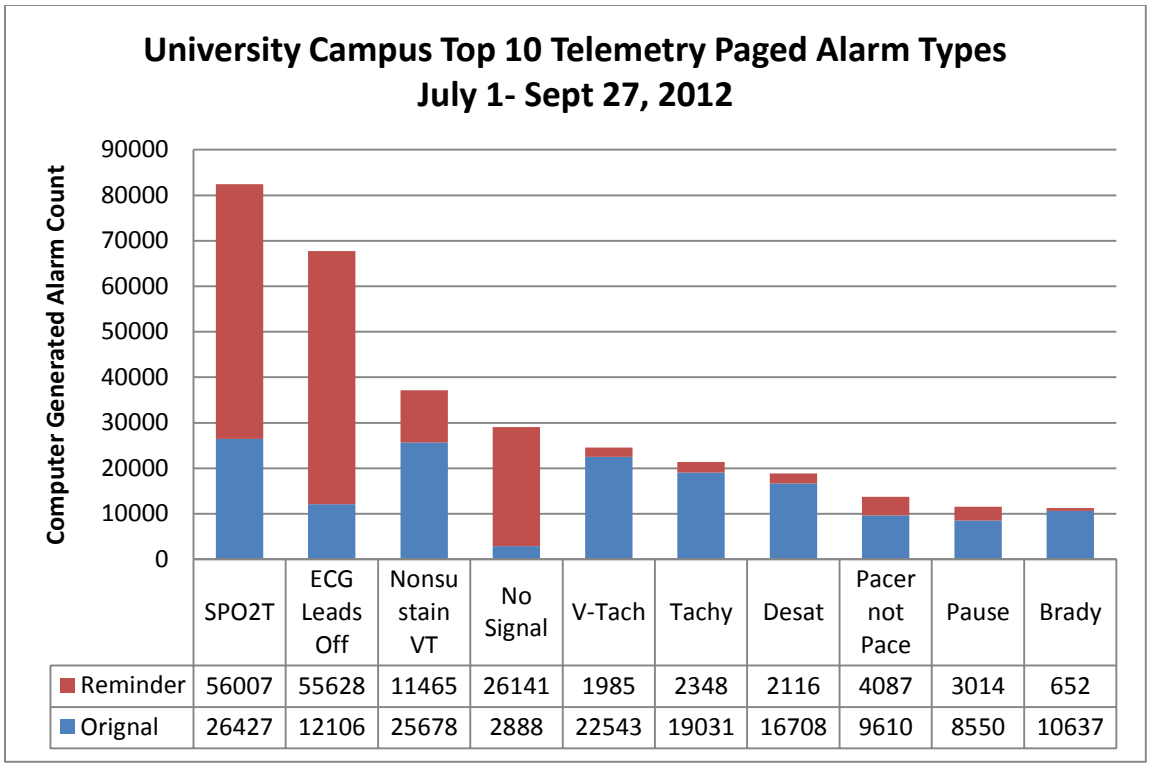

Figure 3: University Campus Top 10 Telemetry Paged Alarm Types

Figure 4 shows the Top Ten Paged Alarm counts from the same time period for the 3 East Cardiac unit. In this case, the "reminder" alarms for ECG "leads Off" (first column on left) and oximeter "No signal" (fifth column from left) totaled 11,496 or 29% of the total of all 39,457 Top Ten alarms for this unit. It is clear that reducing the number of reminder alarms that contribute to noise and alarm fatigue could be beneficial to the operations of this unit and that proportionally they represent a large target.

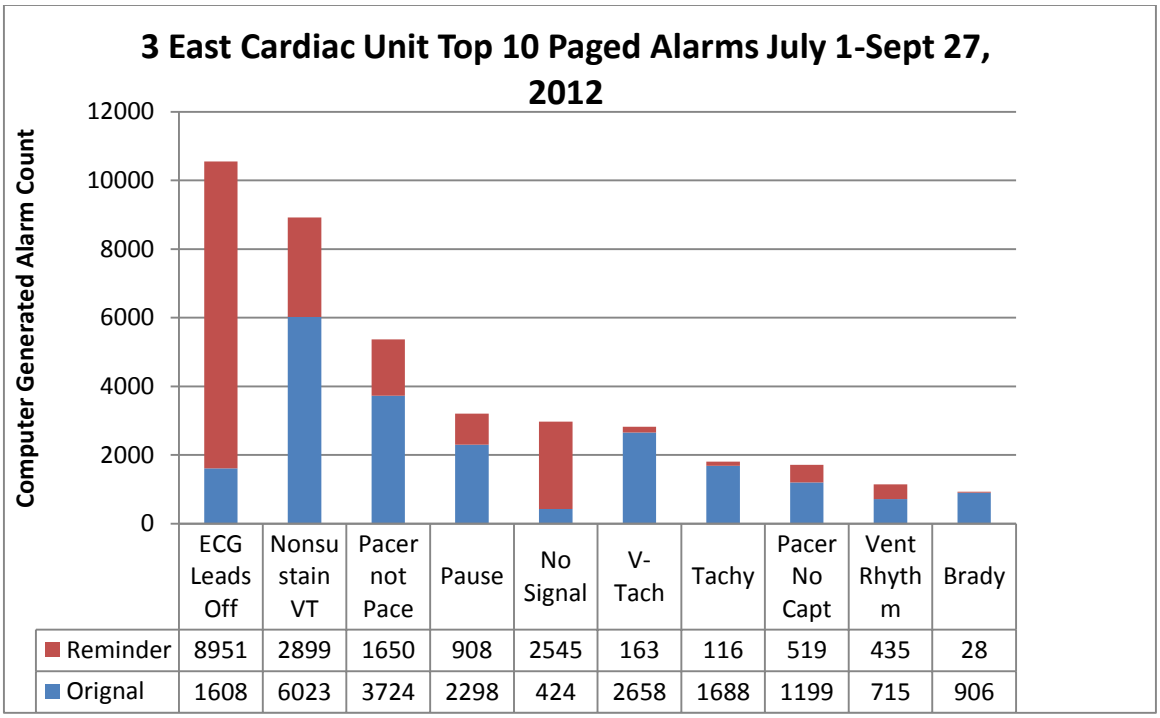

Figure 4: 3 East Cardiac Unit Top 10 Paged Alarms

Step 4: Root Cause Analysis

To understand the daily initiation of all alarms that sound in this unit, and how staff responds to the notification, observation was conducted in the 3 East Cardiac telemetry unit. Data were collected from the Philips Intellispace Management system, but the system only records alarms paged to the cellular phones of nurses and PCAs. Several days' worth of observations done in September of 2012 recorded how staff responded to (or ignored) the alarms. These observations revealed how little attention was given to the central monitoring system, except in the event of a red alarm incident. It also showed how nurses would silence alarms for all patients when they did go to the Patient Information Center if they knew the condition was false, regardless of whether or not the patient was assigned to them. Observation also included collection of all alarms events, even those that are not captured through the Intellispace system, to more accurately predict the number of alarms

generated in the unit. In total, close to ten hours of observation in the unit were completed. Figure 5 below illustrates that in this data collection exercise the ECG leads off alarm condition occurred most often. (Observational Worksheet 3 East UM Appendix E)

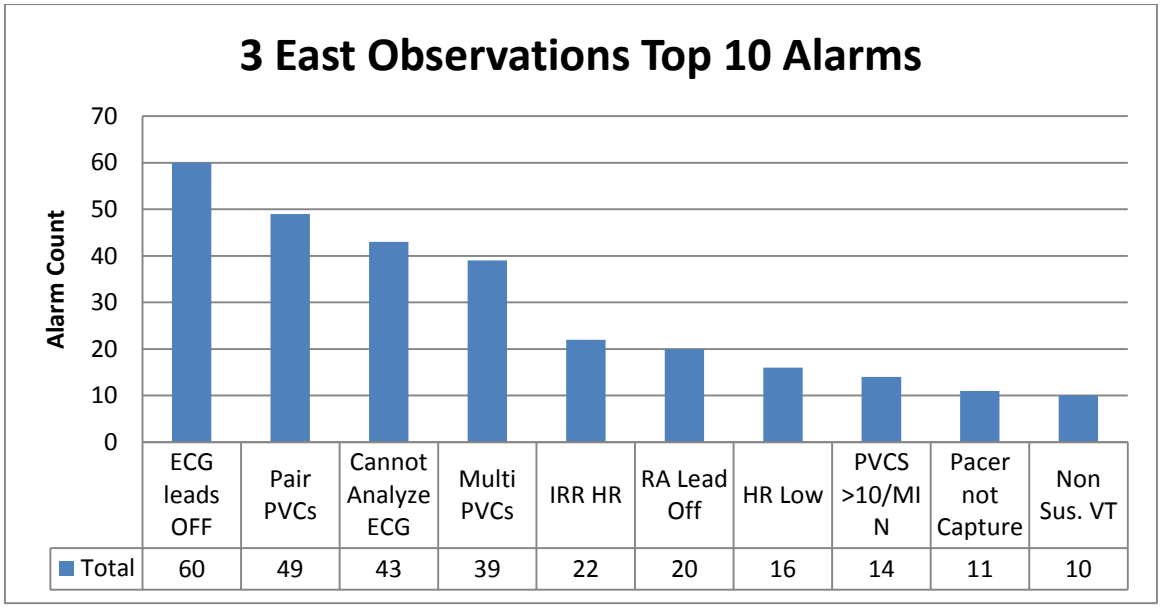

Figure 5: 3 East Observation Top 10 Alarms

Gemba Walk

A Gemba walk is a lean tool used to observe the workplace without interrupting the workflow. The intent is to observe employees and the workplace in order to learn the routines and determine where value is added, or not, within the system. A Gemba walk was done during the observation period on 3 East with particular focus on response to alarms. From this, knowledge of how nurses and PCAs interact with each other relative to alarms was gained. Some alarms were paged to only nurses and not their corresponding PCA, while others were sent to both. On occasion nurses would receive a page and then ask their PCA to address the alarm. It also became apparent that nurses

would only use the patient information center (PIC) when it was convenient, and did not routinely exhibit the behavior of viewing or silencing the alarms.

Root Cause Meeting

On October 24, 2012 an A3 meeting regarding the ECG "leads off" and SpO_2 "no signal" alarms was held. The meeting included Mary Buttitta (nurse manager for 3 East), Lori Pellitier (Director of Performance Improvement), Terri Crofts (Director of Clinical Engineering), and Rob Beatty (Biomedical Engineer), as well as various nurses and PCAs who contributed as they passed through the meeting area. The goal of this meeting was to use the data collected to create the fish bone diagram, Figure 6, to capture the root cause analysis for the multitude of ECG "leads off" and SpO_2 "no signal" alarms in the 3 East Cardiac unit. The fish bone diagram was drawn on a large sheet of blank paper and placed on the wall in front of the group. Four categories of possible causes: man, machine, materials, and methods, were labeled as shown in Figure 6, which provided a framework for the discussion. Over the course of an hour or more the diagram was filled with potential root causes for the targeted alarms with input coming from all participants. The next step was to design

potential countermeasures and research their feasibility.

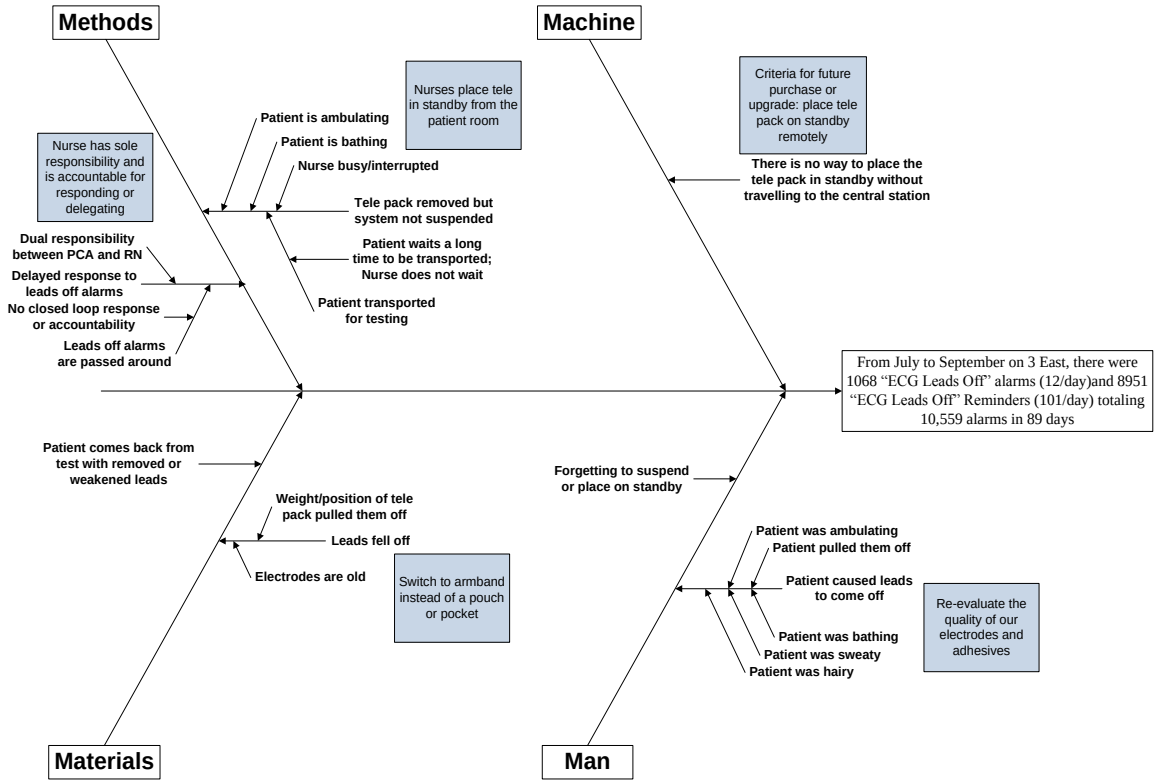

Figure 6: Fishbone Diagram

Chapter 5: Design of a New System

This chapter covers the selection of the countermeasures for the root causes of ECG “leads off” and SpO_2 “no signal” alarms. The timeline and procedure for implementation are also explained.

Target Condition

After the A3 meeting was conducted it was evident that there was no single cause for the number of ECG “leads off” and SpO_2 “no signal” alarms. Countermeasures to address each cause were discussed during the meeting but their feasibility was not determined. The first step of designing the new system began with investigation of the limitations and capabilities of the resources available to this department within the UMMHC facility.

The first countermeasure I pursued, shown in Figure 7, was the possibility of purchasing a new or upgrading the current telemetry system to allow for stand-by mode to be achieved through the telemetry pack in the patient rooms.

Countermeasure	Implemented	Reasoning	Alternative
Consider new or upgrading telemetry system to allow standby mode	No	Stand-by mode not possible with equipment due to patient safety considerations, no budget approved	--
Change location of telemetry pack on patient to reduce chance of disconnection	No	Other units in hospital have tried varying locations without success	--
Re-evaluate brands of electrodes and adhesives to determine if better products are available	No	Budgetary; bound to current equipment through contract	--
Removal of Patient Care Assistants from receiving alarm pages	Yes	Places responsibility on nurses to delegate tasks to PCA; creates closed loop	--
Make it possible for telemetry packs to be placed on standby mode remotely	No	Functionality does not exist for remote standby condition due to patient safety reasons	***Suspension*** of alarms for 1, 2, or 3 minutes by nurse/PCA through telemetry pack in patient room

Figure 7: Table of Considered Countermeasures

A meeting with Joseph J. Frassica, Vice President and Chief Medical Informatics Officer/ Chief Technology Officer for Philips Healthcare was held on November 30, 2012 to inquire about the capabilities of the telemetry system. At this meeting Joseph J. Frassica shared that there is no method to initiate stand-by mode in any models of Philips telemetry. The reasoning behind this is that if a patient were to accidentally activate this feature they could unintentionally remove themselves from monitoring, thus leaving healthcare providers blind to their condition. Fortunately,

the functionality of alarm suspension was discovered at this meeting. If the settings are adjusted at the PIC, pressing both buttons on the telemetry pack can suspend alarms for one, two, or three minutes.

On December 18, 2012 a meeting with Nancy Dejesus, the Clinical Resource Manager at UMMHC was held to determine the possibility of the countermeasure of re-evaluating the quality of electrodes and adhesives as well as SpO_2 sensors. UMMHC currently uses electrode leads and adhesives from Covidien through a contract which was developed to save the health center money. In the past other brands of electrode lead sets have been used. The switch to Covidien was made to reduce costs but not necessarily to increase quality. Discussion with Nancy Dejesus led to the conclusion that changing electrode lead sets and/or adhesives would not be possible for the time being due to budgetary reasons. In reference to SpO2 sensors, the hospital is already utilizing multiple styles of sensors, none of which have been reported to work better than another.

After gathering information regarding these two countermeasures, a meeting with Mary Buttitta was planned to determine which countermeasures would be implemented. At this meeting the re-evaluation of quality of electrodes and the SpO_2 sensors was taken off the table, as was the evaluation of location of telemetry packs because nurse's reported none of the locations seemed to work better than another.

The two countermeasures which were proposed for implementation were the utilization of the alarm suspension functionality and the removal of PCAs from receiving ECG "leads off" and SpO_2 "no sensor" alarms. PCAs no longer receiving these two alarms on their cellular telephones created a closed loop. With only the nurses receiving these pages, Figure 8, they would have to delegate the

task to their PCA directly, if they decided not to respond directly themselves and not rely on the assumption that PCAs were addressing the alarms.

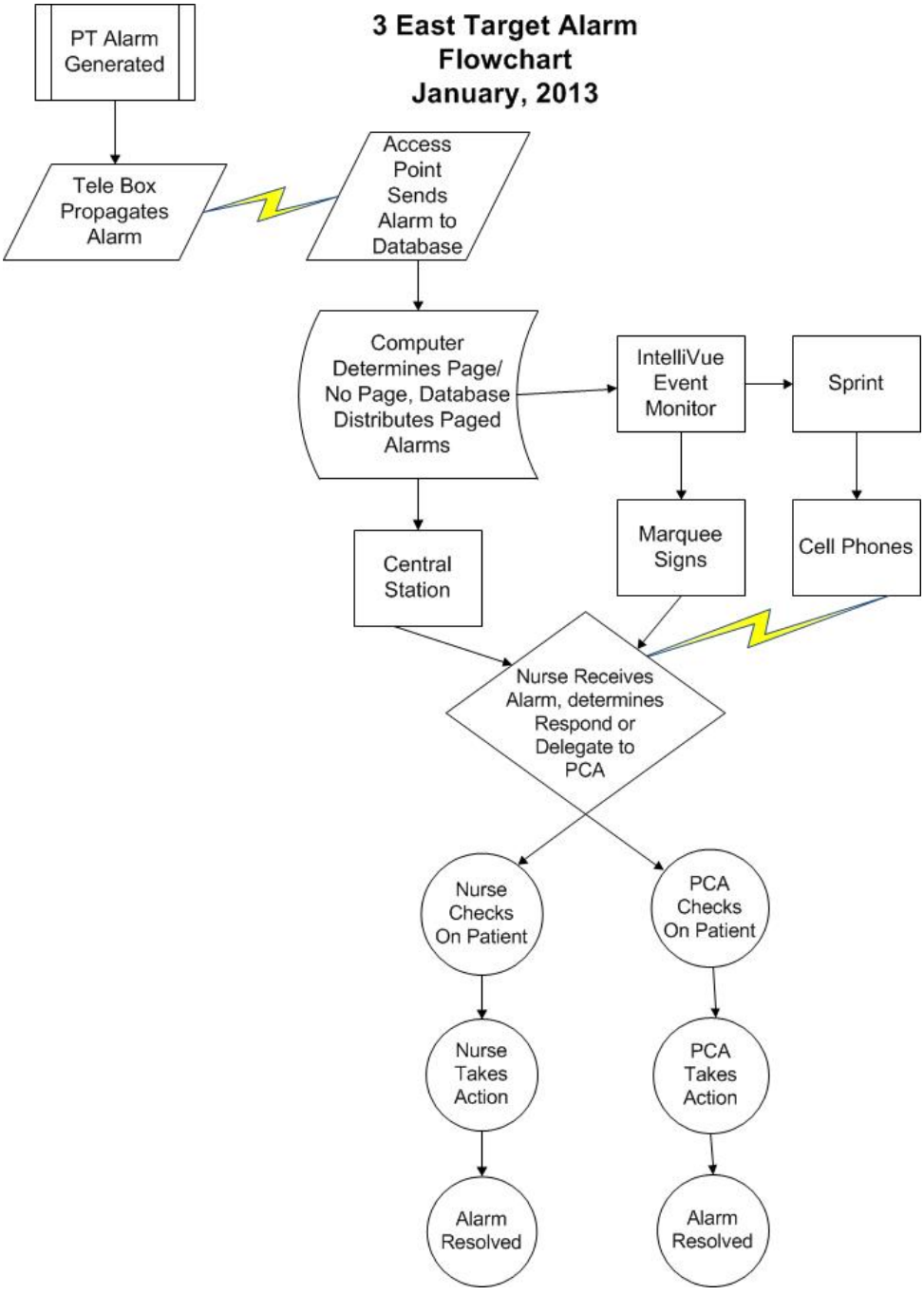

Figure 8: 3 East Cardiac Unit Target Alarm Flowchart

Before implementing the utilization of the alarm suspension functionality it was important to design how the function would work. With the help of Rob Beatty, biomedical engineering technician at UMMHC, testing of the functionality was conducted. It was decided that the unit would suspend alarms for two minutes, and potentially change to one minute or three minutes depending on nurses' feedback.

Implementation Plan

The implementation plan was to first inform and educate the staff on 3 East of the changes that would be made, and then one week later begin using the new system. On January 14, 2013 Mary Buttitta issued a staff newsletter explaining the functionality of the telemetry packs to suspend alarms, as well as notice that the PCAs would no longer be receiving pages for ECG "leads off" or SpO_2 "no sensor" alarms. During the following week the staff continued work as normal and on January 21, 2013 the new design of work-flow was implemented.

Follow-Up

The changes agreed to were properly implemented and routine weekly visits to the 3 East unit were conducted. During these visits staff members were interviewed and observations were recorded. Notes on these observations are located in Appendix F: 3 East Unit Observations- Post Re-design and discussed in Chapter 7 Conclusion section.

Chapter 6: Results of the System Re-design

This chapter presents the data that was collected during three initial two week periods compared with data from two separate two week periods preceding the implementation of the new procedure.

Results

23 alarm conditions were recorded in 3 East Telemetry Unit during five separate two week periods December 24, 2012 through January 6, 2013, January 7, 2013 through January 20, 2013, January 28, 2013 through February 10, 2013, February 11, 2013 through February 24, 2013, and February 25, 2013 through March 10, 2013. The total number of the 23 paged alarm conditions for each of the two week periods is represented in Figure 9. The total number of alarms for the periods before the implementation of the new design is 9601 and 8022. After the change the number of alarms for the three periods is 17106, 6977, and 6890. As can be seen in Figure 9 the number of alarms during the January 28, 2013 through February 10, 2013 period is disproportionately large in comparison to the other two week periods. The reason for this was a disruption in the alarm pages due to an upgrade to the nurses' and PCAs' cellular phones. During that particular two week period new phones were issued, but a software issue prevented many of the pages from actually being sent to the phones. While the alarms were being generated the nurses and PCAs were not receiving all of them and therefore not tending to them, causing more alarms to be generated. This was a problem outside of this project.

Aside from the troublesome two week period, it can be seen the total number of alarms has decreased post implementation of the new design. The ratio of original to reminder also

decreased, prior to implementation that ratio was 1:1.4 and post implementation it decreased to 1:0.8 which is nearly a 50% decrease.

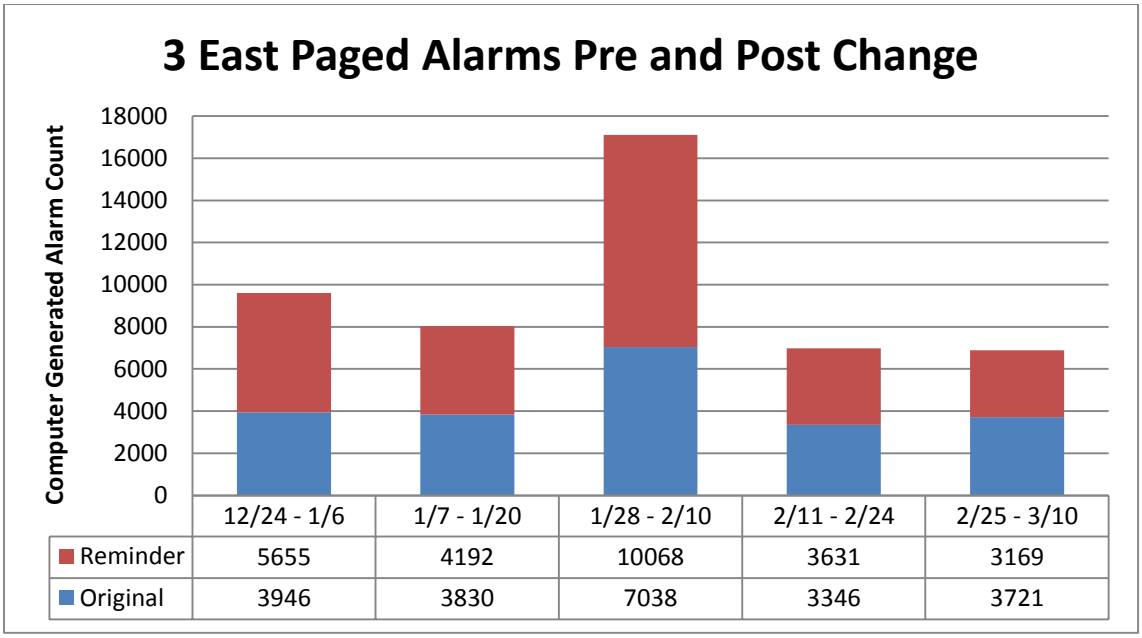

Figure 9: 3 East Cardiac Unit Paged Alarms

In regards to the ECG "leads off" and SpO_2 "no signal" alarms Figure 10 and Figure 11 display the amount of alarms for the various two week periods. The total number of "leads off" and "no signal" alarms can be expressed as a ratio of initial alarm to reminder alarm. This ratio was 1:8 for the SpO_2 "no signal" alarms pre-implementation meaning that for each initial "no signal" alarm condition paged, 8 subsequent reminder alarms were paged. Reminder alarms continue to be paged until a caregiver silences the alarm at the central station. For the ECG "leads off" alarm condition the ratio was 1:6 or 6 reminder alarms paged for each initial paged alarm condition. Because the changes were made on January 21, 2013 data was not collected for analysis the week following the change to allow the staff time to adjust to the new system. In this period there were 6977 alarms, a reduction of 1045 or 12%. In comparison between the

weeks of January 7, 2013 through January 20, 2013 and January 28, 2013 through February 10, 2013; of the 1045 decrease in total alarms, 271 were ECG “leads off” and SpO_2 “no signal” alarms. This represents a 38% reduction attributable to these two specific alarm types.

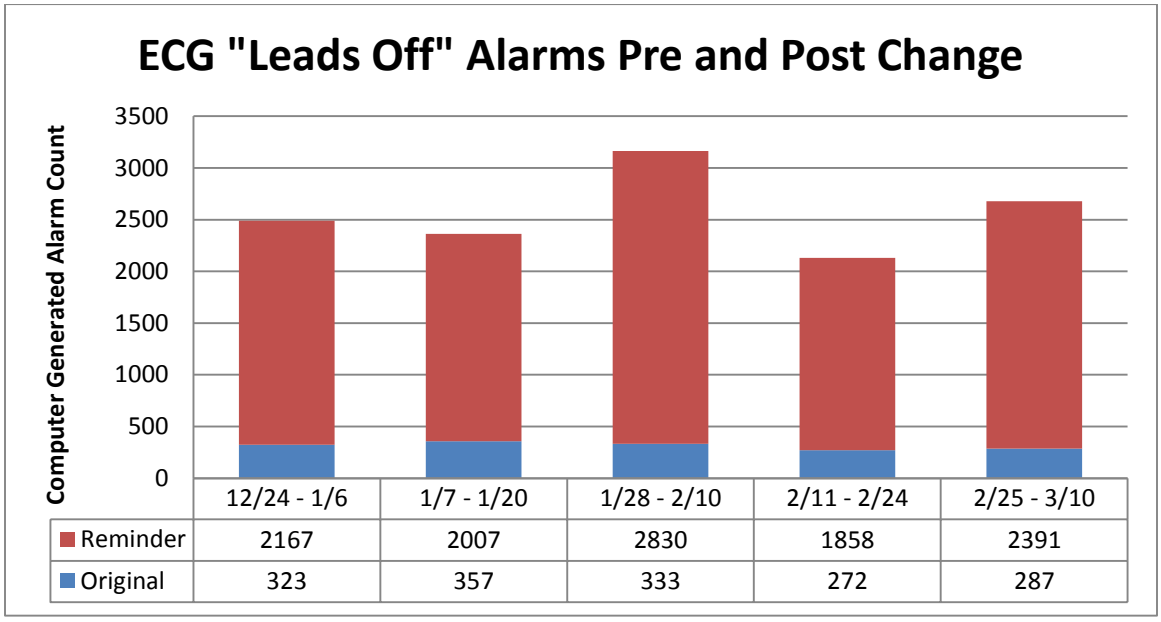

Figure 10: 3 East Cardiac Unit Paged ECG “Leads Off” Alarms

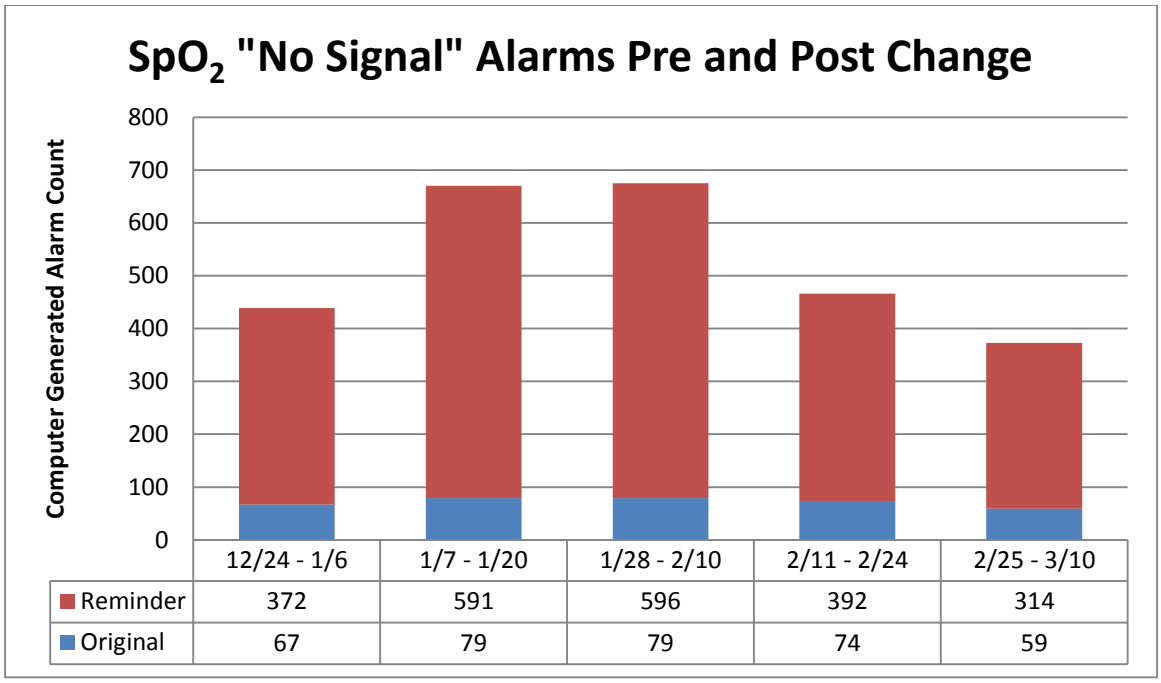

Figure 11: 3 East Cardiac Unit Paged SpO_2 "No Signal" Alarms

The data from the period shows a reduction in the ratio of initial alarms to reminder alarms for the SpO_2 "no signal alarms" condition. For the 79 initial alarms generated in the January 7, 2013 through January 20, 2013 data sample there were 591 reminder alarms, a ratio of 1:8. In the February 11, 2013 through February 24, 2013 period there were 74 initial alarms generated but only 392 reminders, a ratio of 1:5 ratio. This means that for every SpO_2 "no signal" alarm there were three fewer reminder alarms generated an elimination of 222 alarms.

The reduction of 1045 paged alarms between the two periods referenced resulted in a 13% reduction in paged alarms. These figures do not completely measure the total impact of the change in overall alarm generation for the following reason. Not all alarm conditions are paged. Therefore, the new practice of suspending alarm generation when caregivers are attending patients with telemetry packs results in fewer alarms being generated in total; those paged and those alarms that are generated but not paged. There is no way to measure this number.

Analysis of new data

Data collected in the healthcare environment is subject to a large amount of variability owing to a variety of factors. Such factors include changes in the patient population numbers, health conditions of the patients, changes in staffing levels or personnel, implementation of new policies or procedures, introduction of new equipment, and a number of other factors that may not be obvious in their contribution.

Chapter 7: Conclusions and Future Recommendations

Follow Up Meetings

A meeting with Mary Buttitta was held on April 11, 2013 to share the data collected and analyzed during the five separate two week periods. Mary expressed the positive reaction from the nurses regarding the new capability to suspend the alarms from the rooms; they are glad to no longer receive pages from a monitored patient to whom they are currently providing assistance. She also shared that the nurses did not like the new responsibility of delegating the SpO_2 "no signal" and ECG "leads off" alarms to the PCAs. They found the additional step in their day-to-day work flow to be an added burden. Mary though is pleased with the change because legally it is the nurses' responsibility to be held accountable for these alarms.

On the same day a meeting with Terri Crofts was held to share the same data collected and relay Mary's input. Terri was also pleased with the results and plans to share them with the executive steering committee that chartered this project in hopes of implementing these countermeasures in more units throughout UMMHC.

Conclusions

This project demonstrated that using the lean process to address a complex problem in the healthcare industry can be successful and that potential solutions to a problem may be present without being obvious. When the root cause analysis for the large number of reminder alarms was being conducted, it was not clear that an alternative use of existing equipment could help alleviate nuisance alarms from being generated. Verification that there was an open loop system with no clear accountability helped identify a contributor to the problem experienced in

the current state. The eight step A3 Report process, which included bringing multiple perspectives together to detail all aspects of the current state, allows a design change to be formulated based on facts and observations rather than the outcome of a brainstorming session. The process followed did not rely on assumptions so there was an opportunity to ask many questions, observe, and identify details that proved to be significant. As major discovery of this MQP project was that features of the existing equipment in the studied telemetry unit could be used to reduce nuisance alarms and potentially help mitigate alarm fatigue.

The project also validated the importance of having a champion, because there was one for this MQP, access to the necessary resources was never a problem. No higher level of authority was required to make the modest changes that were part of the target design. Although some of staff are less enthusiastic about the new closed loop system for response to the alarm conditions focused on in this project, the benefits are consistent with the institution's mission statement.

Although the target design did not result in the same rate of change for both alarm conditions that were targeted, it did result in a significant reduction in overall alarms for the unit studied. More investigation or further tracking over time would be necessary to explain or understand why the targeted alarm results differed. The results show that by detailed analysis and observation improvements to a process can be made without having to spend money or make major changes. The data collected in this project suggest that there may be potential benefits for other departments experiencing high rates of nuisance alarms. The experience of this MQP may provide the basis for future projects in other departments at UMMHC.

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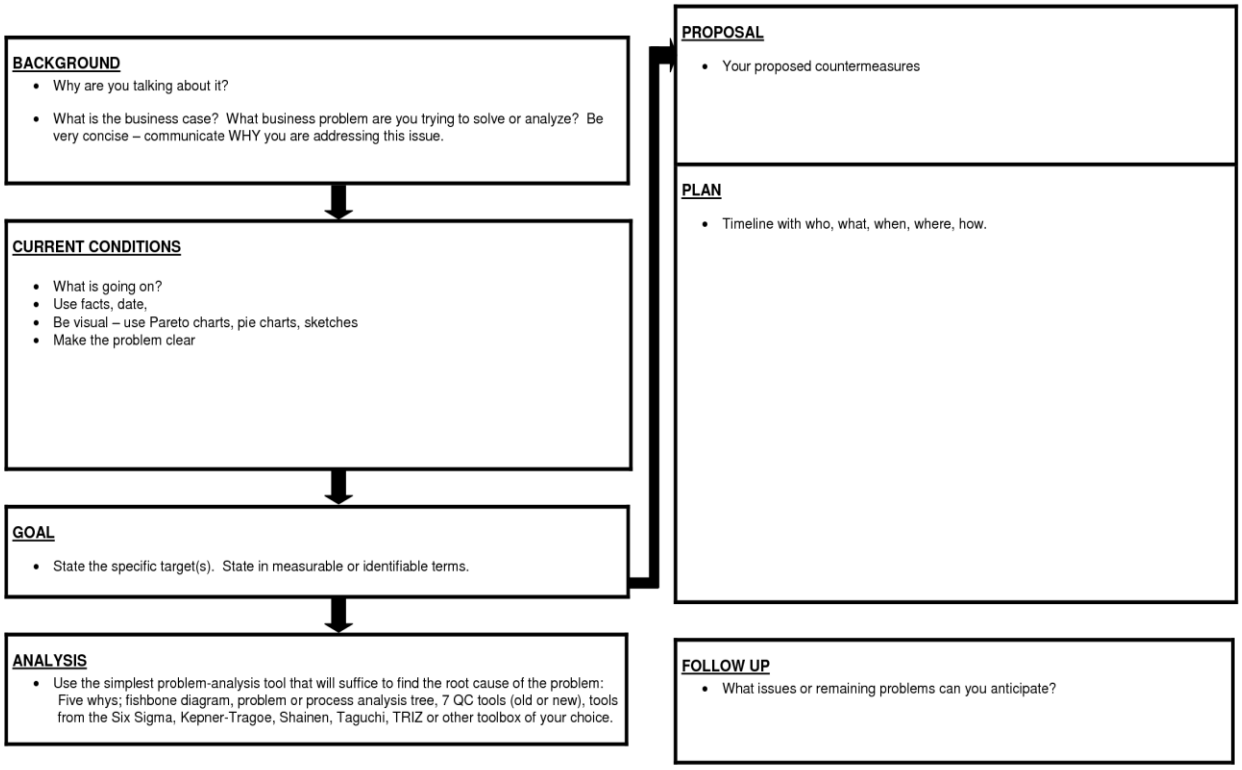
Appendices

Appendix A: A3 Report Format

Title: ***What are you talking about?***

Date: **Latest Draft**	Owner: **Preparer of the A3**
Approval Date:	Manager Approval:



Appendix B: UMMC Policy Process Improvement Charter

Process Improvement Charter: Clinical Alarm Management and Distribution

Project Information

Leadership

Executive Steering Committee:

Project Sponsors:

-Clinical Engineering

-Quality and Patient Safety

-Risk Mgmt

Does this have to be people?

Process Owner:

Participant/Process

Team members and Dept :

- Name – Dept
- Name – Dept
- Name – Dept
- Name – Dept
- Name – Dept
- patient

Process Scope: Start/Stop

Start:

- Alarm condition is generated by the physiological monitor.

Stop:

Process Scope: In/Out

In Scope:

Distribution methods, human factors, answering process and parameters for alarms from bedside monitors, telemetry monitors, central stations, and Emergin (cell phones and signs).

Process Purpose

Patient monitoring systems measure physiological parameters. When a problem arises with the patient's condition, it is the monitor's job to alarm in order to alert caregivers of the situation.

Project Goals

Goals/Key Measures:

FY 2012 Goals:

- Decrease the total number of false critical alarms generated by XX% (goal under discussion)
- Decrease the total number of non-actionable nuisance and false alarms by XX%
- Create a standard recommended response time for answering alarms for different settings and alarm types
- Increase caregiver trust in the validity of the alarms generated
- Increase regulatory compliance with TJC and Clinical Alarms System Policy
- Increase patient satisfaction (HCAHPS) by improving the environment of care

Problems/Case for Change

- High percentage of nuisance alarms and false alarms and a low percentage of "actionable" alarms is creating alarm fatigue and alarm desensitization.
- Severely decreased caregiver trust in the alarm system.
- Limited parameter and source distinction between alarm sounds and/or visual displays.

Voice of the Patient

- High noise levels due to excessive alarms make resting and sleeping very difficult.
- Burden of nuisance and false alarms on the staff slows response times to both real alarms and nurse calls.
- Unanswered alarms creates anxiety for the associated patient.

Project Time Frame

- Planning Meeting #1 – date
- Planning Meeting #2 – date
- Planning Meeting #3 – date
- Value Stream Mapping Sessions: date
- Follow up meeting #1
- Follow up meeting #2
- Follow up meeting #3

Determine project timeframe and milestones

Last Update: 5/16/2012

Charter Owners: (name of Project Sponsor)

Appendix C: UMMHC CITC, A3 Enhanced PDSA template

(A3) Enhanced PDSA

Project Title: Date:
Lead: Page:

Team Members:
Problem Statement:
Scope (In/Out):
Background/Current Conditions:
Root Causes:

Goals:
Estimated Project Completion:

Plan · Do · Study · Act (PDSA)

Countermeasures (Plan):
Implementation (Do):
Results/Conclusion (Study):
Follow-up Actions (Act):

Enhanced PDSA

Instructions

1. Include title and date in the header
2. List team members. Identify Leader(s).
3. Problem Statement: Briefly state the problem. *i.e. simply; Meetings consistently start late. i.e. clinically; "High abandonment rate (averaging 31.9% weekly over the past 4.5 months) of patients and providers calling the Cardiology clinic number (3452), is causing patient and staff dissatisfaction."*

4. Scope (In/Out): Define limits on what is and what is not being included in this analysis. This could be departments, patient types, or process paths.
   i.e. Worcester campuses only

5. Background/Current Conditions: What happens today? Describe the context or history of the situation. What is the result of the problem? What is being observed? Who is involved or affected (stake-holders)? What reports or measures are being used to track performance in the area? This can include a process map, pictures, or other visual representation.
   i.e. Has been happening for a long time. Organization is meeting heavy. Late meetings cause people to be late and/or subsequent meetings to start late. Sample testing shows on average 75% of meetings start late. Average lateness is 7 minutes.

6. Root Causes: Using tools such as 5 Whys, Fishbone, Pareto Chart, or other graphs explore what are the root causes of the symptoms. Sometimes you will need to research data, interview staff, or do a Gemba walk.
   i.e. Cannot find parking space, shuttle running late, cannot find room, room is locked, waiting for an elevator, ran into colleague in hallway, late from another meeting, etc.

7. Goals: Describe the results you would like to see addressing the major factors contributing to the current condition. Include cost, timing, and impact.
   i.e. Reduce average number of meetings that start late; reduce length of time meetings start late; improve productivity by evaluating the overall frequency of meetings, length of meetings, and efficiency of meetings towards accomplishing meeting agenda.

8. Estimated Project Completion: Estimate beginning/ending dates and important milestones.
   i.e. Would like to work on this in the next quarter (April-June, 2010)

9. Countermeasures (Plan): What do you plan to do at a high level? Every countermeasure is a Lean tool. What waste are you eliminating? What results do you expect to see? What would possibly go wrong? (identify and predict potential failure modes before implementing)
   i.e. Standard work for nurse triage or test ordering; Visual board for discharge status; Signal for test ordering required or patient ready in waiting room.

10. Implementation (Do): Describe what actions you are planning to do. Identify steps including who is assigned and when it is due. Carry out the change or test.
    i.e. Develop protocol for meeting agenda contents including format and distribution of agenda to attendees 2 days prior to meeting. Expect to see reduction of late meeting starts to 25%. Work with HR to develop protocol(Sue). Communicate protocol(Bob).

11. Results/Conclusion (Study): Collect data and begin analysis. What behaviors did you observe? What happened? What were the challenges? What did you learn? Did you meet your measurement goal listed in the countermeasures (show results)?
    i.e. 50% of meetings started late with average late time being 5 minutes..

12. Follow-up Actions: (Accept, Adapt, Abandon) Are we ready to make a system change (if so: who, what, when, where)? Do we need to make revisions and test again in next PDSA?
    i.e. Expand communication efforts to get the message out. Hold special classes on preparing an agenda and meeting effectiveness. Try promoting meeting length being 45 minutes instead of an hour.

Appendix D: Observational Worksheet 3 East UM

Alarm Type	Alarm Category	Classification (T/F/N)	T Start	T Action	Time Silence	Action Taken (Y/N)	Notification Method	Notes
Brady	Red Alarm	F	10:51:50	10:51:10	10:52:00	Y		
Brady	Red Alarm		2:02:40	2:02:50	2:02:50			
Cannot Analyze ECG	In-Op	N	1:12:30	---	1:12:40	N		
Cannot Analyze ECG	In-Op	N	1:35:00	---	1:35:20	N		
Cannot Analyze ECG	In-Op	N	1:35:20	---	1:35:55	N		
Cannot Analyze ECG	In-Op	N	1:42:20	---	1:43:10	N		
Cannot Analyze ECG	In-Op	F	---	10:21:00	10:21:30	Y	PIIC/Students in room observing patient	Some ECG alarms off. Artifact in waveform.
Cannot Analyze ECG	In-Op	N	10:23:50	---	10:24:15	N		
Cannot Analyze ECG	In-Op	N	10:36:50	---	10:37:15	N		
Cannot Analyze ECG	In-Op	N	10:49:30	---	10:50:00	N		
Cannot Analyze ECG	In-Op	N	11:20:00	---	11:20:35	N		
Cannot Analyze ECG	In-Op	N	11:22:15	---	11:22:50	N		
Cannot Analyze ECG	In-Op	N	11:40:15	---	11:41:30	N		
Cannot Analyze ECG	In-Op		11:13:20	---	11:14:00	N		
Cannot Analyze ECG	In-Op				11:25:15			
Cannot Analyze ECG	In-Op		11:26:45		11:27:30			
Cannot Analyze ECG	In-Op				11:30:40			II
Cannot Analyze ECG	In-Op		11:34:15		11:34:40			
Cannot Analyze ECG	In-Op		12:38:15		12:38:30			II
Cannot Analyze ECG	In-Op		12:40:00		12:41:30			III
Cannot Analyze ECG	In-Op		12:40:30		12:40:35			
Cannot Analyze ECG	In-Op		12:44:30		12:44:45			
Cannot Analyze ECG	In-Op		12:48:10					
Cannot Analyze ECG	In-Op				12:55:45			
Cannot Analyze ECG	In-Op		1:00:20		1:00:40			
Cannot Analyze ECG	In-Op		1:10:05		1:11:50			
Cannot Analyze ECG	In-Op		1:47:00		1:47:05			II
Cannot Analyze ECG	In-Op		1:48:15		1:48:50			RA L OFF III ECG OFF II CNAECG II
Cannot Analyze ECG	In-Op		1:55:30					
Cannot Analyze ECG	In-Op		1:00:00		1:10:00	Y		
Cannot Analyze ECG	In-Op	N	2:01:45		2:02:00	N		
Cannot Analyze ECG	In-Op	N				N		
Cannot Analyze ECG	In-Op	N	2:40:45		2:41:50			
ECG leads OFF	In-Op	N	---	---	13:10:00	N		
ECG leads OFF	In-Op	N	12:53:01	---	12:53:05	N		Alarm turned on and off almost immediately
ECG leads OFF	In-Op	N	12:55:20	---	12:55:30	N		
ECG leads OFF	In-Op	N	12:56:15	---	12:56:30	N		
ECG leads OFF	In-Op	N	12:57:00	---	12:58:00	N		I was told by nurse patient keeps moving
ECG leads OFF	In-Op	N		---		N		
ECG leads OFF	In-Op	N		---		N		
ECG leads OFF	In-Op	N	13:05:10	---	13:05:30	N		
ECG leads OFF	In-Op	N	13:05:35	---	13:05:40	N		
ECG leads OFF	In-Op	N	1:11:00	---	1:13:00	N		
ECG leads OFF	In-Op	N	1:12:40		1:12:50	N		
ECG leads OFF	In-Op	N	1:26:00	---	1:26:10	N		
ECG leads OFF	In-Op	N	10:22:00	10:34:00	10:34:00	Y		Patient finally hooked up
ECG leads OFF	In-Op	N	10:23:50	---	10:23:55	N		
ECG leads OFF	In-Op	N	10:45:00	---	10:45:05	N		
ECG leads OFF	In-Op	N	11:07:35	---	11:08:30	N		
ECG leads OFF	In-Op	N	11:27:35	---	11:27:40	N		
ECG leads OFF	In-Op	N	11:30:00	---	11:31:10	N		
ECG leads OFF	In-Op	N	11:38:35	---	11:38:40	N		
ECG leads OFF	In-Op	N	11:39:50	---	11:40:15	N		
ECG leads OFF	In-Op	N	11:46:00	---		N		
ECG leads OFF	In-Op	N	11:50:00	---	11:51:00	N		
ECG leads OFF	In-Op		11:07:15	---	11:10:00	N		
ECG leads OFF	In-Op		11:13:00	---	11:13:20	N		
ECG leads OFF	In-Op		11:20:20	---	11:20:25	N		
ECG leads OFF	In-Op		11:24:30					
ECG leads OFF	In-Op		11:33:00		11:33:40			IIII
ECG leads OFF	In-Op							III

ECG leads OFF	In-Op		12:46:00					II
ECG leads OFF	In-Op		12:50:30					
ECG leads OFF	In-Op		12:54:00	12:57:00	12:57:00	Y		TURNED SOME ECG ALARMS OFF
ECG leads OFF	In-Op		1:00:00		1:05:00			
ECG leads OFF	In-Op		1:05:30		1:09:30			
ECG leads OFF	In-Op		1:10:00		1:11:50			
ECG leads OFF	In-Op							"she is in bath, I don't turn off cause they won't turn back on"
ECG leads OFF	In-Op							
ECG leads OFF	In-Op		2:57:15		3:00			
ECG leads OFF	In-Op		3:04:15		3:05:50			
ECG leads OFF	In-Op	N				Y	PIIC	Patient pulled off. Action taken because nurse told someone I was watching.
ECG leads OFF	In-Op	N	1:09:00	1:21:00	2:21:00	Y		PATIENT PUT ON TELE STBY
ECG leads OFF	In-Op	N	1:44:45		1:48:00	N		
ECG leads OFF	In-Op	N	1:45:00		1:45:15	N		
ECG leads OFF	In-Op	N	2:39:15	2:44:15	2:44:15	Y		PUT ON TELE STBY
ECG leads OFF	In-Op		2:56:30					
ECG leads OFF	In-Op		3:10:30		3:10:40			
HR High	Yellow Arrhythmia - Rate		2:14:00					
HR High	Yellow Arrhythmia - Rate		2:45:20		2:48:20			
HR High	Yellow Arrhythmia - Rate		1:17:00		1:20:00			
HR High	Yellow Arrhythmia - Rate	N	11:45:30	---	11:48:30	N		
HR High	Yellow Arrhythmia - Rate		2:10:45		2:13:50			
HR High	Yellow Arrhythmia - Rate		10:23:00	---	10:25:00	N		Self correcting alarm
HR Low	Yellow Arrhythmia - Rate		10:42:30	---	10:45:00	N		
HR Low	Yellow Arrhythmia - Rate		11:05:15	---	11:07:00	N		
HR Low	Yellow Arrhythmia - Rate		11:13:20	---	11:16:00	N		
HR Low	Yellow Arrhythmia - Rate		11:16:30	---	11:19:15	N		
HR Low	Yellow Arrhythmia - Rate		10:50:00	---	10:51:50	N		
HR Low	Yellow Arrhythmia - Rate		10:55:15	---	10:58:00	N		
HR Low	Yellow Arrhythmia - Rate		10:59:00	---	11:00:30	N		
HR Low	Yellow Arrhythmia - Rate		11:01:00	---	11:04:45	N		
HR Low	Yellow Arrhythmia - Rate		11:07:30	---	11:10:00	N		
HR Low	Yellow Arrhythmia - Rate		11:10:20	---	11:13:00	N		
HR Low	Yellow Arrhythmia - Rate		11:21:30	---	11:24:30	N		
HR Low	Yellow Arrhythmia - Rate		11:25:40		11:28:20			
HR Low	Yellow Arrhythmia - Rate		11:27:45		11:31:30			
HR Low	Yellow Arrhythmia - Rate		11:31:10		11:34:15			
HR Low	Yellow Arrhythmia - Rate		11:35:30		11:38:30			
HR Low	Yellow Arrhythmia - Rate	N	10:58:40	---	11:00:20	N		
IRR HR	Yellow Arrhythmia - Rate	N	10:25:45	---	10:38:30	Y		
IRR HR	Yellow Arrhythmia - Rate	N	10:35:00	---	10:35:30	N		
IRR HR	Yellow Arrhythmia - Rate	N	11:03:15	---	11:04:30	N		
IRR HR	Yellow Arrhythmia - Rate	N	11:13:25	---	11:14:30	N		
IRR HR	Yellow Arrhythmia - Rate	N	11:25:25	---	11:28:00	N		
IRR HR	Yellow Arrhythmia - Rate	N	11:36:16	---	11:36:55	N		

IRR HR	Yellow Arrhythmia - Rate	N	12:58:38		1:03:00	N		*nurse reviewed ecg traces only
IRR HR	Yellow Arrhythmia - Rate	N	1:08:30		1:19:50	N		*is latching?
IRR HR	Yellow Arrhythmia - Rate	N	1:20:30		1:29:00	N		
IRR HR	Yellow Arrhythmia - Rate	N	1:41:45		1:42:10	N		
IRR HR	Yellow Arrhythmia - Rate	N	1:53:40		1:55:10	N		
IRR HR	Yellow Arrhythmia - Rate	N	2:02:00		2:02:20	N		
IRR HR	Yellow Arrhythmia - Rate	N	2:10:50		2:18:18	N		
IRR HR	Yellow Arrhythmia - Rate	N	2:22:15		2:30:30	N		
IRR HR	Yellow Arrhythmia - Rate	N	2:32:30		2:33:00	N		* talked to nurse. Necessary but annoying because patient has afib and there is no other alarm to sig
IRR HR	Yellow Arrhythmia - Rate	N	2:42:00		2:42:30	N		
IRR HR	Yellow Arrhythmia - Rate	N	2:55:00		2:59:30	N		
IRR HR	Yellow Arrhythmia - Rate	N	3:02:00		3:02:15	N		
IRR HR	Yellow Arrhythmia - Rate	N	3:14:00		3:15:15	N		
IRR HR	Yellow Arrhythmia - Rate	N	3:24:00		3:25:00	N		
IRR HR	Yellow Arrhythmia - Rate	T				Y	1st alarm sound, second check PIIC	Nurse was already in patient room
IRR HR	Yellow Arrhythmia - Rate	T	1:38:20	---		Y	1st alarm sound, second check PIIC	Nurse was already in patient room
Leadset Unplug	In-Op	N	---	---	---	N		
LL Lead OFF	In-Op		3:04		3:06			
Missed Beat	Yellow Arrhythmia - Beat Detection		2:22:10					
Multi PVCs	Yellow Arrhythmia - PVCs		12:56:00		12:59:00			
Multi PVCs	Yellow Arrhythmia - PVCs		1:04:30		1:07:30			
Multi PVCs	Yellow Arrhythmia - PVCs	N	1:08:30		1:09:30	N		
Multi PVCs	Yellow Arrhythmia - PVCs	N	1:19:50		1:21:30	N		
Multi PVCs	Yellow Arrhythmia - PVCs		1:24:00		1:27:00			
Multi PVCs	Yellow Arrhythmia - PVCs		1:29:45		1:31:30			
Multi PVCs	Yellow Arrhythmia - PVCs		1:40:15		1:43:15			
Multi PVCs	Yellow Arrhythmia - PVCs	N	1:42:10		1:44:00	N		
Multi PVCs	Yellow Arrhythmia - PVCs		1:50:40		1:53:40			
Multi PVCs	Yellow Arrhythmia - PVCs	N	1:55:10		1:57:20	N		
Multi PVCs	Yellow Arrhythmia - PVCs		2:02:00		2:05:00			
Multi PVCs	Yellow Arrhythmia - PVCs		2:11:20		2:19:00			
Multi PVCs	Yellow Arrhythmia - PVCs	N	2:16:00		2:21:00	N		
Multi PVCs	Yellow Arrhythmia - PVCs	N	2:33:00		2:33:30	N		
Multi PVCs	Yellow Arrhythmia - PVCs	N	2:46:00		2:49:00	N		
Multi PVCs	Yellow Arrhythmia - PVCs		2:47:00		2:50:00			
Multi PVCs	Yellow Arrhythmia - PVCs	N	3:02:15		3:05:15	N		
Multi PVCs	Yellow Arrhythmia - PVCs		3:05:00		3:08:00			
Multi PVCs	Yellow Arrhythmi	N	10:40:00	---	10:43:00	N		

	a – PVCs							
Multi PVCs	Yellow Arrhythmia - PVCs	N	11:11:15	---	11:12:40	N		
Multi PVCs	Yellow Arrhythmia - PVCs	N	11:14:00	---	11:16:30	N		
Multi PVCs	Yellow Arrhythmia - PVCs	N	11:15:40	---	11:18:15	N		
Multi PVCs	Yellow Arrhythmia - PVCs	N	11:26:00	---	11:29:30	N		
Multi PVCs	Yellow Arrhythmia - PVCs	N	11:27:40	---	11:30:50	N		
Multi PVCs	Yellow Arrhythmia - PVCs		---	---	10:43:00	N		
Multi PVCs	Yellow Arrhythmia - PVCs		10:45:30	---	10:46:15	N		
Multi PVCs	Yellow Arrhythmia - PVCs		10:56:10	---	---	N		
Multi PVCs	Yellow Arrhythmia - PVCs		11:10:10	---	11:13:15	N		
Multi PVCs	Yellow Arrhythmia - PVCs		11:20:20	---	11:23:20	N		
Multi PVCs	Yellow Arrhythmia - PVCs		12:45:00		12:48:00			
Multi PVCs	Yellow Arrhythmia - PVCs		12:58:40		1:01:20			
Multi PVCs	Yellow Arrhythmia - PVCs		1:13:15		1:16:00			
Multi PVCs	Yellow Arrhythmia - PVCs		1:26:30		1:29:30			
Multi PVCs	Yellow Arrhythmia - PVCs		1:26:30		1:29:30			
Multi PVCs	Yellow Arrhythmia - PVCs		1:38:00		1:41:00			
Multi PVCs	Yellow Arrhythmia - PVCs		1:50:30		1:53:30			
Multi PVCs	Yellow Arrhythmia - PVCs							
Multi PVCs	Yellow Arrhythmia - PVCs		2:56		2:59			
Multi PVCs	Yellow Arrhythmia - PVCs		2:57:15		3:00:15			
Multiform PVCs	Yellow Arrhythmia - PVCs	T	12:57:00	---	---	N		Escalated
Multiform PVCs	Yellow Arrhythmia - PVCs	T	13:08:00	---	13:11:00	N		
Multiform PVCs	Yellow Arrhythmia - PVCs	T	1:14:00	---	1:14:40	N		
Multiform PVCs	Yellow Arrhythmia - PVCs	T	1:25:00	---	1:25:20	N		
NBP High	Yellow - NBP		2:06:20	2:06:45	2:06:45	Y		alarm sus. Sp02 off. All alarms off.
NBP Int	Yellow - NBP		11:05:00	---	---	N		
NBP Int	Yellow - NBP		3:04:30					
NBP Int	Yellow - NBP	N						
NBP Int	Yellow - NBP		3:05:00					
No Signal	In-Op	N	13:00:00	---	13:13:00	N		Finally hooked patient up and alarm turned itself off.
No Signal	In-Op	N	11:19:45	---	11:20:00	N		
No Signal	In-Op		12:48:00		12:48:05			I
No Signal	In-Op		1:08:30		1:09:15			
No Signal	In-Op		1:20:00					
No Signal	In-Op		3:05:50					
No Signal	In-Op		3:18					
No Signal	In-Op	N	1:45:15		2:00:00	N		
No Signal	In-Op	N	2:08:00		2:08:30	N		
Non Sus. VT	Yellow Arrhythmia - PVCs	T	12:54:00	---	12:57:00	N		Alarm Time Out
Non Sus. VT	Yellow Arrhythmia - PVCs	T	1:15:00	---		N		
Non Sus. VT	Yellow Arrhythmia - PVCs	N	10:53:40	---	10:55:40	N		
Non Sus. VT	Yellow Arrhythmia - PVCs	N	11:06:30	---	11:08:00	N		
Non Sus. VT	Yellow Arrhythmi		1:05:30		1:08:30			

	a – PVCs							
Non Sus. VT	Yellow Arrhythmia - PVCs		1:18:00		1:21:00			
Non Sus. VT	Yellow Arrhythmia - PVCs		1:25:15		1:28:15			
Non Sus. VT	Yellow Arrhythmia - PVCs	N	2:30:30		2:32:30	N		
Non Sus. VT	Yellow Arrhythmia - PVCs	N	3:00:00		3:02:00	N		
Non Sus. VT	Yellow Arrhythmia - PVCs		3:09:45		3:12:45			
Pacer not Capture	Yellow Arrhythmia - PVCs	F	10:27:30	10:34:15	10:30:00	Y		Nurse did ECG review, and told me its giving that error because of the PVCs.
Pacer not Capture	Yellow Arrhythmia - PVCs	N	10:44:00	---	10:46:00	N		
Pacer not Capture	Yellow Arrhythmia - PVCs	N	11:04:30	---	11:06:30	N		
Pacer not Capture	Yellow Arrhythmia - PVCs	N	11:14:30	---	11:17:00	N		
Pacer not Capture	Yellow Arrhythmia - PVCs	N	11:28:00	---	11:30:00	N		
Pacer not Capture	Yellow Arrhythmia - PVCs	N	11:34:45	---	11:36:15	N		
Pacer not Capture	Yellow Arrhythmia - PVCs	N	11:36:55	---	11:38:30	N		
Pacer not Capture	Yellow Arrhythmia - PVCs	N	11:39:40	---	11:42:40	N		
Pacer not Capture	Yellow Arrhythmia - PVCs	N	11:42:00	---	11:45:00	N		
Pacer not Capture	Yellow Arrhythmia - PVCs		3:26:15					
Pacer not Capture	Yellow Arrhythmia - PVCs	N	1:39:50	---	1:41:30	N		
PACER NOT PACE		N	11:32:30	---	11:35:30	N		
Pair PVCs	Yellow Arrhythmia - PVCs	T	12:57:10	---	13:00:10	N		Alarm Time Out
Pair PVCs	Yellow Arrhythmia - PVCs	T	13:02:00	---	13:05:00	N		
Pair PVCs	Yellow Arrhythmia - PVCs	T	1:10:00	---	1:12:30	N		
Pair PVCs	Yellow Arrhythmia - PVCs	T	10:25:55	---	10:27:30	Y		
Pair PVCs	Yellow Arrhythmia - PVCs	N	10:32:15	---	10:35:00	N		
Pair PVCs	Yellow Arrhythmia - PVCs	N	10:35:30	---	10:38:10	N		
Pair PVCs	Yellow Arrhythmia - PVCs	N	10:48:50	---	10:50:30	N		
Pair PVCs	Yellow Arrhythmia - PVCs	N	10:50:30	---	10:54:15	N		
Pair PVCs	Yellow Arrhythmia - PVCs	N	10:56:00	---	10:59:00	N		
Pair PVCs	Yellow Arrhythmia - PVCs	N	11:10:50	11:11:00	11:12:30	Y		
Pair PVCs	Yellow Arrhythmia - PVCs	N	11:48:00	---	11:51:00	N		
Pair PVCs	Yellow Arrhythmia - PVCs	N	11:52:00	---		N		
Pair PVCs	Yellow Arrhythmia - PVCs		10:46:15	---	10:49:45	N		
Pair PVCs	Yellow Arrhythmia - PVCs		10:50:45	---	10:52:30	N		
Pair PVCs	Yellow Arrhythmia - PVCs		11:19:20	---	11:22:30	N		
Pair PVCs	Yellow Arrhythmia - PVCs		12:38:30		12:42:00			
Pair PVCs	Yellow Arrhythmia - PVCs		12:42:45	12:45:00	12:45:20	Y	PAGED	CNAECG I RA II
Pair PVCs	Yellow Arrhythmia - PVCs		12:44:20		12:47:00			
Pair PVCs	Yellow Arrhythmia - PVCs		12:45:15		12:48			
Pair PVCs	Yellow Arrhythmia - PVCs		12:50:25		12:53:10			

Pair PVCs	Yellow Arrhythmia - PVCs		1:05:00		1:08:05			
Pair PVCs	Yellow Arrhythmia - PVCs		1:05:50		1:08:50			
Pair PVCs	Yellow Arrhythmia - PVCs		1:33:00		1:36:00			
Pair PVCs	Yellow Arrhythmia - PVCs		1:42:00		1:45:00			
Pair PVCs	Yellow Arrhythmia - PVCs		1:46:00		1:49:00			
Pair PVCs	Yellow Arrhythmia - PVCs		1:47:45		1:51:00			
Pair PVCs	Yellow Arrhythmia - PVCs		1:55:00		1:58:00			
Pair PVCs	Yellow Arrhythmia - PVCs		2:15:00					
Pair PVCs	Yellow Arrhythmia - PVCs		2:03:15		2:06:15			
Pair PVCs	Yellow Arrhythmia - PVCs		2:08:00		2:11:00			
Pair PVCs	Yellow Arrhythmia - PVCs		2:12:00		2:15:00			
Pair PVCs	Yellow Arrhythmia - PVCs		2:12:30		2:15:30			
Pair PVCs	Yellow Arrhythmia - PVCs		2:12:50					
Pair PVCs	Yellow Arrhythmia - PVCs		2:45:00		2:48:00			
Pair PVCs	Yellow Arrhythmia - PVCs		2:51:30		2:54:30			
Pair PVCs	Yellow Arrhythmia - PVCs		2:54:30		2:57:30			
Pair PVCs	Yellow Arrhythmia - PVCs		3:07		3:10			
Pair PVCs	Yellow Arrhythmia - PVCs		1:05:00		1:08:00			
Pair PVCs	Yellow Arrhythmia - PVCs	N	1:09:30		1:12:30	N		
Pair PVCs	Yellow Arrhythmia - PVCs		1:33:45		1:36:40			
Pair PVCs	Yellow Arrhythmia - PVCs	N	1:58:20		2:02:00	N		
Pair PVCs	Yellow Arrhythmia - PVCs	N	2:02:20		2:05:20	N		
Pair PVCs	Yellow Arrhythmia - PVCs		2:08:00		2:13:45			
Pair PVCs	Yellow Arrhythmia - PVCs		2:24:45		2:28:30			
Pair PVCs	Yellow Arrhythmia - PVCs	N	2:42:30		2:45:30	N		
Pair PVCs	Yellow Arrhythmia - PVCs	N	2:52:30		2:55:00	N		
Pair PVCs	Yellow Arrhythmia - PVCs	N	2:52:30		2:55:00	N		
Pair PVCs	Yellow Arrhythmia - PVCs	N	2:59:30		3:00:00	N		
Pair PVCs	Yellow Arrhythmia - PVCs		3:02:45		3:05:45			
Pair PVCs	Yellow Arrhythmia - PVCs	N	3:06:30		3:09:45	N		
Pause	Yellow Arrhythmia - Beat Detection	N	10:58:30	---	10:58:40	N		
Pause	Yellow Arrhythmia - Beat Detection		1:54:00		2:18:00			
PVCS >10/MIN	Yellow Arrhythmia - PVCs	T				Y	1st alarm sound, second check PIIC	Nurse was already in patient room
PVCS >10/MIN	Yellow Arrhythmia - PVCs	N	12:55:56		12:59:00	N		*PATIENT IN 310B HAS A-FIB SO ANY ALARM THAT WENT OFF INDICATING IRREGULAR RHYTHM WAS
PVCS >10/MIN	Yellow Arrhythmia - PVCs		1:19:10		1:22:00			
PVCS >10/MIN	Yellow Arrhythmia - PVCs	N	1:31:30		1:33:40	N		
PVCS >10/MIN	Yellow Arrhythmia - PVCs	N	1:44:00		1:47:00	N		
PVCS >10/MIN	Yellow		1:57:15		2:00:15			

	Arrhythmia – PVCs							
PVCS >10/MIN	Yellow Arrhythmia - PVCs	N	1:57:20		1:58:20	N		
PVCS >10/MIN	Yellow Arrhythmia - PVCs		2:08:00		2:11:00			
PVCS >10/MIN	Yellow Arrhythmia - PVCs	N	2:08:00		2:11:20	N		
PVCS >10/MIN	Yellow Arrhythmia - PVCs	N	2:18:15		2:24:45	N		
PVCS >10/MIN	Yellow Arrhythmia - PVCs	N	2:33:30			N		
PVCS >10/MIN	Yellow Arrhythmia - PVCs	N	2:50:30		2:52:30	N		
PVCS >10/MIN	Yellow Arrhythmia - PVCs	N	3:15:15		3:18:15	N		
PVCS >10/MIN	Yellow Arrhythmia - PVCs	N	3:25:00		3:28:00	N		
RA Lead Off	In-Op		10:58:00	---	10:58:15	N		
RA Lead Off	In-Op		11:06:00	---	11:07:00	N		
RA Lead Off	In-Op		11:07:15	---	11:19:20	N		There was an alarm that was greater whose noise over powered this. When that alarm timed out, thi
RA Lead Off	In-Op		11:26:45		11:28:30			
RA Lead Off	In-Op		11:28:00					III
RA Lead Off	In-Op		12:38:00		12:38:15		I	II
RA Lead Off	In-Op		12:45:30		12:45:35			
RA Lead Off	In-Op		12:59:00		12:59:20			
RA Lead Off	In-Op		1:03:00		1:03:05			
RA Lead Off	In-Op		2:51:00		2:51:01			
RA Lead Off	In-Op	N	2:05:30			N		
R-ON-T PVC	Yellow Arrhythmia - PVCs	N	11:22:45	---	11:25:25	N		
R-ON-T PVC	Yellow Arrhythmia - PVCs		1:43:50		1:46:50			
Run PVCs	Yellow Arrhythmia - PVCs	N	10:55:40	---	10:57:45	N		
Run PVCs	Yellow Arrhythmia - PVCs	N	1:33:40		1:36:40	N		
Run PVCs	Yellow Arrhythmia - PVCs	N	1:48:50		1:51:50	N		
SPO2 No Sensor	In-Op	N	---	---	13:10:00	N		Alarm type not silenced
Tachy	Red Alarm	T	1:27:10	2:27:15	1:27:35	Y	1st alarm sound, second check PIIC	Prints ECG, Nurses reviewed arrhythmia. Nurse went into patient room.
Tachy	Red Alarm	T	1:29:50	1:30:00	1:39:20	Y	1st alarm sound, second check PIIC	Nurse was already in patient room / silenced by another nurse (who also went to check if the nurse n
Tachy	Red Alarm	T	1:30:40	1:30:40	1:30:45	Y	1st alarm sound, second check PIIC	Nurse was already in patient room
Tachy	Red Alarm	T	1:34:00	1:34:00	1:34:20	Y	1st alarm sound, second check PIIC	Nurse was already in patient room
Tachy	Red Alarm	T	1:38:25	1:38:25	1:38:30	Y	1st alarm sound, second check PIIC	Nurse was already in patient room
Tachy	Red Alarm	T	1:40:00	1:40:00	1:41:30	Y	1st alarm sound, second check PIIC	Nurse was already in patient room
Tachy	Red Alarm	T	1:42:05	1:42:05	1:42:22	Y	1st alarm sound, second check PIIC	Nurse was already in patient room
Tachy	Red Alarm	T				Y	1st alarm sound, second check PIIC	Nurse was already in patient room
V-Fib/Tach	Red Alarm		3:05:15	3:05:30	3:05:45	Y		
V-Fib/Tach	Red Alarm		3:05:15	3:05:30	3:05:45	Y		
V-Tach	Red Alarm	F	2:21:00	2:22:20	2:22:20	Y		ecg review.
Vent Rhythm	Yellow Arrhythmia - PVCs	N	10:57:45	---	10:58:40	N		
V-Fib/Tach	Red Alarm		12:50:00	12:50:20	12:50:20			
V-Tach	Red Alarm	F	10:40:40	10:41:30	10:41:00	Y		
V-Tach	Red Alarm	F	2:36:40	2:36:50	2:36:50	Y	PIIC	review ECG
V-Tach	Red Alarm	F	2:37:40	2:37:50	2:37:50	Y	PIIC	review ECG
V-Tach	Red Alarm	F	2:37:50	2:38:00	2:38:00	Y	PIIC	review ECG

Appendix E: Indications for Telemetry Monitoring

Indications for Telemetry Monitoring

DIAGNOSIS	UTILIZATION	RECOMMENDATION GUIDELINE FOR DISCONTINUING TELEMETRY
Pacemaker Insertion or Adjustment *Suspicion of Pacemaker* **Dysfunction**		- Successful implantation or adjustment of pacemaker with no observed malfunctioning X 24 – 48 hours
Resuscitation from cardiac arrest		-until ICD is placed - unless secondary to drug effect and arrhythmia resolves monitor 12 hours thereafter
High risk lesions at cardiac cath		-24 hours after intervention (ie left Main or equivalent)
Non-urgent PCI with complications		-24 hours
AV block Mobitz II or higher		-Continuous until permanent pacemaker unless secondary to drug effect and arrhythmia resolves monitor 12 hours thereafter
Post cardiac surgery		-48-72 hours
Rule Out Myocardial Infarction **(Low Risk)**	Normal EKG upon admit with chest pain No previous history of angina or MI	- D/C monitor if 3 negative CPKs or negative troponins with no 12 lead EKG changes
Rule Out Myocardial Infarction **(High Risk)**	History of MI, known CAD, past CABG Diabetes, Elderly	- D/C if all serial CPKs and troponins are within normal limits and 12 lead EKGs without changes over 24 hours

	12 Lead EKG with changes or questionable changes	- Successful management of pain, medication and patient ruled out by enzymes and 12 lead EKG - Monitor patient with activity, if no problem then D/C
Status post Myocardial Infarction	- history of VT/V fib only in 24 – 48 hour period in the setting (without further events) of an MI	- NO observed arrhythmia and no chest pain for 48 - 72 hours after MI - 24 – 48 hours after transfer out of ICU
Acute Coronary Syndromes (unstable angina)		- pain free x 24 – 48 hours
Congestive Heart Failure Presents with angina New diagnosis of failure with suspected angina/MI Evidence of existing arrhythmia requiring management	**Telemetry not indicated if:** - patients with known failure who do NOT have issues listed under the CHF definition on the left UNLESS potassium levels <3.5or >5.5 or excessive diuresis is evident	- Rule out MI by enzymes and appropriate cardiac markers (24 hours) - Heart failure determined not to be related to ischemia - No observed significant arrhythmias for 24 hours or successful management of any existing arrhythmias - Stable potassium levels with diuresis (2 successive blood draws 12 hours apart)
Atrial Fibrillation **New onset or rapid rate** **Anti Arrhythmic Treatment**	- Monitor for pro-arrhythmia while loading antiarrhythmic **Telemetry not indicated if:** - this is a chronic condition, rate is controlled, and patient is asymptomatic	- Successful rate control (for 12-24 hours) with no plans for cardioversion (chemical or electrical) - Successful cardioversion with no reconversion to afib after 24 hours
		RECOMMENDATION GUIDELINE FOR

DIAGNOSIS	UTILIZATION	DISCONTINUING TELEMETRY
Blunt Traumatic Cardiac Injury	**Telemetry indicated for:** -patient who presents with abnormal EKG or injury consistent with cardiac contusion	- NO observes arrhythmia x 24 hours
Electrolyte Imbalances	Telemetry should be used: - potassium is <3.2 or >5.5 (unless baseline for renal failure patients) - potassium infusion >10-20 mEq/hr - Mg + + < 1.5 - Ca + + < 8.0 - Ca + + > 11	- Resolution of electrolyte imbalance
Syncope	Telemetry indicated x 48 hours	- Day 3: telemetry may be discontinued if arrhythmic causes have been ruled out
Arrhythmia Management SVT/Bradycardia **Unstable rhythm abnormality or conduction disturbance**	Telemetry indicated 24 – 48 hours in patients presenting with arrhythmia	Return of NSR or NO evidence of arrhythmias x 48 hours
VT	Telemetry indicated 24 to 48 hours	At the discretion of attending MD
Drug Toxicity	Telemetry indicated 24 - 48 hours – dependent on drug half life.	Blood levels are within normal range or risk of cardiac arrhythmia has been ruled out.

Prolonged QT with associated Ventricular arrhythmia		Continuous until definitive therapy

DIAGNOSIS	**UTILIZATION**	**RECOMMENDATION GUIDELINE FOR DISCONTINUING TELEMETRY**
Post operative patients with sleep apnea	If pt is receiving continuous pulse oximetry	24-48 hours
Percutaneous coronary artery intervention (PCI)		24 hours
Other Conditions when justified: **Thyrotoxic Crisis with Tachycardia**		-24 hours then remove
TIA **CVA**		Recommending 48 hours of continuous telemetry monitoring with initiation when patient is placed on ED monitor
Adult Guidelines for IV medications		As defined by pharmacy protocols

Appendix F: 3 East Unit Observations- Post Re-Design

- Nurses/PCAs were notified of changes through flyers posted around unit, emails, and at staff meetings
- Nurses expressed annoyance of having to contact PCAs for alarms
- PCAs said this was a benefit- now know which alarms there are responsible for and have to address immediately
- PCAs are would like to be able to use the alarm suspension feature as well
    - Currently only nurses use permitted to use this function
    - They are typically responsible for bathing and assisting patients, as well as changing lead sets
        - would be convenient to be able to silence alarms while doing this, especially with ECG
- Nurses said it took them a while to remember to inform PCAs of ECG and SpO_2 alarms because it was a change in work flow
    - Not a difficult adjustment, just too time to get used to
- Nurses like suspending alarms in rooms when they are assisting patients and they know alarms will be generated
    - Helping a patient stand-up and practice walking
    - Administering specific medicines
    - Re-applying electrode adhesives