**National Association of Clinical Nurse Specialists**
**Alarm Safety Crosswalk**
**Table 1**

| Organization | AACN | AAMI | ECRI | Hopkins | TJC | Healthcare Technology Foundation (HTF) |
|---|---|---|---|---|---|---|
| **Website / Resource** | **http://www.aacn.org** | **www.aami.org** | https://www.ecri.org | Cvach Article<br>Graham Article<br><br>Spotlight on Success: Johns Hopkins improves clinical alarm safety with escalation algorithms. | http://www.jointcommission.org | www.thehtf.org |
| **Cost to Access to online resources** | Free | Free | Webinars free for members; $249 for non-members | Free | Free | Free |
| **Education Recommendations: Initial or ongoing** | No | No | No | Reinforce and standardize nursing education on monitoring skills. | NPSG 6: Reduce harm associated with clinical alarm systems | No |
| **Competency:** | No | www.aami.org | No | Create a monitor competency checklist that reinforces the practical elements regarding alarm management and ensures that nursing staff is capable of monitoring patients effectively.<br><br>Spotlight on Success: Johns Hopkins improves clinical alarm safety with escalation algorithms. | No | No |
| **Type of Technology with Alarms:** | 1. Cardiac monitors<br>2. Pulse oximetry<br>3. Ventilators<br>4. Bed Exit Alarms | Webinar: How to Identify the Most Important Alarm Signals to Manage | No | Use smart alarms or alarm technology that incorporates delays<br><br>Spotlight on Success: Johns Hopkins improves clinical alarm safety with escalation algorithms. | NPSG 6: Reduce harm associated with clinical alarm systems | No |
| **Technology Assessment: Any direction on how to do a technology assessment?** | No | 1. Alarm Parameter Inventory<br>2. Alarm Inventory Grid Sample<br>3. How to Identify the Most Important Alarm Signals to Manage: | No | Change ECG electrodes daily or when ECG tracings are poor<br><br>Spotlight on Success: Johns Hopkins improves clinical alarm safety with escalation algorithms. | Prepare an inventory of alarm-equipped medical devices used in clinical areas, and identify the default alarm settings and the limits appropriate for each care area.<br><br>NPSG 6: Reduce harm associated with clinical alarm systems | No |
| **Recommendations for assessment of current state?** | Gap Analysis | No | No | Recognize the Contributing Conditions:<br>1. Alarm parameters were not set to actionable levels<br>2. Alarm thresholds were set too tight resulting in too many false positives<br>3. Staff working in large clinical units did not have clear accountability to respond to alarm conditions<br>4. Patient rooms with closed doors made it difficult for staff to hear alarm signals<br>5. Too many duplicate alarm conditions desensitized staff to alarm signals<br>6. Lengthy time-lags between installation of devices and staff training on those devices did not allow for staff to | Identify the most important alarm signals to manage based on the following:<br><br>1. Input from the medical staff and clinical departments;<br>2. Risk to patients if the alarm signal is not attended to or if it malfunctions;<br>3. Whether specific alarm signals are needed or unnecessarily contribute to alarm noise and alarm fatigue;<br>4. Potential for patient harm based on internal incident history; | National Clinical Alarms Survey |

**National Association of Clinical Nurse Specialists**
**Alarm Safety Crosswalk**
**Table 1**

| Organization | AACN | AAMI | ECRI | Hopkins | TJC | Healthcare Technology Foundation (HTF) |
|---|---|---|---|---|---|---|
| | | | | become accustomed to the auditory alarm signals of new equipment<br><br>Using data to drive alarm systems improvements. | 5. Published best practices and guidelines. | |
| **Recommendations for Defaults** | No | www.aami.org | No | Graham Article | No | No |
| **Recommendations for best practice** | www.aacn.org | Christiana Hospital | | Interventions to Improve Alarm Safety:<br><br>Evidence Based Practice Recommendations to decrease alarm fatigue covering:<br>1. Technology<br>2. Hospital<br>3. Caregiver<br>Cvach Article<br><br>Spotlight on Success: Johns Hopkins improves clinical alarm safety with escalation algorithms. | 1. To help reduce nuisance alarm signals, change single-use sensors (i.e. ECG leads) according to manufacturer's recommendations.<br>2. Assess whether the acoustics in patient care areas allow critical alarm signals to be audible. | |
| **Address Special Populations (e.g., peds)** | No | Children's National Hospital | No | No | No | No |
| **Template for reports; dashboards** | AACN Alarm Fatigue Materials | Children's National Hospital | No | Develop an alarm management policy or address alarm management in an existing cardiac monitor policy.<br><br>Spotlight on Success: Johns Hopkins improves clinical alarm safety with escalation algorithms. | No | No |
| **The Joint Commission (TJC): NPSG** | No | No | No | No | NPSG 6: Reduce harm associated with clinical alarm systems | 1. R3 Report ı Requirement, Rationale, Reference<br>2.VHA Patient Safety Assessment Tool<br>3. Work plan for the NPSG (Hyman): http://thehtf.org/clinical.asp |
| **CUSP (Comprehensive Unit based Safety Program)** | No | No | No | Utilized CUSP on participating units:<br>A five-step program designed to change a unit's workplace culture—and in so doing bring about significant safety improvements—by empowering staff to assume responsibility for safety in their environment. This goal is achieved by providing employees education, awareness, access to organizational resources, and a toolkit of interventions. Its five steps include:<br>1. Train staff in the science of safety<br>2. Engage staff to identify defects<br>3. Senior executive partnership/ safety rounds<br>4. Continue to learn from deficits<br>5. Implement tools for improvement.<br><br>Using Data to Drive Alarm System Improvements | No | No |

**National Association of Clinical Nurse Specialists**
**Alarm Safety Crosswalk**
**Table 1**

| Organization | AACN | AAMI | ECRI | Hopkins | TJC | Healthcare Technology Foundation (HTF) |
|---|---|---|---|---|---|---|
| **Change Strategies** | Gap Analysis | No | No | No | No | No |
| **Order Sets** | No | www.aami.org | No | No | No | No |
| **Resources** | AACN Alarm Fatigue Materials | www.aami.org | www.aami.org | | The Joint Commission Sentinel Event Alert, Number 50, April, 2013<br>TJC Sentinel Event Alert. Alarms | Clinical Alarms Management and Integration |
| **Forms, templates, data formats** | AACN Alarm Fatigue Materials | www.aami.org | www.aami.org | Using Data to Drive Alarm Systems Improvements | Resource Guide: Risky Business<br>Conducting Proactive Risk Assessments: Joint Commission Resources<br>Quality & Safety Network | 1. NTI Action Pack:<br>2. Fault Tree Analysis of clinical alarms (Hyman) http://thehtf.org/clinical.asp |
| **Strategies on how to obtain monitor data** | No | No | No | Recommended data to obtain:<br>1. # Of high / medium / low priority and technical alarms over a defined period<br>2. Average duration of alarms<br>3. Average daily census and average daily census on telemetry<br>Spotlight on Success: Johns Hopkins improves clinical alarm safety with escalation algorithms. | No | No |
| **Media Available Webinars, voice over PPT, videos** | Webinars | Webinars Resources | No | No | Joint Commission webinar on Alarm Safety (May 1, 2013)<br>TJC Alarm Webinar Transcript | No |

**National Association of Clinical Nurse Specialists**
**Alarm Safety Crosswalk**
**Table 2: Alarm Fatigue Literature**

| Article | Design/Purpose | Sample/Setting | Measurements/Instruments | Results | Strengths and Weaknesses | Relevance to Problem | Level of Evidence and Grade |
|---|---|---|---|---|---|---|---|
| Association for the Advancement of Medical Instrumentation. (2011). A siren call to action. | White paper of recommendations from AAMI Alarm Safety Summit in 2011.<br><br>Clarion themes, challenges, and priority actions established by experts. | Summit participants included AAMI; FDA; TJC; ACCE; and ECRI | | Established 7 clarion themes, a call to action to eliminate harm related to alarms. | *Strengths:*<br>1. Clarion themes are inclusive; include the challenge, the priority action, and accountability.<br>2. Short term / long term solutions<br>*Weaknesses:*<br>1. Lack of dissemination<br>2. Document is complex | Addresses broad spectrum of alarm safety issues. | |
| Benjamin et al., (2013), Impact of cardiac telemetry monitoring on patient safety and cost. | Quality Improvement<br><br>Retrospective analysis of patient with cardiac monitoring within 4 teaching hospitals to quantify telemetry over-monitoring | Analysis of 1095 adult patients with cardiac telemetry on medical surgical and progressive units (non-ICU), at 4 teaching hospitals | Retrospective analysis of 1095 monitored telemetry patients<br>Researchers reviewed total days of telemetry monitoring, incidents of arrhythmias, adherence to guidelines for ECG monitoring and adherence to appropriate discontinuation of telemetry<br>Total days of telemetry measured | More than 30% of all telemetry days did not meet accepted indications for monitoring<br>The incidence of significant arrhythmia on a day where the patient was not-indicated for monitoring was extremely small 3.1 out of 100 telemetry monitored days<br>Telemetry monitoring can be expensive. It is estimated to cost $53.00 per patient per day for telemetry; conservative estimates assume for 400 bed hospital patients with no indication for monitoring can cost hospital up to $250,000 per year. | *Strengths:* large study of four different hospitals; findings of the study reveal similar trends in monitoring utilization among organizations<br>*Weaknesses:* economic analysis was limited; it only included cost of staff monitoring. Indirect costs were not included for maintenance of equipment or potential outflow of patients needing telemetry beds | Time attending to alarms of non-indicated monitoring patients takes time and attention away from patients in need of monitoring.<br>Reducing over-monitoring reduces costs and improves safety | Level III<br>Grade B |
| Borowski et al., (2011). Reducing False Alarms of Intensive Care Online-Monitoring Systems: An Evaluation of Two Signal Extraction Algorithms. | Review of medical device alarms<br>The purpose of the article was to present the current situation regarding clinical alarms and their problems in intensive care such as lack of clinical relevance, and alarm fatigue | Review of 10 key articles based on the workshop titled "Too many alarms? Too few alarms? Organized by the section patient Monitors and the Workgroup Alarms of the German Association of Biomedical Engineering<br>Workshop held November 25th, 2009 | Research themes:<br>Ergonomics and human factors engineering could improve clinical effectiveness and usability of alarms<br>Alarm algorithms can be used to optimize alarm modalities, and combine existing data into smart monitors<br>Intelligent alarm systems are needed for a higher level of abstraction and suppression using alarm validation | Several studies have demonstrated that the majority of alarms created by patient monitoring systems have no clinical relevance | *Strengths:* Table of literature included with clear description of each article<br>*Weaknesses:* Search strategy, inclusion/exclusion criteria not included | The purpose of this article was to present the current issues and significance of alarm fatigue within the ICU environment<br>This article was included (despite a large focus on smart alarms), because it discussed how human factors are just as important as engineering factors to minimize alarms | Level V<br>Grade C |
| Clochesy, Cifani, & Howe, (1991). Electrode site preparation techniques: a follow-up study. | Comparison of electrode site preparation techniques<br>A posttest-only control group design was used to study the effect of electrode site preparation techniques on reducing electrical potential across ECG skin electrodes | One hundred twenty healthy volunteers were randomly assigned into one control and three treatment groups of 30 subjects each. | The three treatments were One Step Skin Prep used once, ECG Prep Pad used five times, and ECG Prep Pad used once. To control for handedness, the skin preparation site was randomly assigned to either the left or right forearm | Skin preparation done by using One Step Skin Prep or the ECG Prep Pads used once significantly decreased skin potentials by 2.3 mV and 3.3 mV respectively. There was no significant difference in the control group and the group in which ECG Prep Pads were used five times. | *Strengths:* Large study sample of 120 individuals<br>*Weaknesses:* skin preparation on arms, and in laboratory not | ***Landmark study used in AACN ECG monitoring recommendations and AHA guidelines on ECG monitoring (Drew et al., 2004). | Level III<br>Grade B |

**National Association of Clinical Nurse Specialists**
**Alarm Safety Crosswalk**
**Table 2: Alarm Fatigue Literature**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Cvach, (2012). Monitor alarm fatigue: An integrative review. | Integrative clinical review investigating the clinical problem of alarm fatigue | Review included 72 articles related to alarm management and alarm fatigue | Major themes:<br>Excessive alarms have detrimental effects on staff; distrust in monitoring that leads staff to disable alarms<br>Nurse response to alarms is matched by the perceived accuracy of the alarm<br>Alarm audibility; humans can only distinguish a small number of audible noises at one time.<br>Technology can be used to improve rate of alarms; delays, adjusting default settings, and customization of alarm limits can be used to reduce false alarms | There are a variety of quality improvement studies that have been successful in reducing the alarm burden with nursing based strategies: skin prep, education, customization of alarms, and review of default settings | *Strengths:* there is a large amount of literature documenting the significant number of false alarms within the clinical setting<br><br>*Weaknesses:* Most evidence related to reducing alarms is from observational studies. Very few RCTs | A knowledge gap exists regarding how to suppress false alarms | Level III<br>Grade A |
| Cvach, Biggs, Rothwell, & Charles-Hudson (2013). Daily electrode change and effect on cardiac monitor alarms: an evidence-based practice approach. | Quality improvement study<br>Purpose of the study was to determine if daily electrode changes reduced number of cardiac monitor alarms in acute care unit | 2 different adult acute care units at John Hopkins:<br>15 bed medical progressive care unit (MPC).<br>25 bed cardiology care unit (CCU) (combined step-down and ICU beds) | Average number of alarms per day measured pre and post intervention<br>Total number of alarms were measured continuously for 8 days pre-intervention and 8 days after intervention<br>Data (total number of alarms) retrieved by clinical engineering | Reduction of total number of alarms per day by 46% | *Strengths:* Clear description methodology. Skin preparation included clipping hair, abrading skin prep site, washing with soap/water, and completely drying before electrode change.<br>Daily electrode change between 8a-noon.<br>All ST/QT alarms set for all patients and used all default monitoring parameters<br>*Weaknesses:* Lack of monitored compliance of unlicensed staff. In future have specific plan to hold staff accountable to ensure daily changes are occurring | Daily change of electrodes with skin preparation resulted in fewer cardiac monitor alarms (reduced number of alarms by 46%)<br>Noted that increases in 'lead off' alarms during electrode change time due to techs not pausing alarms during daily electrode change. Alarms are silenced when taking patients off monitors for any reason. | Level III<br>Grade B |
| Drew et al., (2004). Practice standards for electrocardiographic monitoring in hospital settings. | Clinical guideline<br><br>Purpose of the guideline is to provide standards for ECG monitoring within the hospital setting | Standards specifically for hospitalized patients; both children and adults | Randomized clinical trials relative to standard ECG monitoring are nonexistent.<br><br>Majority of the consensus is based on expert opinions and research in the field of electrocardiography. | Guidelines offer recommendations for ECG lead placement, skin preparation, and what patient | *Strengths:* Guideline offers first and only ECG standards based on retrospective adverse outcomes for monitored patients. Includes RCTs<br>*Weaknesses:* there are very few RCTs related to monitoring standards or appropriate parameters, leads, or what patients to monitor and for how long. Much of the guideline is expert consensus. Little information given on disclosure of authors or plans/tools/guides for implementing the standards within healthcare organizations. | Only published standards of ECG monitoring | Level II<br>Grade B<br>An overall score of 4/7 was based on AGREE Research Trust (2009) tool for appraising guidelines |

**National Association of Clinical Nurse Specialists**
**Alarm Safety Crosswalk**
**Table 2: Alarm Fatigue Literature**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Edworthy, (2013). Medical audible alarms. | Review of the available research related to design of auditory alarms in healthcare<br>Aim of the article it to demonstrate that false alarms for medical devices are unacceptable and alarm design principles must be addressed | Literature searched specifically for audibility and visual medical alarms<br>Review examined 50 journal articles, three books, and 100 conference papers | Main themes:<br>There are a high number of false alarms<br>There is a lack of standardized alarm philosophy and mapping of alarms to provide end users and understanding of alarm priorities<br>Audible alarm design can be improved; users cannot interpret and understand the vast number of melodic tones of alarms<br>IEC-60601-1-8 is an international standard aimed at harmonizing medical device alarms. This provides a philosophy of alarms to prevent proliferation of alarms that determines the success of alarms | There are a high number of false alarms and reduction in false alarm rates means that the design of audible alarms must be improved.<br>Standardization of audible alarms is best practice. | *Strengths:* Provides unique perspective of alarm management from biomedical sciences perspective and the ability of humans to detect audible alarms<br>*Weaknesses:* Narrative review; search strategy, inclusion criteria not included | Practical alarm management strategies such as delays are likely to reduce the rate of false alarms<br>There is a need for standardization of alarm principles, audibility, and alarm ergonomics | Level V<br>Grade C |
| Feder & Funk, (2013). Over-monitoring and alarm fatigue: For whom do the bells toll? | Expert Opinion/ Descriptive review<br>Overview of literature related to over-monitoring | Hospitalized patients both adults and pediatrics | Presents articles that suggest monitoring does not contribute to early detection of clinically relevant arrhythmias, decrease long term mortality or alter treatment of patients; instead it is distracting and contributes to the high number of false and irrelevant alarms.<br>No literature to support telemetry monitoring as a method to prevent, detect, or improve survival for cardiac arrest | Rationale that more monitoring leads to more alarms without a significant improvement in outcomes for many patients.<br>Based on information from literature, 35% of all monitored patients have no indication for monitoring | *Strengths:* Rationale for not supporting widespread monitoring supported by retrospective studies examining survival and outcomes with/without telemetry monitoring<br>*Weaknesses:* No RCTs comparing outcomes of monitored and unmonitored patients. Recognition that practice standards are now outdated; need updated standards based on new monitoring technology | Over-monitoring is a contributing factor to alarm fatigue and the high number of false alarms | Level V<br>Grade B |
| Funk et al., (2010). Unnecessary arrhythmia monitoring and underutilization of ischemia and QT interval monitoring in current clinical practice: Baseline results of the Practical Use of the Latest Standards for Electrocardiography Trials. | Multi-site prospective observational study examining ECG monitoring based on American Heart Association's standards for ECG monitoring<br>Purpose is to determine if patients are appropriately monitored as ongoing efforts to reduce clinically insignificant alarms. | 17 cardiac units in 17 hospitals 15 in the United States, one in Canada and one hospital in Hong Kong.<br>Hospitals were either academic medical centers or community hospitals, all received IRB approval, and all organization treat medical and cardiac surgical patient populations | Medical records were reviewed by 3 experienced ICU nurse researchers to determine if the patient had either a Class I or Class II indication for monitoring. Furthermore, the researchers reviewed monitoring for QTc/ST segment monitoring<br>5 day visit to each unit | Total of 1816 patients<br>89.9% patients with indication for monitoring were monitored<br>84.9% of patients with no indication for monitoring were monitored<br>Of patients with indication for ST segment monitoring, 34.5% were monitored with ST segment monitoring<br>Of patients with indication for QTc monitoring, only 21.4% had a documented QTc interval within the past 24 hours | *Strengths:* Large multisite study. Uses clear definitions for indications for monitoring from AHA standards. Patients randomly selected. Also tracked use of ST segment and QTc monitoring that are known to detect serious clinical events.<br>*Weaknesses:* Authors suggest that the staff of the study and may have changed their behaviors because they knew the study was in progress (Hawthorne Effect) | Monitoring is inappropriate and can result in unnecessary alarms:<br>There is over-monitoring for patients with no indication for monitoring<br>Patients with indication for ST segment or QTc monitoring are under monitored | Level III<br>Grade B |
| Funk et al. (2013). An alarming rate of unnecessary monitoring in the Practical Use of the Latest Standards of Electrocardiography (PULSE) trial. | Poster<br><br>Evaluation of appropriate use of ECG monitoring | Analysis of data from PULSE trial: multisite RCT addressing ECG monitoring practices | Prospective medical records review for class I and class II indications for ECG monitoring.<br>4,678 observations on 3,250 patients in 17 hospitals in cardiac care units | 26% of patients had no indication for monitoring | | Over monitoring leads to unnecessary alarms.<br>Eliminating unnecessary monitoring will decrease the alarm burden and decrease sentinel events related to alarm fatigue. | Level II<br><br>Grade B |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Gorges, Markesitz, & Westenskow, (2009). Improving alarm performance in the medical intensive care unit using delays and clinical context. | Observational study<br>Observing monitor alarms in ICU; study of how many alarms are observed to be ignored by staff and how many are actionable. After observation, determine how many alarms could have been avoided by an alarm delay.<br>The purpose of the study was to observe alarms in the Medical ICU to identify methods for reducing the number of false alarms by using delays and finding correlations between alarms and clinical context | 200 hours of direct staff observation in a Utah 12 bed Medical ICU | Number of alarms were recorded as well as the number of tasks performed in response to alarms<br>1214 alarms occurred<br>2344 tasks were performed in response to the alarms<br>-On average 6.07 alarms occurred each hour<br>-41% of alarms were ignored<br>-Alarms were active for an average duration of 17 seconds before acted on<br>-36% of the alarms were ineffective | A 14 second delay would have eliminated 50% of the ignored alarms<br>A 19 second alarm would have eliminated 67% of all alarms.<br>Suctioning, washing, repositioning, and oral care caused 152 ignored or ineffective ventilator alarms | *Strengths:* Demonstrates that introduction of an alarm delay improves alarm reliability at the expense of lengthening response time. Appeared that staff respond selectively to alarms or wait before responding. Unique perspective for classifying alarm based on response rather than event triggering the alarm<br><br>*Weaknesses:* observation based; subjective of context awareness of alarms that is difficult to define | Many alarms are false or provider induced.<br>Introducing alarm delays and purposefully silencing alarms during routine care (such as suctioning) can make alarms more reliable and elicit a more timely response, reduce workload, reduce the noise pollution, and potentially improve patient safety. | Level III<br>Grade B |
| Graham & Cvach, (2010). Monitor alarm fatigue: Standardizing use of physiological monitors and decreasing nuisance alarms. | Quality improvement project<br>Purpose of the study was to determine if RN adjustment of alarm limits on monitors, changes to default alarm settings, and involvement of interdisciplinary monitor task force team reduced number of monitor alarms and improved noise level of the unit. | 15 bed Medical ICU<br>John Hopkins Hospital<br>Data from January 2006 to June 2007 | Clinical engineers counted all cardiac alarms for an 18 day period both pre and post intervention.<br>4 types of alarm categories:<br>*Crisis:* Asystole VT, VF, bradycardia<br>*Warning*: tachycardia, bradycardia<br>*Advisory:* pulse oximetry and PVCs<br>*Message:* irregular<br>*System warning*: lead failure or arrhythmia<br>Study also measured pretest/posttest RN questionnaire on monitor knowledge and perception of unit noise level | Critical monitor alarms were reduced by 43% from baseline data due to adjustment of alarm limits, and implementation of an interdisciplinary monitor policy.<br>Pretest: 83% of nurses changed alarm parameters when a patient condition changed,<br>Post intervention 94% of RNs reported to change alarm parameters to individual patient needs<br>Pretest: 78% of nurses changed alarm parameters at the beginning of their shift.<br>Post: 94%<br>Noise level: Rated 1-5 (1= low, 5=high noise level)<br>Pre: 4.0/5 unit overall noise<br>Pre: 3.1/5 noise from monitors<br>Post intervention: 3.5/5 unit overall noise<br>Post 2.97/5 noise from monitors | *Strengths:* breakdown of all alarms before and post intervention in table.<br>-No interpretation of alarms as false/true<br>-Study included cardiac telemetry alarms and pulse ox alarms.<br>*Weaknesses:* Surveys on alarm limit adjustment compliance and unit noise level may not be accurate as survey not required and was on volunteer basis for RNs. Single unit study | RN adjustment of alarm limits is starting point in reducing number of physiologic monitor alarms<br>Nurses must be trained to adjust alarm limits. RNs were advised to widen alarm limits for blood pressure and heart rate by +/- 20 points of the patient's normal values. | Level III<br>Grade B |

**National Association of Clinical Nurse Specialists**
**Alarm Safety Crosswalk**
**Table 2: Alarm Fatigue Literature**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Gross, Dahl, & Neilsen, (2011). Physiologic monitoring alarm load on medical/surgical floors of a community hospital. | Quality Improvement Study<br>Purpose of the study was to determine if it was possible to significantly reduce the number of physiologic monitor alarms for med/surg patients by adjusting alarm limits (HR high alarm from 120 to 130 and pulse oximetry low alarm from 90 to 85) | A 79 med/surg beds of community hospital located in urban Arizona<br>Data collected over 1 year time period | Retrospective evaluation of alarm frequency from April 2009 to January 2010<br>Before alarm limit adjustment, the average rate of alarms was 95.6 alarms per patient per day.<br>For all patients, the average hours of monitoring were 16.5 hours/patient. | Reduction of alarm frequency by 50% by adjusting high HR alarm from 120 to 130<br>Reduction of pulse ox alarm by 36% reducing the Sp02 alarms from 90% to 85%. | *Strengths:* True and false alarm criteria specifically defined<br>-Raw data provided for true alarms, false alarms, and uncertain alarms.<br>-Alarms reviewed by two independent clinical researchers for validity, in case of disagreement a third clinical 'judge' was used<br>-Included both telemetry and pulse oximetry<br>*Weaknesses:* Only 34% of HR alarms and 63% of pulse ox alarms considered true alarms continue to work on sensitivity/specificity of clinical alarms. | Current alarm limits from Philips monitors appear to be too tight for non-ICU patient and contribute to an unnecessarily high alarm load.<br>-Small adjustments in clinical alarms limits significantly reduce alarm load<br>Studied only critical or high priority alarms for telemetry | Level III<br>Grade B |
| Harris, Manavizadeh, McPherson, & Smith, (2011). Do you hear bells:<br>The increasing problem of alarm fatigue. | Quality Improvement<br>Descriptive study outlining one organization's strategies for heightening awareness of alarm fatigue to reduce alarm burden | 988 bed academic community hospital with Magnet designation<br>Three hospital entities sites | The organization developed a multidisciplinary team of staff, biomedical engineers, and educators to strategize ways to reduce the alarm burden<br>The team provided education to the bedside staff regarding alarm fatigue. Staff also received education on the monitor capabilities.<br>Education on monitoring capabilities was in a CD format for staff to review | The team analyzed baseline alarm data, reviewed hospital protocols for alarm management.<br>Discovered in this process that staff did not know how to use monitors to their full potential; no training was offered on monitoring. Preceptors taught new staff what they knew about monitors. No formal education<br>After education for staff (6 months) the alarms were re-evaluated: the ICU had a 30% improvement in alarm burden and a 12% reduction in alarms was noted on progressive units | *Strengths:* Article provides discussion of the challenges to implementing a change at a large hospital with multiple entities.<br>*Weaknesses:* The study did not provide methodology for collecting baseline alarm data or how or when the follow-up data collection was completed. No raw data is provided only two percentages indicating there was a reduction in the alarms. Sample size is not provided. | A reduction in alarm burden was achieved though educating nurses about alarm fatigue, customization of alarm parameters, and the capabilities of the monitors. | Level VI<br>Grade C |
| The Joint Commission, Patient Safety Advisory Group. (2013, April 8). Sentinel Event Alert. Medical device alarm safety in hospitals. | Regulatory Safety Alert<br>Sentinel event (SE) database; FDA Maude database. | Identified risks associated with clinical alarms based on reports in sentinel event database. | Information from sentinel event database. | Recommendations / potential strategies for improvement | *Strengths:* clear data & recommendations.<br><br>*Weaknesses:* Industry experts believe reports underrepresent actual number of events. | Raised awareness across healthcare about the risks associated with the overwhelming number / volume of alarms. | |
| The Joint Commission (2013). Spotlight on Success: Johns Hopkins improves clinical alarm safety with escalation algorithms. | Interview w/ clinical expert about QI project on escalation strategies for alarm safety | Discussion of QI project from Johns Hopkins; introduced alarm escalation | New wireless device to create escalation process for clinical alarms | Outside of the escalation QI project:<br>1. Identified 7 strategies to improve alarm safety<br>2. 53% decrease in high priority alarms<br>3. 23% decrease in duration of high priority alarms | *Strengths:* 7 strategies recommended are within the scope of most organizations to integrate immediately.<br><br>*Weaknesses:* Nomenclature is vendor specific for the alarms. Escalation strategy requires purchase of wireless devices | Seven strategies are clear and can make a significant impact without structural changes / significant resources.<br>Introduction of wireless devices would be more challenging. | Level VI<br><br>Grade C |

**National Association of Clinical Nurse Specialists**
**Alarm Safety Crosswalk**
**Table 2: Alarm Fatigue Literature**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Jonasson, (2007). A prospective study on the relevance of skin preparation for noise, impedance and ECG intervals among healthy males. | Prospective study<br>Study designed to determine relevance of ECG skin preparation to reduce noise and impedance (artifact) among healthy males | 22 healthy male test subjects<br>June 2006<br>Halmsted, Sweden | Male subjects wearing ECG monitors were recorded over 5 minute time periods at 5 time points at 3 separate 24 hour visits with different types of ECG skin prep<br>1. No skin prep<br>2. Abrasion only<br>3. Abrasion and alcohol skin prep<br>At the end of each visit, i.e. 24 hours after electrode application, each subject was questioned regarding itching from the electrodes on a five-step scale of no itching, mild, moderate, severe, and very severe itching.<br>Artifact measured in ECG impedance and ECG amplitude.<br>-Sandpaper, grain 400, was used for skin abrasion<br>- Skin impedance was to be measured prior to each ECG recording period in leads V2 and V3 using a Prep-Check Electrode Impedance Meter | Skin preparation by abrasion showed statistically significant reduction in skin impedance and noise for all ECG leads (compared to no skin preparation)<br>Skin cleansing with alcohol is not warranted. | *Strengths:* All statistical data included in article<br>-Controlled study environment<br>-Documentation of body size, weight, BMI<br>-Impedance measured in individuals leads<br>*Weaknesses:* Lack of randomization<br>-Small sample size | -Skin itching and irritation did not differ between three skin preps<br>-Hair was trimmed on all patients, no study findings on clipping vs. shaving hair for optimal electrode adhesion | Level III<br>Grade B |
| Korniewics, Clark, & David, (2008). A national online survey on the effectiveness of clinical alarms. | Descriptive Analysis based on a national survey to identify the problems associated with alarms in hospitals | Researchers received survey results from t 1327 healthcare workers'=<br>94% worked in acute care hospitals<br>51% were RNs<br>31% worked in ICU<br>Survey was developed by a 16 member task force of nurses and clinical engineers | 81% reported alarms disrupt care<br>78% distrust alarms and disable them<br>>90% agreed that that there is a need for prioritized and easily differentiated audible and visual alarms | The survey results suggest that there is a need for<br>Equipment redesign<br>Clinicians who take an active learning in how to use physiologic monitoring correctly<br>Hospitals must recognize the complexities of managing clinical alarms | *Strengths:* one of very few studies describing the perspective of the bedside staff in dealing with the alarm burden<br>*Weaknesses:* convenience sample of respondents<br>Surveys may not provide the most accurate data related to a subject area | It is necessary to provide staff with education and policies related to alarm responsiveness and awareness of alarm fatigue | Level VI<br>Grade C |
| Medina, Clochesy, & Omery, (1989). Comparison of electrode site preparation techniques. | Comparison of electrode site preparation techniques<br>A posttest-only control group design | 60 health volunteers were randomly divided into one control and two treatment groups of 20 subjects each<br>Within each group, the skin preparation for the ECG electrodes (treatment) was further assigned randomly to either the right or left forearm. | Skin preparation with One Step Skin Prep, ECG prep pads, or no skin preparation | Skin preparation by using One Step Skin Prep significantly decreased skin potentials (-1.90 mV) whereas the group in which ECG Prep Pads were used and the control group had no significant change | *Strengths:* randomized trial<br>*Weaknesses:* testing only in laboratory setting on patient forearms. Small sample size | ***Landmark study used in AHA guidelines on ECG monitoring (Drew et al., 2004) | Level II<br>Grade B |
| Melendez & Pino, (2012). Electrocardiogram Interference: A Thing of the Past? | Quasi-Experimental design<br>ECG interface was controlled and studied in a laboratory environment and then tested in the clinical environment<br>Purpose of the study is to find the best method to reduce interference of physiologic waveforms from electrodes to improve alarm reliability | In the laboratory: a controlled electrode impedance mismatch was simulated on one patient with various skin preparations on the left leg.<br><br>In the clinical setting<br>ECG interference was tested in the cardiac stress test laboratory and the electroencephalography (EEG) laboratory | Interference from electrodes on monitoring was measure using impedance monitors.<br>Interference was measured in the laboratory setting on test patients with test equipment and then further tested in real clinical settings | Skin preparation with pumice was more effective that skin adhesive or alcohol<br>Dry electrodes that are not kept in manufacturer packaging causes the electrodes to dry and lose effectiveness<br>Train clinical and technical staff on what causes electrode interference | *Strengths:* Interference was measured using with impedance meters to create objective measurement of interference<br>*Weaknesses:* Sample size unknown. All skin preparations tested are not included in the study methodology. Article describes a 'trial and error' technique to slowly changing out products, skin preparations, and electrodes until interference was reduced | With consistent skin preparation and testing of electrodes with impedance meters, interference can be eliminated in some clinical settings including the operating room<br>Simple changes such as fresh electrodes and skin preparation make potentially dramatic changes in performance of ECG monitors | Level III<br>Grade C |

**National Association of Clinical Nurse Specialists**
**Alarm Safety Crosswalk**
**Table 2: Alarm Fatigue Literature**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Phillips, (2006). Clinical alarms: Complexity and common sense. | Expert Opinion/ Descriptive analysis<br>The article provides a guide from the acute care team in evaluating alarm systems in the clinical environment<br>Review of components of alarm safety programs | Includes strategies for review of alarms and evaluation of alarm burden in all acute care settings | Article provides assessment tools for use in evaluation of organizational alarm systems<br>Steps in evaluation include:<br>An environmental assessment<br>Assessment of alarm response; who is responsible for responding to and assessing alarms<br>Assessment of alarm system problems from environmental, user, technical, and other categories. | Assessment of alarm system will guide clinical policies related to<br>Initiation and prioritization of alarms<br>Policies related to silencing and disabling alarms<br>Bed to bed notifications<br>Bedside device integration<br>How to deal with 'lead off'<br>Volume of alarms | *Strengths:* article provides an evidence based tool kit for assessing alarms within an organization and strategies for reducing alarm burden<br>*Weaknesses:* No guides for appropriate default settings or methods for customizing individual patient alarms | Clinical alarms are important in the healthcare environment but it is essential for organization to make efforts to improve the reliability of alarms.<br>Standardization of alarm management techniques is critical to creating alarm systems that are safe<br>** Reviewing the previous shifts alarm customization is essential to creating a cultural norm to customize alarms | Level VI<br>Grade B |
| Sendelbach, (2012). Alarm fatigue. | Literature Review<br>Overview of phenomenon of alarm fatigue and alarm management literature | Includes review of total number of alarms measured in a variety of clinical settings: emergency departments, critical care, operating rooms, and medical/surgical units. | Based on the current literature, there is a range of only about 0.6%- 8% of alarms that are clinically significant | Based on the high rate of false alarms there are a variety of practice alerts to address alarm fatigue:<br>Biomedical engineering to consider smart alarms and alarm mapping to reduce alarms<br>Nursing policy and procedure for skin preparation, ongoing education, and alarm customization are recommended<br>Hospitals must educate staff and pay attention to the default settings and monitoring capabilities of organizational software | *Strengths:* comprehensive analysis of the issue of alarm fatigue and task forces working on reducing false alarms<br>*Weaknesses:* only offers overview of literature and no recommendations for individual organizational alarm improvement strategies | Provides an overview of the clinical problem of alarm fatigue and safety concerns related to the high number of false alarms in the current healthcare environment | Level V<br>Grade B |
| Sendelbach, S., & Funk, M. (2013). Alarm Fatigue: A Patient Safety Concern. | Clinical review<br><br>Identify strategies to decrease alarm fatigue | Information from TJC, ECRI, HTF, AAMI, AACN related to alarm safety | Major themes:<br>1. Described alarm fatigue: how, why, impact<br>2. Discussed recommendations by each organization to combat alarm fatigue | Recommendations:<br>Alarms need to be sensitive and specific.<br>Interventions to decrease alarm fatigue have not been rigorously tested. | *Strengths:* Proposed future research in false alarms; non-actionable alarms; appropriate use of monitoring; processes of care | Identified alarm systems that are supposed to help, but actually increase risk because of alarm fatigue | |
| Siebig et al., (2010). Intensive care unit alarms: How many do we need? | Observational study to validate the number of a cardiac alarms among critically ill patients to determine the relevance of alarms | Medical intensive care unit at a University Hospital<br>from Jan 2006 to May 2007<br>Recording of 982 hours of alarm data | 982 hours recorded by video and observed by a physician<br>Video recordings were annotated for alarm relevance and technical validity<br>Physiologic data from monitors was recorded at 1 second intervals that were extracted from the monitoring network software | Within the 982 hours there were a total of 5934 alarms<br>40% of alarms did not describe the patient condition correctly<br>68% of alarms were caused by staff manipulation<br>Only 15% were true alarms<br>Most (70%) of alarms were simple threshold alarms<br>45% were related to arterial blood pressure monitoring from arterial lines | *Strengths:* Comprehensive analysis of each type of alarm and validation by observing physician related to the relevance and clinical 'trueness' of each alarm<br>*Weaknesses:* Possible bias introduced by individual interpretation of clinical relevance of alarms. Other studies had 2-3 clinical observers to arrive at group consensus of alarm relevance | Suggestion that because most alarms are due to simple thresholds customization of alarm limits may significantly reduce the number of false alarms<br>It is suggested that customization for alarm parameters could be targeted around +/- 20% of 'normal' | Level III<br>Grade B |

**National Association of Clinical Nurse Specialists**
**Alarm Safety Crosswalk**
**Table 2: Alarm Fatigue Literature**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Urden, L. D., & Stacy, K. M. (2011). Clinical nurse specialist orientation: ready, set, go! | Qualitative study<br><br>Design the CNS orientation process using the 3 spheres of influence | CNS team at Magnet community hospital | 1. Review of the literature<br>2. Initial competency validation checklist for CNS | Development of evidence based tool for orientation of the new CNS or CNS new to the hospital | *Strengths:* Evidence based tool for orientation of CNS<br><br>*Weaknesses:* External validity is questionable, only done in one setting. | Outlines the spheres of influence of the CNS | Level VI<br><br>Grade C |
| Welch (2011). An evidence-based approach to reduce nuisance alarms and alarm fatigue. | Quality Improvement Study<br>Study to determine if adjustment of alarm thresholds reduces number of alarms for pulse oximetry monitors in post-surgical patients.<br>Retrospective analysis of alarm load pre/post intervention. | Post-surgical patients on 36 bed floor over 11 month time period | Baseline data: most common alarm is SpO2 less than 90% that alarmed 4.4% of the entire monitoring time equating to 63 minutes per patient per day<br>Intervention (reducing alarm threshold to 89, 88, 87, 86 or 85) and delaying the alarms at times ranging from 5-15 seconds | Decreasing alarm thresholds from 90% to 88% decreases alarms by 45%<br>Reducing the low alarm threshold from 90% to 85% decreases alarm rate by 75%<br>Increasing alarm delays from 5 seconds to 15 seconds reduces alarm rate by 70% | *Strengths:* Large sample size, measurements over extended period of time.<br>*Weaknesses:* Only measured alarms of pulse oximetry. No discussion of alarms due to disconnections of cable, loss of connection due to application of sensors to pulse ox alarms. | Altering alarm limits or slightly delaying alarms is a cost effective approach to reducing burden of alarm fatigue<br>Not all institutions ok with lowering alarm limits by large amounts in critically ill or acutely ill patients. | Level III<br>Grade B |
| Whalen et al., (2013). Novel Approach to the Management of Clinical Alarm Fatigue. | Quality Improvement Study<br>Study to determine variables that would safely reduce noncritical telemetry monitor alarms by altering manufactures default alarm settings | General medical-surgical unit at Boston Medical Center<br>24 bed pilot unit<br>2 week time period | Alarm data, nurses response to alarms, unit noise in dB, and patient satisfaction, and nursing perception of noise were measured<br>Baseline data: 87,823 audible alarms per week on the unit. After intervention: 9967 alarms in one week on the pilot unit.<br>Default alarm settings altered and education for RNs to customize alarms<br>Nursing staff perception of noise via anonymous survey | Overall an 89% reduction in audible alarms was achieved on the pilot unit ($t = 8.84$; $P < .001$)<br>The incidence of Code Blue events decreased by 50%<br>Noise levels evaluated in decibels from 54-90 dB pre-implementation<br>Post-implementation noise ranged from 60-72 dB.<br>Patient satisfaction scores based on Press-Ganey. Nurse domain rank increased by 15 percentile ranks, noise in room increased by 12, promptness to call lights increased by 39. Overall rank increased by 31<br>Nursing perception of noise increased from noise is acceptable 0% of the time to post-study of noise acceptable 64% of the time | *Strengths:* complete report of changes to alarms, alarm distribution and statistical significance of alarm burden pre/post study<br>*Weaknesses:* nursing satisfaction post-implementation measured by 'comments' rather than established tool | A significant reduction in alarm burden can be achieved without costly resources or new technology.<br>Incidence of safety events was successfully decreased and patient satisfaction improved | Level III<br>Grade B |

**Articles Not Included in Literature Review that Provide Background Information**

**National Association of Clinical Nurse Specialists**
**Alarm Safety Crosswalk**
**Table 2: Alarm Fatigue Literature**

| Article | Design/Purpose | Rationale for not including in Literature Review |
|---|---|---|
| Association for the Advancement of Medical Instrumentation, (2011). | 2011 Summit; a call to action for addressing healthcare alarms<br>Key stakeholders are identified and seven themes related to alarm management are addressed | Provides background and overview of medical device safety issues related to alarms. Summit publication provides background information regarding the history of alarm fatigue, medical device alarms, and significance of the problem. |
| Bonzheim et al., (2011). Communication Strategies and Timeliness of Response to Life Critical Telemetry Alarms | Descriptive analysis of technological communication strategies to alert providers of critical alerts | Focus is primary on technology/smart alarm integration of monitoring equipment with pagers and alerts to communicate alarms with bedside staff. Focus is on smart monitoring |
| Bush-Vishniac et al., (2005). Noise levels in Johns Hopkins Hospital | Descriptive analysis of noise levels in John Hopkins Hospital; particular at night | Provides background evidence related to the problem of noise in hospitals and the noise that is attributed to alarms and physiologic monitors |
| Emergency Care Research Institute (2011). | An organizational publication that regularly reviews healthcare technology | Background information on tracking and evaluating medical device safety and safety issues related to alarm fatigue |
| Hannibal (2011). ECG Challenges: Monitor Alarms and Alarm Fatigue | Descriptive analysis/Expert Opinion related to the history of alarm fatigue | Provides background information and definition of alarm fatigue |
| Keller (2012). Making clinical alarm management a patient safety priority. | An introduction into the top ten health safety concerns | Background information related to safety of medical devices |
| Kerr & Hayes (1983). An "alarming situation in the intensive therapy unit. | Descriptive analysis of alarm fatigue | Older article; provides background and history of alarm sensitivity and alarm fatigue |
| Kowalczyk (2011). 'Alarm fatigue' linked to patient's death. | Newspaper article describing a highly publicized patient death attributed to alarm fatigue | Background information related to alarm fatigue and patient safety |
| Mazer (2012). Creating a Culture of Safety<br>Reducing Hospital Noise | Expert opinion | Background information. Description of noise in hospitals; what devices contribute to noise burden |
| Poghosyan, Clarke, Finlayson, & Aiken, (2010). Nurse Burnout and Ratings of Quality of Care: A Six-Country Study | Descriptive analysis examining the effects of nursing burnout on patient outcomes | Background information related to the patient safety risks associated with nursing burnout |
| Pugh, Jones, & Griffith, (2007). The impact of noise in the intensive care unit. | Literature review describing sources of noise in ICU environment | Background information; alarms contributing to noise |
| Wallis (2012). Alarm fatigue linked to patient death. | Descriptive analysis/ Expert opinion of risks associated with hospital noise | Background information related to alarms contributing to noise in hospitals |
| Yoder et al., (2012). Noise and Sleep Among Adult Medical Inpatients: Far From a Quiet Night | Observational study quantifying the noise levels in hospitals | Background information related to alarms and noise |

**Level of Evidence** (Melnyk & Fineout-Overholt, 2011)

| | |
|---|---|
| Level I | Systematic review & meta-analysis of randomized controlled trials; clinical guidelines based on systematic reviews or meta-analyses |
| Level II | One or more randomized controlled trials |
| Level III | Controlled trial (no randomization) |
| Level IV | Case-control or cohort study |
| Level V | Systematic review of descriptive & qualitative studies |
| Level VI | Single descriptive or qualitative study |
| Level VII | Expert opinion |

**Grade Rating: Strength of Evidence** (Melnyk & Fineout-Overholt, 2005)

| | |
|---|---|
| Grade A<br>High | Reflects a high degree of clinical certainty and is based on availability of high quality level I, II, or III evidence. |
| Grade B<br>Moderate | Reflects moderate clinical certainty and is based on availability of level III and/or level IV evidence. There are some minor flaws or inconsistencies |
| Grade C<br>Weak | Level V, VI, or V evidence. There is limited or low quality evidence; has limited or unknown effectiveness |