

Benjamin Mock, MSN, BSIE, RN; Yvonne Buchheit, BHS, RRT, NPS, ACCS; Melissa Dowler, MSN, RN-BC; Micah Dunlap, BS; Bob Edwards, BS; Jaqueline Ryan, MS, BSN, RN, CCRN-CMC-CSC, ATC; Jessica Hoehne, MSN, RN, CMSRN; Dawnel Strathmann-Vargas, CBET; Alana Creel, BSN, RN, CCRN; Tom Creamer, BSN, RN, CCRN

Introduction

- 72% to 99% of all clinical alarms are false or nonactionable (Sandelbach & Funk, 2013).
- Excessive volumes of alarms mask discernability and actionability of critical alarms (Lacherez, Seah, & Sanderson, 2007).
- Secondary alarm notification (SAN) devices, such as phones and pagers, are known to reduce total alarm burden (Jacques, 2017).
- Alarm fatigue leads to the desensitization of critical alarms and lengthens time to nursing and multidisciplinary interventions (O'Connor & O'Dea, 2021).

Research Question

For nurses working in intensive care units (ICUs), does standardizing middleware algorithms and SAN device notification pathways reduce notification volume and perceptions of alarm fatigue in 5 months?

Synthesis of the Evidence

LOE I	LOE II	LOE III	LOE IV	LOE V	LOE VI	LOE VII
	1	1	4	3	7	

Sixteen articles were included in the synthesis of evidence. All articles examined alarm reduction or alarm management practices in ICUs, progressive care or step-down units, or implicated nursing's perceptions of alarms in acute care in their study design.

- Databases Searched:** CINAHL, PubMed, Google Scholar.
- Keywords:** Intensive Care Units, Physiologic Monitoring, Clinical Alarms, Nursing, Critical Care Nursing, Alarm Fatigue, Alarm Management, Secondary Alarm Notification.
- Themes:** Excessive alarm volume, alarm sound and audibility, secondary alarm notification algorithms, technological capabilities to reduce non-actionable alarms.

Methods

Team

- A multidisciplinary team was formed with representatives from nursing leadership, nursing staff, quality improvement, patient safety, information technology, and clinical engineering.

Framework

- A guideline for improvement outlined by the ECRI Institute to reduce alarm fatigue was utilized in conjunction with the Institute for Healthcare Improvement's Model for Improvement (ECRI, 2014; Langley et al., 2009).

Initial Data

- Historical data of alarms and notifications were analyzed to identify the highest concentration of volumes.

Context

- Staff nurses were interviewed on their experiences with high volume alarms and notifications and themes were identified to guide intervention development.

Evidence to Intervention

- SAN logic was adjusted to increase discernability amongst urgency level.
- Low urgency SANs were given longer periods of wait before escalating.
- Focused education of SAN devices was provided to reduce escalations.

Evaluation

- Pre-Post Alarm and Notification volume were analyzed
- GEMBA walks were performed to understand staff nurse perspectives.

Sustainment

- Developed policy to highlight changes and standardization.
- Oversight on alarm and notification presented to informatics stakeholders.
- Allowing greater time to answer a notification in low urgency reduces non-actional escalated notifications.

Setting

- Academic medical center in mid-Missouri with over 500 beds
- Level 1 Trauma Center
- A Cardiac ICU, Surgical ICU, 2 Medical ICUs, and a Neuroscience ICU comprise the adult acute care ICUs in this quality improvement initiative.
- Project timeline of 10 months from initial consultation to sustainment was projected.

Interventions

- Standardization of notification pathway and display logic by urgency level
- Differentiation of notification by color and urgency level
- Robust education of the use and functionality of the SAN devices in use
- Development of monitoring reports on alarm and SAN volume by unit
- Formalized policy on SAN logic with recurring evaluation

An escalation timing of 60 seconds, instead of 30 seconds, for low urgency alarm notifications reduced total SAN volume by 10.7 notifications per ICU patient bed day without affecting nursing quality or patient safety.

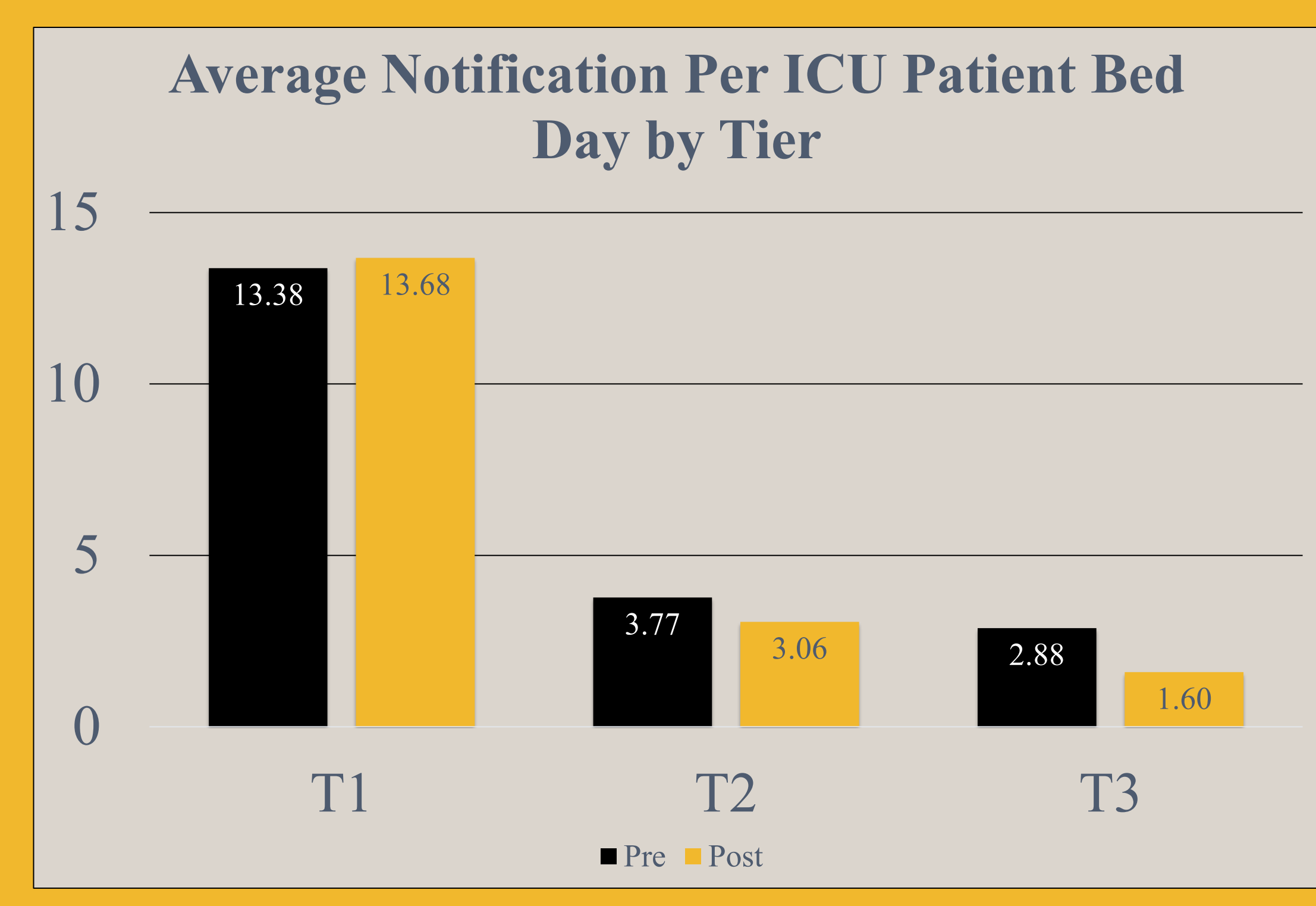
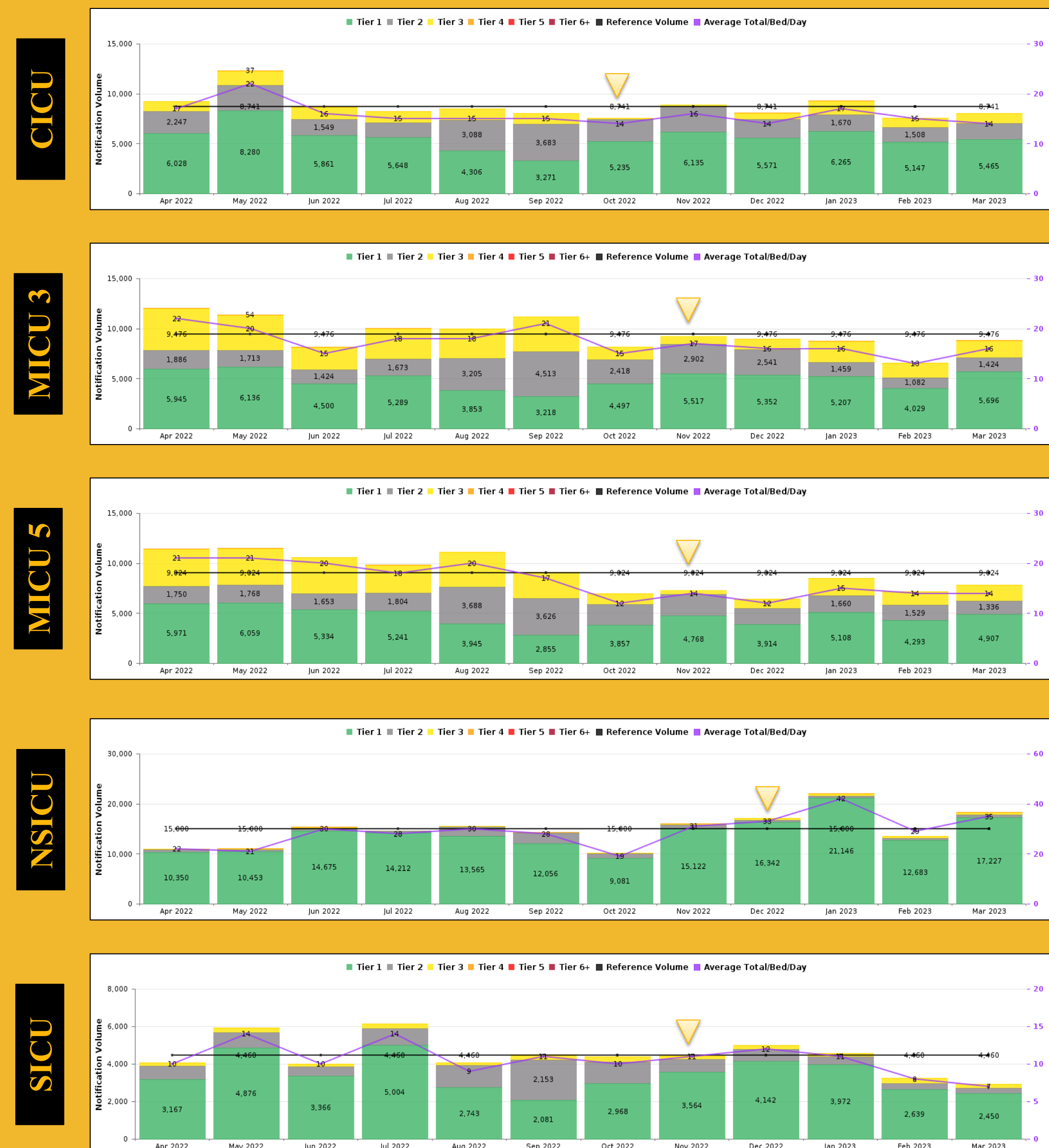
Alarm management bundles should consider the effect of SAN volume and display logic in their strategies to reduce alarm fatigue in the ICU setting.

Secondary Alarm Notification Display Logic – Pre-Intervention

Alarm Urgency	Alarm	Color	Beeps	Repetitions	Seconds
Normal	Patient	Green	5	2	5
Normal	Toilet	Green	5	2	5
Normal	Water	Green	5	2	5
Normal	Pain	Green	5	2	5
Normal	Bed Exit	Green	5	2	5
Normal	Bath Assist	Green	5	2	5
High	Bath Emergency	Green	5	2	5
High	Respiratory	Green	5	2	5
Normal	Cord Out	Green	5	2	5
High	Epileptic	Red	5	3	8
Max	High Heart Rate	Red	10	2	15
Max	Low Heart Rate	Red	10	2	15
Max	Aystole	Red	5	3	6
Max	Vtach	Red	5	3	6
Max	Vfib	Red	5	3	6
Medium	Staff Assist	Green	10	2	7
Max	Code Blue	Blue	Siren	40	5

Secondary Alarm Notification Display Logic – Post-Intervention

Alarm Urgency	Alarm	Color	Beeps	Repetitions	Seconds
Normal	Patient	Green	2	0	-
Normal	Toilet	Green	2	0	-
Normal	Water	Green	2	0	-
Normal	Pain	Green	2	0	-
Medium	Bed Exit	Yellow	3	1	5
Medium	Bath Assist	Yellow	3	1	5
Medium	Bath Emergency	Yellow	3	1	5
Medium	Respiratory	Yellow	3	1	5
Medium	Cord Out	Yellow	3	1	5
High	Epileptic	UNCHANGED			
High	High Heart Rate	Orange	4	2	4
High	Low Heart Rate	Orange	4	2	4
High	Aystole	Red	5	3	3
High	Vtach	Red	5	3	3
High	Vfib	Red	5	3	3
High	Staff Assist	UNCHANGED			
Max	Code Blue	UNCHANGED			



Heat Map of SAN Volumes

Event Category	Event Type	Alarm Type Per Bed Day				
		PCU	SICU	MICU	NSICU	CCU
NURSE_CALL	AUX_ALARM	0.039258	0.042929	0.04300091	0.019608	0.049407
	BED_EXIT	0.860414	0.532828	0.48032937	1.311275	0.798419
	BED_EXIT_NURSE	0.001091	0	0	0	0.005929
	CODE_BLUE	0.033806	0.035354	0.03659652	0.041667	0.059289
	EPILEPTIC	0	0	0	0.14951	0
	GO_TO_TOILET	0.369684	0.34596	0.3494968	0.281963	0.298419
	GO_TO_TOILET_NURSE	0.010905	0	0	0.007383	0.013834
	GO_TO_TOILET_OT	0.027263	0.005051	0.00365965	0.022059	0.009881
	GO_TO_TOILET_TECH	0	0	0.002525	0	0
	NORMAL_CALL	6.708833	4.770202	3.78133577	3.977941	4.719368
	NORMAL_CALL_NURSE	0.098146	0.007576	0.00457457	0.328431	0.464427
	NORMAL_CALL_OT	0.899673	0.113636	0.06770357	0.453431	0.241107
	NORMAL_CALL_TECH	0.005453	0.012626	0.00182983	0	0.005929
	PAIN_MEDICATION	0.526718	0.507576	0.30649588	0.397059	0.36166
	PAIN_MEDICATION_NURSE	0.014177	0	0	0.009804	0.017787
	PAIN_MEDICATION_TECH	0.003093	0	0	0	0
	PS_DISCONNECT	0.252999	0.214646	0.16010979	0.203431	0.162055
	PS_DISCONNECT_NURSE	0.002181	0	0	0	0
	PS_DISCONNECT_TECH	0.001091	0	0	0	0
	RESPIRATORY	0.335878	0.116162	0.03385178	4.919118	0.043478
	RESPIRATORY_NURSE	0.003272	0	0	0	0
	RESPIRATORY_TECH	0.001091	0	0	0	0
	SHOWER_EMERGENCY	0.047983	0	0.01555352	0.051471	0.017787
	SHOWER_EMERGENCY_OT	0.003272	0	0	0.046569	0
	STAFF_ASSIST	0.035987	0.075758	0.084172	0.114951	0.081028
	TOILET_EMERGENCY	0.218103	0.113636	0.03842655	0.007383	0.104743
	TOILET_EMERGENCY_OT	0.030534	0	0	0.27451	0.001976
	WATER	0.274809	0.25	0.24885636	0.007383	0.177866
	WATER_NURSE	0.004362	0.002525	0	0	0.017787

ECRI Staff Nurse Survey

- Major Themes:**
- Alarm and SAN volume are overwhelming
 - Hard to see alarm monitors while performing care duties
 - SAN devices do not communicate pertinent information
 - Training on SAN devices is not standardized
- Minor Themes:**
- Some SANs broadcast to more clinicians than necessary
 - Clinicians are unaware of alarm response protocol
 - It is difficult to use the SAN device as a communication device when alarming

Post-Implementation GEMBA

- Unit Clerk:** "There are less call lights that come to the clerk phone now. It doesn't seem there are as many alerts anymore."
- Staff Nurse 1:** "There feels like there is less stimulus now."
- Staff Nurse 2:** "I like that the VFIB and VTACH alarms don't go to everyone anymore. It seems quieter on the unit now."
- Nursing Supervisor:** "The unit feels quieter, and staff have noticed a difference."

Discussion

Increasing the time from SAN initiation to escalation from 30 seconds to 60 seconds for low urgency alarms saw a 20.5% (P < 0.001) reduction in escalated form Tier 1 to Tier 2. Further escalations were reduced from Tier 2 to Tier 3 by 45.8% (P < 0.001) and from Tier 3 to Tier 4 by 28.2% (P < 0.001). Compared with the pre-intervention SAN volumes there was a 39% reduction in total SAN following implementation resulting in the removal of 112,290 SANs, or about 10.7 notification per bed day. Staff expressed a noticeable difference in quietness and reduced interruptions caused by SAN devices. Leadership involvement in GEMBA walks with staff pre and post implementation ensured that changes were clinician focused and led to successful change of alarm notifications within the ICU setting. Nursing quality measures and patient safety events were tracked and showed no negative impact related to SAN changes.

Limitations

- Lack of equipment to measure sound decibel effect
- Hospital HCAHP survey vendor was changed during the project and data was not able to be analyzed for impact.
- Leadership resistance towards delay type alarms for high false-positive alarm notifications limited impact.

References

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