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PGY2

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Project Title: Analyzing alarms based on continuous physiologic data monitoring in the PICU

Study Purpose and Rationale

The volume of clinical alarms can be significant in any hospital environment, particularly in intensive care units in which continuous vital sign monitors are ubiquitous. The burden of monitor alarms has been shown to vary widely between children's hospitals and between units within each hospital, with neonatal intensive care units (NICUs) and pediatric intensive care units (PICUs) producing the most alarms per patient per day[1]. Monitors are typically set with manufacturer-determined vital sign ranges that prioritize sensitivity at the cost of specificity, leading to high alarm volumes. It is well documented that health care providers can be exposed to incredibly high numbers of alarms per day, up to 1000[3], and the vast majority, up to 90-99%, do not require action[2,3,7,8]. This can lead to providers becoming desensitized and silencing alarms without evaluating the patient, a condition known as alarm fatigue[7]. Inappropriate silencing of alarms or adjustment of alarm settings can have serious, often fatal, consequences for patients[7]. One study showed that PICU nurses' response times to alarms increased as the number of nonactionable alarms (motion artifact, etc.) in the preceding few hours increased[2]. Between 2005 and 2008, the FDA reported 566 patient deaths attributed primarily to monitor alarm issues.[8] In fact, inadequate alarm practices have been listed among the top 10 technology safety hazards facing the healthcare world by the Emergency Care Research Institute (ECRI) every year since 2007, and even topped the list in 2015.[11]

In addition to inducing sensory overload in providers, the noise of so many alarms can be detrimental to patients, providers, and families alike. The sound environment in NICU has been shown to exceed the maximum acceptable level of 45 dB, recommended by the AAP[5]. PICUs are even louder, with basal noise levels often exceeding 60 dB[6]. Excess noise disrupts sleep, increases anxiety, and can affect communication between providers and families. 2-10% of preterm infants will ultimately be diagnosed with hearing impairments, compared to 0.1% of the general population[5]. Excess noise in the NICU can contribute to apneas and increased heart and respiratory rates, leading to increased energy expenditure and fewer calories available for growth [5]. One study showed that preterm infants who were given silicone earplugs had significantly increased Mental Development Index scores at 18-22 months of corrected age compared to infants who did not have earplugs, although the study was limited by small sample size[5]. Furthermore, high alarm burdens have been linked with increased burnout among ICU nurses[4].

Some work has been done to attempt to reduce unnecessary alarms. Tweaking and customizing settings on alarms machines to reduce the range of conditions that prompt alarms have been shown to have positive effect in several initiatives in adult intensive care units[9,10]. In one such project, nurses underwent a standardized training to customize alarms for each patient, resulting in a 43% reduction in alarms from baseline data[10]. Another initiative at Johns Hopkins in which alarm parameters were individualized by unit resulted in a 24-74% reduction in alarms per bed per day in six intensive care units[9]. Customizing vital sign monitor settings shows great promise in helping to reduce the burden of nonessential alarms in pediatric critical care environments to combat alarm fatigue, reduce noise pollution, and improve patient care.

Current Practice at CHONY

Currently, ICU providers are inundated with alarms all day, the vast majority of which do not require action. Manufacturer-determined values for minimum and maximum vital signs for neonatal, pediatric, and adult patients are used initially, but these parameters are frequently altered on an individual basis at the nurses' discretion.

Our Approach

The burden of alarm fatigue in PICUs of a few children's hospitals has been characterized before, but no one has experimented with altering alarm parameters and examining how those changes would affect the number of alarms that providers hear on an average day or during the critical time before a cardiac or respiratory arrest.

Our goals are to:

1. Develop a comprehensive understanding of the equipment and situation.
    a. Identify the automatic manufacturer-determined parameters for value-based vital signs alarms (blood pressure, heart rate, oxygen saturation, end tidal CO2) in the PICU for each age group of patients (each age group (0-12 months, 1-5 years, 6-15 years, > 15 years).
    b. Identify which parameters can be changed on current monitors in the PICU, and how often they are changed.
    c. Quantify the average number and types of value-based vital sign alarms that sound per patient in 3 CHONY PICUs in the last four years.
2. Align patients who experienced cardiac or respiratory arrest in a CHONY PICU by their event in order to identify intermediate outcomes that warn of impending collapse.
    a. Describe the distribution of times from admission to arrest.
    b. Look back at the vital sign changes that occurred in the 1-2 hours preceding each arrest.
        i. For each age group, characterize the distributions of vital signs for patients in and out of the peri-arrest period. Identify values and trends.
        ii. For each age group, determine if there were statistically significant changes in the number and types of alarms that sounded in the peri-arrest period.
            1. Look at individual alarms and combinations of alarms.
            2. Look at alarm values and trends (i.e. extreme or sustained changes.)
            3. Look at individual patients' baselines, etc.
3. Alter alarm parameters and simulate the effect on the number of alarms that would have sounded.
    a. For each age group, change one vital sign parameter (ex. minimum systolic blood pressure) at a time and estimate the number of alarms that would have sounded in and out of the peri-arrest period.

Study Subjects

All patients who experienced a cardiac or respiratory arrest in three CHONY PICUs (9 Central, 9 Tower, and 11 Central) from June 2017 to present.

Potential Benefits

If we can identify parameters for each age group that decrease the number of unnecessary alarms while retaining pertinent alarms, we could implement those in the PICU and reduce alarm fatigue while increasing responsiveness to actionable alarms, potentially reducing response time to critical alarms and improving patient outcomes.

Potential Risks

If we change vital sign parameters incorrectly, we could prevent important alarms from sounding, leading to overlooked clinical changes and possibly danger to patients.

Potential Conflict of Interest

No potential conflicts of interest.

Human Subject Research IRB

The use of continuous ICU data for this study was approved by the IRB in 2019 (protocol number: AAAS2101, approved 2/7/19). Elizabeth Hyde was added to the IRB as an Investigator on 7/6/21.

Cost of the Study

The research portion does not require any funding, as it will be carried out on my computer using R. The implementation portion will also not require any cost, as the optimal result of this project is a new set of normal vital sign parameters for each age group that would simply require altering the settings on existing continuous value-based monitors in the ICU.

References

1. Schondelmeyer AC, Brady PW, Goel VV, et al. Physiologic Monitor Alarm Rates at 5 Children's Hospitals. J Hosp Med. 2018;13(6):396-398. doi:10.12788/jhm.2918
2. Bonafide, C.P., Lin, R., Zander, M., Graham, C.S., Paine, C.W., Rock, W., Rich, A., Roberts, K.E., Fortino, M., Nadkarni, V.M., Localio, A.R. and Keren, R. (2015), Association between exposure to nonactionable physiologic monitor alarms and response time in a children's hospital. J. Hosp. Med., 10: 345-351. https://doi.org/10.1002/jhm.2331
3. Ruskin, Keith J.[a]; Hueske-Kraus, Dirk[b] Alarm fatigue, Current Opinion in Anaesthesiology: December 2015 - Volume 28 - Issue 6 - p 685-690 doi: 10.1097/ACO.0000000000000260
4. Topf M, Dillon E. Noise-induced stress as a predictor of burnout in critical care nurses. Heart Lung. 1988 Sep;17(5):567-74. PMID: 3417467.
5. Almadhoob A, Ohlsson A. Sound reduction management in the neonatal intensive care unit for preterm or very low birth weight infants. Cochrane Database Syst Rev. 2015 Jan 30;1:CD010333. doi: 10.1002/14651858.CD010333.pub2. Update in: Cochrane Database Syst Rev. 2020 Jan 27;1:CD010333. PMID: 25633155.
6. de Oliveira et al. “View of Noise Levels in a Pediatric Intensive Care Unit: An Observational and Correlational Study.” View of Noise Levels in a Pediatric Intensive Care Unit: an Observational and Correlational Study | Online Brazilian Journal of Nursing, Online Brazilian Journal of Nursing, www.objnursing.uff.br/index.php/nursing/article/view/4043/html.
7. Joint Commission. Medical device alarm safety in hospitals. Sentinel Event Alert. 2013 Apr 8;(50):1-3. PMID: 23767076.
8. Citing reports of alarm-related deaths, the Joint Commission issues a sentinel event alert for hospitals to improve medical device alarm safety. ED Manag. 2013 Jun;26(6):suppl 1-3. PMID: 23776996.
9. Using Data to Drive Alarm System Improvement Efforts: The Johns Hopkins Hospital Experience . Healthcare Technology Safety Institute (HTSI) , 2012, www.premiersafetyinstitute.org/wp-content/uploads/Johns-Hopkins-White-Paper.pdf.
10. Graham, Kelly & Cvach, Maria. (2010). Monitor Alarm Fatigue: Standardizing Use of Physiological Monitors and Decreasing Nuisance Alarms. American journal of critical care : an official publication, American Association of Critical-Care Nurses. 19. 28-34; quiz 35. 10.4037/ajcc2010651.
11. Emergency Care Research Institute (ECRI). (2015). Top 10 health technology hazards for 2015. Retreived from: https://www.ecri.org/Resources/Whitepapers_and_reports/Top_Ten_Technology_Hazards_2015.pdf