Internship Report

Clinical Alarm Management Project
Neonatal Intensive Care Unit (NICU)
IWK Health Centre
Halifax NS

Master of Health Informatics

HINF 7000

Dalhousie University

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EXECUTIVE SUMMARY

Research confirms that more than 70% of clinical alarms are unnecessary. Exposing clinicians to high volume of undesirable alarms may cause alarm fatigue associated with increasing patient risks and deaths. Alarm fatigue is mainly driven by the excess number of non-actionable alarms which are the alarms associated with self-correcting conditions that do not need clinical intervention. Alarm fatigue is considered as a common and significant healthcare problem that needs special attention. The Emergency Care and Research Institute (ECRI) recommends some strategies to eliminate the alarm fatigue and emphasizes on the importance of involving clinical staff, especially nurses, while working on those strategies. The main objective is to eradicate the alarm fatigue to pave the way for a safer and improved healthcare environment.

The current open-bay NICU at IWK Health Centre was opened in 1992 and was considered as a state of the art at the time. Concerns with this setting include: lack of privacy and confidentiality, no individual control over the environment in terms of noise, light, temperature, and most unfavorable, a lack of space for families to stay with their vulnerable, critically ill infants. Recently, IWK Health Centre has decided to build a new NICU single-family room unit which is expected to solve all issues of the current open-bay model. Families will have a private room with double sleep sofa, three-piece washroom, and privacy doors which is anticipated to increase their comfort and willingness to stay for prolonged times with their baby. Based on many researches, the new model of care will provide numerous benefits for infants, families and staff.

The principle purpose of the internship project was to work with clinical teams and IT teams under the umbrella and guidance of the Biomedical Engineering Department within IWK Health Centre to establish an effective clinical alarm management strategy for NICU and reduce their alarm fatigue. Then, to propose a workflow best practice for assigning care teams to the patient monitors and End User Devices (EUDs) for effective utilization in the new NICU single-family room care setting. The scope of work has been defined to the primary alarm signals produced by patient monitors (Philips) with its various locations inside NICU (please view figure 3), in addition to the primary alarm signals produced by two types of ventilators (Servo-I and VN-500). Patient monitors were desired to be fully integrated with the middleware (Connexall) to produce and escalate secondary alarm signals to the care team EUDs (iPhones). A clinical alarm steering committee was created to provide strategic directions and secure the necessary approvals. Similarly, a NICU task force was created to accomplish major tasks in a timely manner aiming at meeting the project deadline through working in a team collaborative environment. The internship road map and milestones were discussed and agreed with all key stakeholders early in the project.

The internship project ended up by proposing a reasonable new clinical alarm strategy for physiological monitoring and ventilators which represent the majority and most crucial monitoring inside the NICU. The project final deliverables (please view appendix B through H) were submitted to both IT teams and Biomedical Engineering Department at the end of the project for their future work. Based on alarm data for three-real NICU case studies that have been collected during the course of the internship, non-actionable alarms represent an average of more than 60% of the total daily alarms inside NICU. Considerable delta gains of -15%, -30% and -46% are anticipated to be achieved if the non-actionable alarms inside NICU are reduced by 25%, 50% or 75% respectively for the same or similar cases.

The internship project was a great learning experience and was a remarkable tool to implement what have been learnt as a clinician and as a prospective health informatician in a real-life experience. It was a concrete opportunity to implement health informatics concepts in a high-quality project that included a complicated and significant healthcare problem like alarm fatigue. Also, it was a wonderful opportunity to practice working collaboratively with other healthcare professionals in a patient centric approach to accomplish project deliverables with a challenging due time. As planned, the internship project has been completed in sixteen weeks under the supervision and mentorship of Manager, Biomedical Engineering at IWK Health Centre. The internship project was full of challenges but at the same time was interesting, meaningful, worthy and rewarding.

1. INTRODUCTION

Research confirms that more than 70% of clinical alarms are unnecessary. Exposing clinicians to high volume of undesirable alarms may cause alarm fatigue associated with increasing patient risks and deaths. Alarm fatigue is mainly driven by the excess number of non-actionable alarms which are the alarms associated with self-correcting conditions that do not need clinical intervention. Alarm fatigue is considered as a common and significant healthcare problem that needs special attention. As a consequence of alarm fatigue, alarm desensitization may be developed and can lead to missing a clinically important or a life threatening critical alarm [1]. The Emergency Care and Research Institute (ECRI) recommends some strategies to eliminate the alarm fatigue. ECRI recommends individual hospitals to review the way alarms are managed and to evaluate their overall alarm load levels and the number of parameters that they are monitoring. It is also suggested to study the nursing staff satisfaction and engagement levels to the alarm management strategies. Furthermore, hospitals might consider revision of the physical design of their units as well as the departmental protocols and policies for alarm management. The Emergency Care and Research Institute (ECRI) recommends some strategies to eliminate the alarm fatigue and emphasizes on the importance of involving clinical staff, especially nurses, while working on those strategies. The main objective is to eradicate the alarm fatigue to pave the way for a safer and improved healthcare environment [1].

2. IWK HEALTH CENTRE

IWK Health Centre—publicly known as the children's hospital in Nova Scotia—offers both primary and tertiary healthcare services for women and children across the Maritime region and beyond. Annually, more than 4,000 babies are delivered at this center which is operated by more than 3,600 employees and more than 900 volunteers. IWK Health Centre, as a research based institution, is involved in a wide range of cutting-edge researches that provide education opportunities to emerging professionals in healthcare sector and beyond [2]. Academically, IWK Health Centre has an alliance with Dalhousie University which assists in the development of many health professions. Furthermore, IWK Health Centre organizes travelling clinics in the fields of pediatric neurology, orthopedics, cardiology and respiratory where other Maritime societies can benefit from IWK expertise [2].

2.1 Open-Bay NICU

The current open-bay NICU was opened in 1992 and was considered state of the art at the time. Patients and families are cared for in 30-40 square foot sites with multiple sites grouped together in large rooms where babies' incubators are separated by curtains [2]. The NICU delivers care for babies throughout Atlantic Canada and Bermuda for premature newborns or those with specific health needs through medical care and family education where NICU encounters are arranged by IWK neonatologists [2]. As time progressed, the demand for families to stay with their babies increased and the IWK Health Centre has only eight sleeping rooms to offer in a unit with 58 patient sites. Concerns with the current unit include: lack of privacy and confidentiality, no individual control over the environment in terms of noise, light, temperature, and most unfavorable, a lack of space for families to stay with their vulnerable, critically ill infants.

2.2 New Single-Family Room (NICU)

According to a study published in the National Center for Biotechnology Information, single-family rooms has a positive impact on the neurobehavioral and medical consequences in babies. The study shows that those babies need fewer medical interventions, experience less pain and physiological stress, develop less infection, and gain weight better. The single rooms are quieter and offer parents a chance to spend more time with their babies especially overnight [3]. A single-family room unit is under construction at the IWK Health Centre, which will allow parents to stay with their babies [3]. Figures 1, 2 and 3 show three-dimensional views of the different sections of the new single-family room.

Figure 1. | New NICU Single-Family Room Care | Overview Station | 3D View |

Figure 2. | New NICU Single-Family Room Care | Central Station | 3D View |

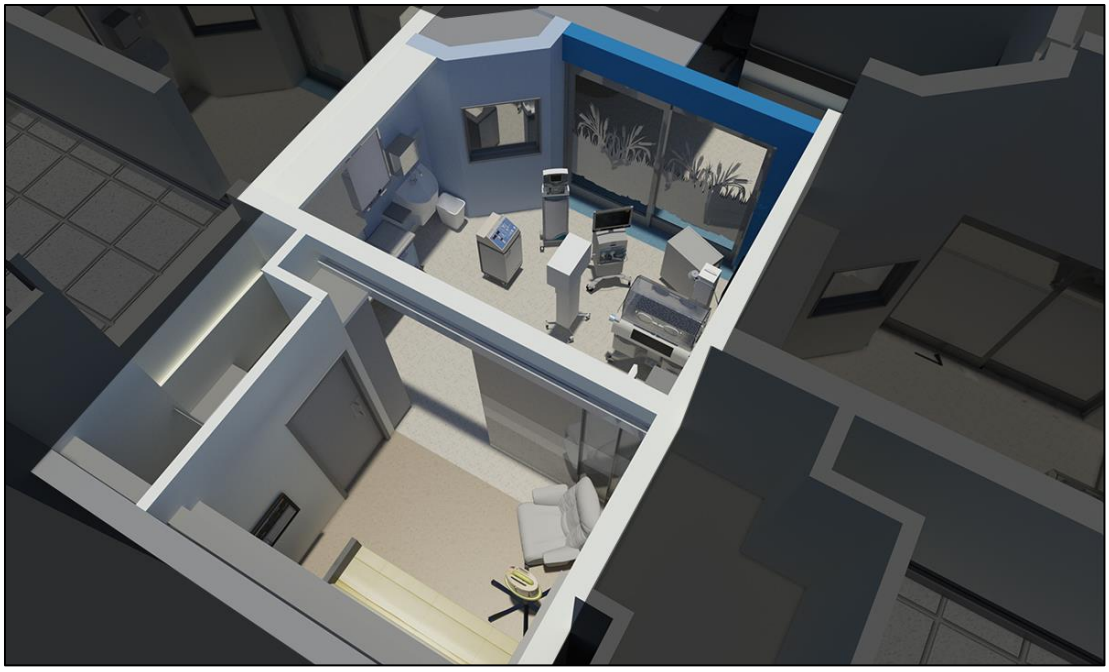

Figure 3. | New NICU Single-Family Room Care | Baby Room | Family Room | Top 3D View |

The new NICU single-family room (SFR) care setting will offer babies and families a private room with an average space of 275 square feet which will improve all the concerns with the current open-bay model. Families will have a double sleep sofa, three-piece washroom, and privacy doors which is anticipated to increase their comfort and willingness to stay for prolonged times with their baby. Based on many researches, table 1 summarizes the expected benefits of new model of care on infants, families and staff.

Infant
Improved long-term language, motor, cognitive outcomes [5, 6]
↓ Length of stay [7, 8]
↓ Rehospitalisation [8]
↓ Pulmonary disease [7]
↓ Medical procedures [5]
↓ Infection [5]
↓ Pain [5]
Better environment (noise, light) [8, 9]
↑ Sleep [9]
↑ Nutrition (↑ human milk, quicker to full feeds) [5, 6, 8, 9]
↑ Weight gain [5]
Family
↑ Privacy [8]
↑ Comfort [8]
↑ Satisfaction [9]
↓ Stress & anxiety [10]
Staff
↑ Perceptions of quality care [9]

Table 1. Benefits of NICU Single-Family Room Care Setting

3. INTERNSHIP ROLE AND WORK PERFORMED

3.1 Role

The internship position was created as the result of a meeting with the Manager, Biomedical Engineering at IWK Health Centre on February 2017. The subject of the meeting was the transformational projects implemented recently at IWK Health Centre and the role of Biomedical Engineering as a facilitator for NICU and PICU (Pediatric Intensive Care Unit) redevelopment projects. It was recognized that the proper clinical alarm management strategy needs to be established for the new single-family room care setting for both NICU and PICU with a strategic objective of reducing the alarm fatigue caused by patient monitors. Also, the best practice for assigning care teams to the patient monitors and EUDs needs to be established parallelly. The result of the meeting was the creation of an internship position for a Health Informatics student with a background in both clinical systems and information technology as a "Biomed Co-op Student". Later, upon starting up the internship position, it was acknowledged as a priority within IWK Health Centre to focus the scope of the project on NICU redevelopment project only because of the time constrain and deadlines for both projects. It was agreed to engage PICU clinical leader as an active member of the NICU project during the internship where they can audit all meetings to be prepared for future execution of PICU project on its due time.

3.2 Scope

As per Figure 3, the principle purpose of the internship project was to work with clinical teams and IT teams under the umbrella and guidance of the Biomedical Engineering Department within IWK Health Centre to establish an effective clinical alarm management strategy for NICU. Then, to propose a workflow best practice for assigning care teams to the patient monitors and End User Devices (EUDs) for effective utilization in the new NICU single-family room care setting. The scope of work has been identified to the primary alarm signals produced by patient monitors (Philips) with its various locations inside NICU; bedside, overview station, and central station, in addition to primary alarm signals produced by two types of ventilators (Servo-I and VN-500). Patient monitors need to be fully integrated with the middleware (Connexall) to produce and escalate secondary alarm signals to the care team EUDs (iPhones).

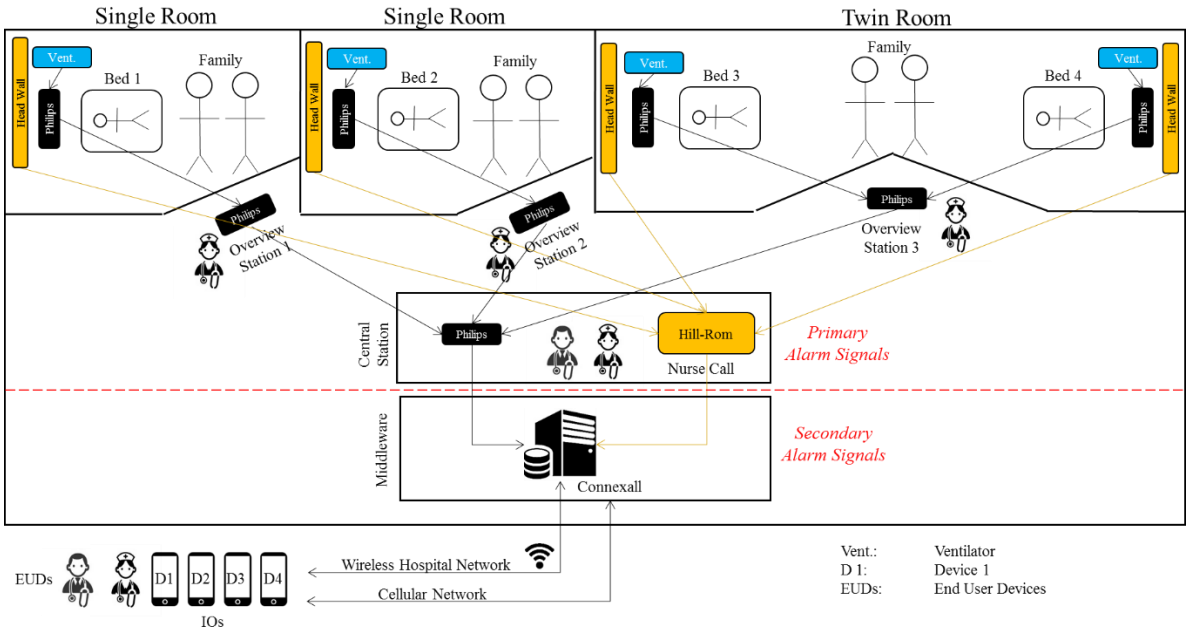

Figure 3. NICU Single-Family Room Care Diagram

3.3 Major Tasks and Subtasks

As per Table 2, the project was divided into six phases with a deadline for each assigned major task and subtask.

		Code	Major Tasks/Subtasks	Deadline	Status as of Aug 04
Phase I	Project Kick-off	NICU 1.1	Project kick-off: Start up meeting Identify project tasks	25-Apr	Done
		NICU 1.2	Project kick-off: Identify project subtasks Agree on project proposed timelines	28-Apr	Done
		NICU 1.3	Project kick-off: Project discussion with the neonatologist and clinical teams Project timelines confirmation	1-May	Done
Phase II	Current Alarm Workflow	NICU 1.4	Current workflow - Open care setting: General discussion points Workflow discussion	3-May	Done
		NICU 1.5	Current workflow modeling - Open care setting: BPMN diagram review with clinical teams	10-May	Done
		NICU 1.6	Current workflow analysis - Open Care setting: Identify workflow bottlenecks Identify reasons for alarm fatigue/load	23-May	Done
Phase III	Alarm Classification	NICU 1.7	Parameters: What are the parameters that need to be monitored? What are the parameters that not needed to be monitored? What else need to be monitored?	24-May	Done
		NICU 1.8	Clinical Alarms Database: Building current alarm configuration database Discuss proposed strategies to reduce alarm load/fatigue Discuss usefullness of patient trend analysis and Horizon/Histogram views	6-Jun	Done
		NICU 1.9	Proposed Clinical Alarms Strategy: Benchmarking & literature review discussion Discuss usefullness of applying smart alarm delays	8-Jun	Done
		NICU 1.10	Proposed Clinical Alarms Strategy: Agree on new classification of patient populations Proposed new alarm list per patient population Proposed new alarm limits per patient population Proposed new alarm delays per patient population Discuss nurse staff survey questionnaire	15-Jun	Done
		NICU 1.11	Proposed Clinical Alarms Strategy: Finalize new classification of patient populations Finalize new alarm list per patient population Finalize new alarm limits per patient population Finalize new alarm delays per patient population	26-Jun	Done
Phase IV	Survey	NICU 1.12	Nurse Staff Survey: Conduct nurse staff clinical alarm survey (Anonymous)	4-Jul	Done
Phase V	New Alarm Strategy	NICU 1.13	New Clinical Alarm Management Strategy - Single Room Care Setting: Case studies discussion - "Current Monitor" vs. "Test Monitor" Final revision of ventilator alarms with respiratory therapist Care teams assignments for single rooms care setting	7-Jul	Done
		NICU 1.14	Connexall Webinar: IWK fully dedicated Webinar General discussion and sum up	13-Jul	Done
		NICU 1.15	New Clinical Alarm Management Strategy - Single Room Care Setting: Primary vs Secondary alarms Transferrable vs Non-Transferable alarms	18-Jul	Done
		NICU 1.16	New Clinical Alarm Management Strategy - Single Room Care Setting: Escalatory vs Non-Escalatory alarms Risk mitigation	20-Jul	Done
Phase VI	IT	NICU 1.12	IT supporting documents: Provide IT teams with the relevant supporting documents after final approval of clinical teams	31-Jul	Done

Table 2. Internship Assigned Major Tasks and Subtasks

3.4 Road Map and Milestones

Figure 4 illustrates the internship road map and milestones that were identified and agreed with all key stakeholders early in the project.

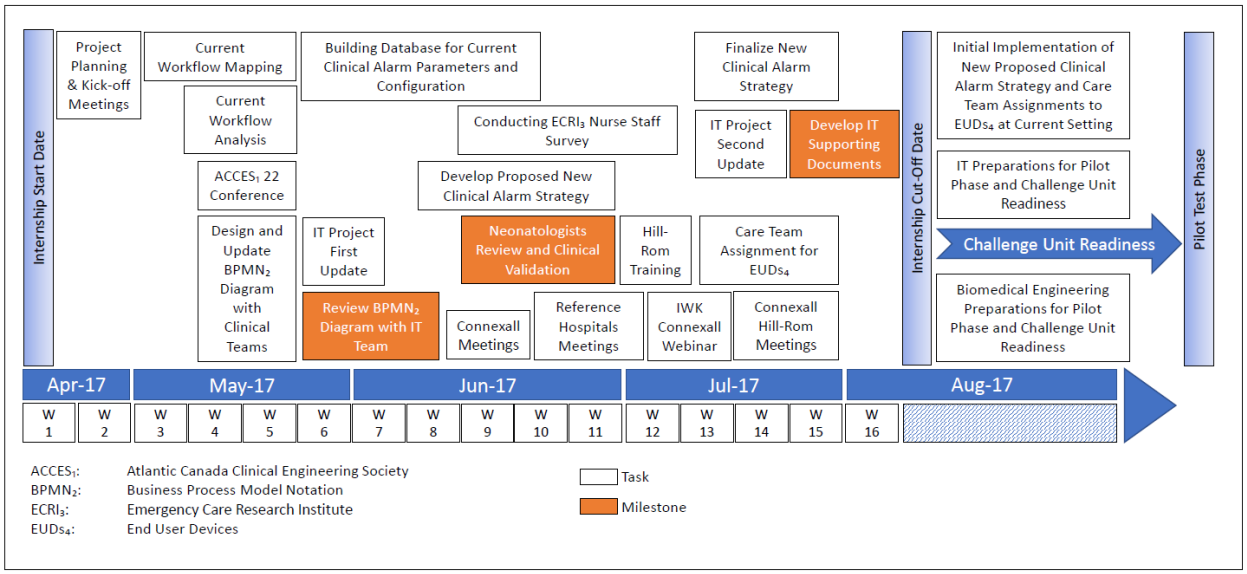

Figure 4. Internship Road Map and Milestones

3.5 Clinical Alarm Management Steering Committee and Task Force

3.5.1 Steering Committee

A clinical alarm steering committee was created for both current NICU project and futuristic PICU project. The main objective was driving the strategic direction and securing the necessary approvals as needed. Table 3 illustrates divergent functions involved in the clinical alarm steering committee and each member's title.

#	Steering Committee Member Title	Function
1.	Neonatologist – NICU	Clinical Teams
2.	NICU Operations Manager, Clinical Lead of NICU Redevelopment	
3.	PICU Redevelopment Project – Clinical Lead	
4.	IT Director – IWK	IT Teams
5.	Technical Analyst, Technology Programs and Services – NSHA	
6.	Computer Services Officer, Internal Services (ISD) – Information, Communication and Technology (ICTS) Enterprise Applications – NSHA	
7.	Manager, Biomedical Engineering	Biomedical Engineering Teams
8.	Biomedical Engineering Project Manager	
9.	Biomedical Engineering Technologist	
10.	Patient Safety Consultant	Quality and System Performance
11.	Health Informatics Intern	Clinical Alarm Management Project Lead

Table 3. IWK – Clinical Alarm Management Steering Committee

3.5.2 Task Force

Similarly, a NICU clinical alarm management task force was created with a weekly meeting schedule during the whole internship project. The main purpose was to accomplish major tasks in a timely manner aiming at meeting the project deadline through working in a team collaborative environment. Regular feedback and updates were provided to the steering committee to secure the necessary approvals based on the outcomes of the weekly task force meetings. Table 4 shows the title of each task force member, key role and expected level of participation.

	Task Force Member Title	Key Role	Attendance Level
1.	Health Informatics Intern	Task force lead	Required
2.	Neonatologist – NICU	Clinical guidance and validation	Required
3.	NICU Operations Manager, Clinical Lead of NICU Redevelopment	NICU nurse clinical lead	Required
4.	Manager, Biomedical Engineering	Strategic guidance	Required
5.	Biomedical Technologist	Biomedical engineering functional lead	Required
6.	NICU Registered Nurse	Nurse champion	Required
7.	Respiratory Therapist	Respiratory therapist champion	Required
8.	Technical Analyst, Technology Programs & Services, NSHA	IT functional lead	Optional except for IT related meetings
9.	Computer Services Officer, Internal Services (ISD) – Information, Communication and Technology (ICTS) Enterprise Applications, NSHA	IT functional lead	Optional except for IT related meetings
10.	Patient Safety Consultant	Patient safety guidance	Optional
11.	PICU Redevelopment Project - Clinical Lead	Auditing meetings for future PICU project implementation	Optional

Table 4. IWK – NICU Clinical Alarm Management Task Force

3.6 Strategies for Reducing the Alarm Load

In reference to ECRI website [4], there are some strategies that were practiced by some institutions and helped in decreasing the number of alarms that staff were exposed to. For instance, changing the priority level of certain alarms—like increasing the priority level of certain alarms; e.g., from moderate to high—may be useful in reducing alarm fatigue because staff will be obligated to respond to the root cause of the alarm once it happens for the first time, rather than leaving the alarm to repeatedly reset and sound again few minutes later. Also, reducing the number of audible alarms could be achieved by separating between actionable and non-actionable alarms. Furthermore, customizing alarm limits to levels that are appropriate for each patient population and avoiding over-monitoring, by reviewing which parameters need to be monitored and maybe disabling other parameters that are not needed to be monitored, can also help in reducing alarm fatigue. For certain alarm conditions, introducing modest delays, between when a condition is recognized and when the alarm is communicated to staff, allows time for self-correcting conditions to resolve themselves. Paying special attention to leads-off (or other sensor-off) alarms and artifact-induced false or nuisance alarms will be helpful in reducing the number of unnecessary technical alarms. ECRI recommends involving clinical teams and working closely with them, especially nurses, while developing those strategies, to assure that changes can be made without putting the patients at risk [4].

3.7 Expected Outcomes

Table 4 illustrates alarm data for three-real NICU case studies that were collected during the course of the internship. Non-actionable alarms represent more than 60% as a one-day average of the total alarms. Considerable delta gains of -15%, -30% and -46% are expected to be achieved if the non-actionable alarms could be reduced by 25%, 50% or 75% respectively for the same or similar cases.

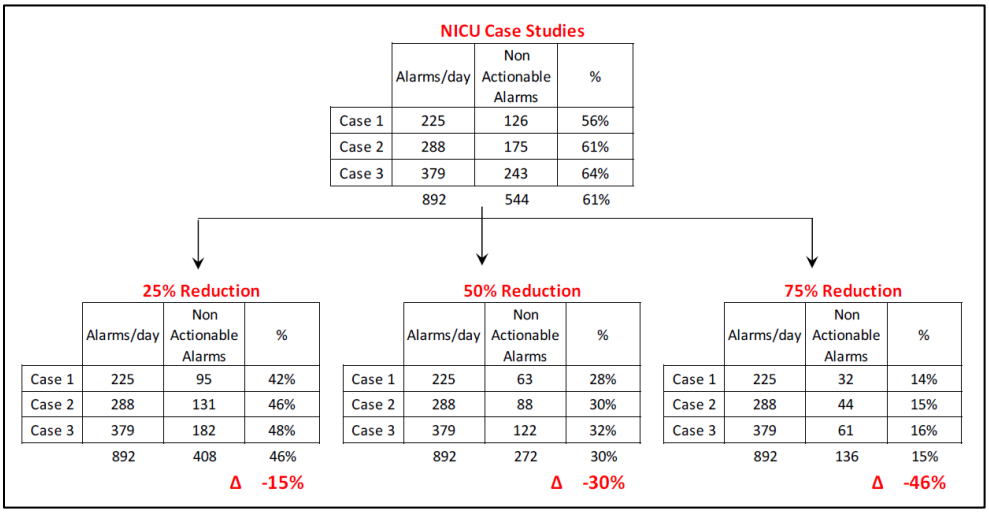

Table 4. | NICU Case Studies | Actionable vs. Non-Actionable Alarms |

3.8 Deliverables (Appendix B through H)

Appendix B illustrates different terminologies related to the newly proposed clinical alarm strategy as agreed by the NICU task force members while Appendix C illustrates the different new roles for care team assignments to the end user mobile devices as also agreed by the task force members. Appendix D shows the newly built NICU alarm database regarding the physiological monitors with the new alarm configuration details including newly proposed alarm limits, modest delays, smart alarm delays and averaging time for the standard NICU patient population. Appendix E represents level one escalation for the primary alarm signal to the primary care givers EUDs with its full details while Appendix F represents the second escalation level to the secondary care givers EUDs with its full details. Appendix G represents the third escalation level to the tertiary care givers EUDs with its full details. Lastly, Appendix H illustrates the fourth escalation level which is considered as the risk mitigation escalation level and the expected total delay time allowed before starting escalation to the emergency team EUDs.

At the end of the internship, the above final project deliverables were presented to the clinical teams in agreement with the assigned neonatologist for their final validation and approval. After securing the necessary approvals, the final project deliverables were submitted to both Biomedical Engineering Department and IT teams for their actions.

4. RELATION TO HEALTH INFORMATICS

4.1 Health Informatics Flow and Use

The internship project started with a complete analysis of the current work process inside NICU open-bay care setting, which was followed by mapping and modelling of their existing clinical workflow related to the clinical alarm management in a BPMN diagram (Please view Appendix A). This BPMN diagram was the foundation for proposing a new clinical workflow for assigning care teams to the EUDs in the new single-family room care setting. Also, a complete database for current clinical alarm configuration was built for all physiological monitoring including patient monitors and ventilators for the current open-bay care setting which was also the base for proposing the new clinical alarm strategy.

4.2 Health Informatics Systems and Issues

During the internship, health data flow, interoperability and integration between different healthcare systems were studied and analyzed. The health data flow for different clinical alarms between bed side monitors, overview monitors and central station monitors (operated by Philips) were studied for the current open-bay care setting and modifications were proposed for the new single-family room care setting. An important part of the internship was the integration of health data related to the clinical alarms produced by patient monitors (operated by Philips) in various locations with the middleware (operated by Connexall) in order to reach the EUDs (operated by Apple). Lastly, health data visualization on patient monitors with its various locations and ventilators were studied and analyzed for the current open-bay care setting and the required changes were proposed for the visualization on the new clinical alarm configuration on both physiological monitors and EUDs upon moving to the single-family room care setting after the completion of NICU redevelopment project.

4.3 Research Methods

4.3.1 Literature Review

A couple of literature reviews were performed during the internship for a variety of topics related to alarm fatigue, alarm management strategies and care team assignment for EUDs for NICU. The main source of information was the ECRI website [4] as guided by the supervisor.

4.3.2 Survey

A nurse staff survey was conducted during the internship to measure the level of satisfaction and engagement among NICU staff nurses to the current clinical alarm management. The survey questionnaire was provided by the ECRI [4] and the proposed list of questions were reviewed and customized by the task force members to meet IWK Health Centre requirements which was allowed by the ECRI [4]. The survey data were collected and analyzed then the results contributed to the final project deliverables.

4.4 Project Management

The internship was managed as a time constrained project where major tasks and subtasks were identified, proposed and agreed with alarm management steering committee and task force members early in the project. Project feedback, updates and variance reporting were delivered to key stakeholders on regular basis during the course of the internship. All schedule variances were efficiently managed where major tasks and subtasks were regularly updated and reprioritized based on the required changes. Project deliverables were submitted for final approvals on due time then shared with both and Biomedical Engineering Department and IT teams for further actions also on due time.

5. PROBLEM ANALYSIS

Alarm fatigue—as a common and significant healthcare problem—was obvious during the course of the internship. The internship project ended up by proposing a reasonable new clinical alarm strategy for physiological monitoring (Philips) and two ventilators (Servo-I and VN-500) which represent the most important and crucial monitoring inside the NICU. However, this new proposed alarm strategy will tackle the alarm fatigue partially because many other alarms producing devices are still used inside NICU. This might be contributing to the alarm fatigue as well. Other alarm producing devices were out of the scope of the internship project because of the time constrains. Examples for other devices that produce audible alarms which were not included in the project are incubators, infusion pumps, patient warming units, hypothermia control, cerebral function monitors, pulse oximeters, enteral pumps, waterless milk warmers and hotline rapid infusers. In order to have a more efficient reduction of alarm fatigue, the above devices need to be studied the same way that was performed during the internship project. Additionally, this could be also achieved through developing clinical practice guidelines for managing clinical alarms inside the NICU which could be further decomposed and computerized into a patient centric clinical decision support system. The newly developed clinical decision support system will provide the ability to centralize all devices that produce alarms inside the whole NICU into a unified new alarm management strategy for both physiological and non-physiological alarm monitoring. This will be reflected positively on reducing the total alarm load and will provide a safer health care environment.

6. CONCLUSIONS

A new clinical alarm strategy was proposed for NICU based on ECRI recommendations including a nurse staff survey that measured their engagement and satisfaction levels. The newly proposed strategy is anticipated to have a considerable reduction in alarm fatigue based on the case studies that were collected and analyzed during the internship project. However, the reduction in alarm fatigue would have been more efficient if the new alarm strategy was extended to the other alarm producing devices that were out of the scope of the project due to time constraints. The internship project was a great learning experience and was a remarkable tool to implement what has been learnt as a clinician and as a prospective health informatician in a real-life experience. It was a concrete opportunity to implement health informatics concepts in a high-quality project that included a complicated and significant healthcare problem like alarm fatigue. Also, it was a wonderful opportunity to practice working collaboratively with other healthcare professionals in a patient centric approach to accomplish project deliverables with a challenging due time. As planned, te internship project was completed in sixteen weeks under the supervision and mentorship of Manager, Biomedical Engineering at IWK Health Centre. The internship project was full of challenges but at the same time was interesting, meaningful, worthy and rewarding.

7. RECOMMENDATIONS

A pilot test phase is suggested to start early during fall 2017 which might last for the full month of September. Pilot testing of the new proposed clinical alarm strategy and care team assignments to the EUDs could be executed in the “Challenge Unit” which is the test environment inside IWK Health Centre. The “Challenge Unit” is operated by ten fully equipped patient rooms where patient simulators—need to be provided by biomedical engineering department—could be attached to the physiological monitors which could imitate the real alarm producing events formed by different patient’s populations. This will allow reviewing and evaluating the impact of the new proposed alarm strategy on alarm fatigue as well as the new proposed care team assignments to the EUDs for a better understanding and providing necessary changes before the “Go Live” phase. Ten clinical scenarios could be proposed by the clinical teams to represent the majority of cases with alarm fatigue, to be studied during the pilot test phase. It is also recommended to first review the new clinical alarm strategy by the task force team members themselves then, to involve NICU nursing staff.

Once the pilot phase is finished and the necessary corrections are made, it is recommended to start initial implementation phase of the new proposed clinical alarm strategy and care team assignments for EUDs in the open-bay care setting. This could be done parallel to the current workflow for the following three months; October, November and December, before commencing the final "Go Live" phase in the new single-family room care setting which is planned during winter 2018. This will minimize the business disruptions and nurses' anxiety which might happen if all the changes—in terms of new single-family room care setting, new clinical alarm management strategy and receiving secondary alarms on their EUDs—are implemented together on the same time without being fully prepared. It is recommended that both Biomedical Engineering and IT teams immediately start actions related to the suggested pilot test phase based on the final project deliverables. It is also recommended to repeat the nurse staff survey after implementing the new clinical alarm strategy and compare the results before and after implementation of the new strategy.

Furthermore, and similarly a new clinical alarm strategy needs to be established for the PICU and suggested to be started during fall 2017 where the PICU pilot testing phase could be started during winter 2018. This might be followed by initial implementation of the new PICU clinical alarm strategy along with the new proposal for care team assignments to the EUDs in the current PICU open-bay business environment for almost one year. Once, the PICU redevelopment construction project is finalized on April 2019, a final "Go Live" phase could be applied in the new single-family room care setting.

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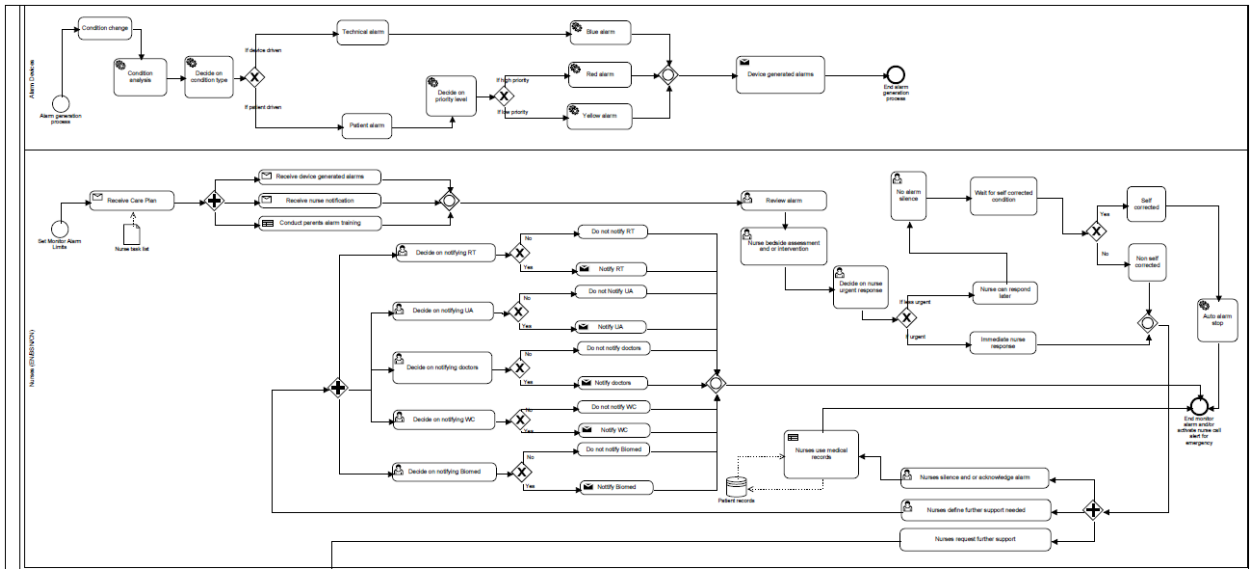
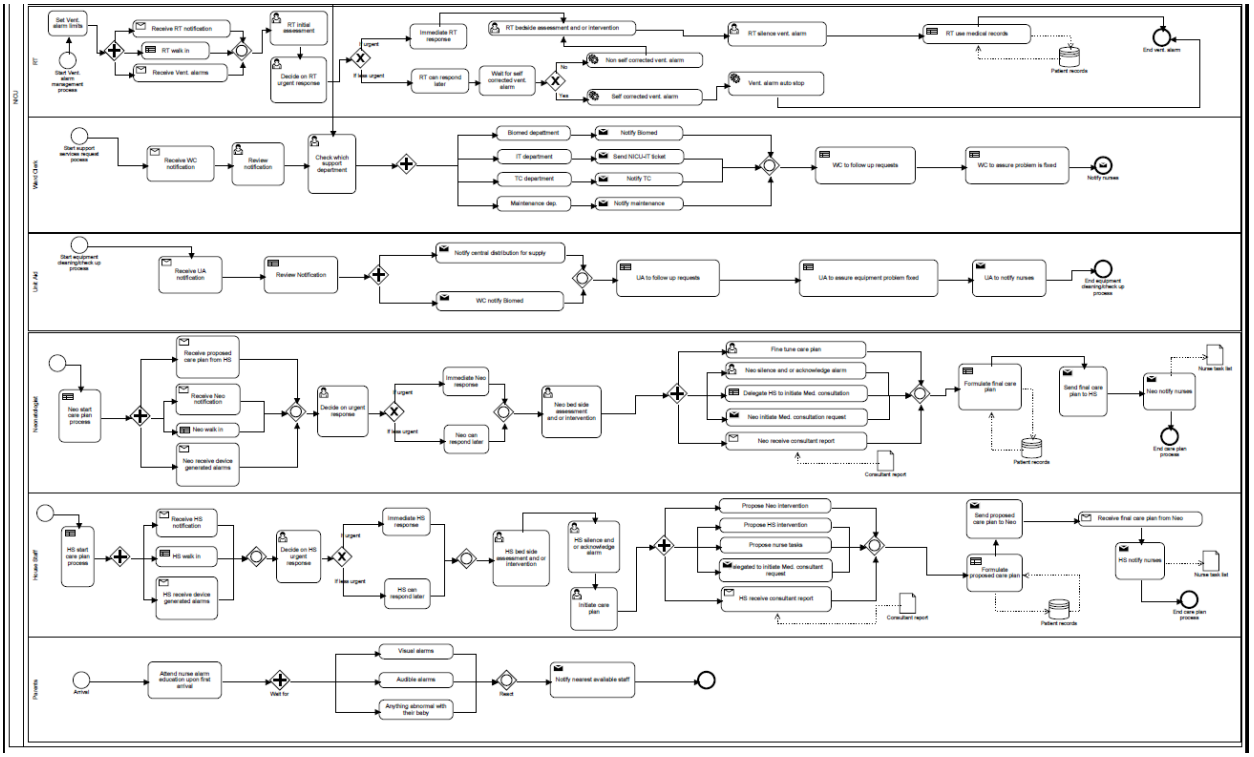
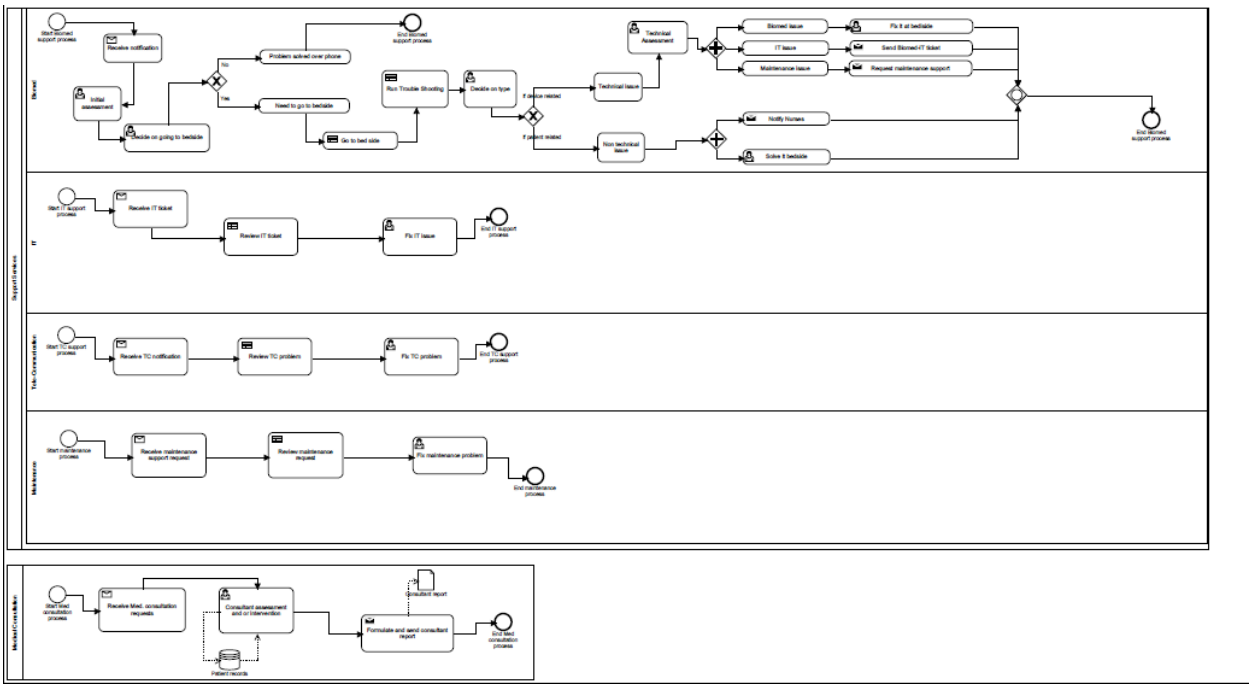
APPENDIX A.


Alarm Creation
Condition change
Alarm generation process
Condition analysis
Decide on condition type
If device driven
If patient driven
Technical alarm
Patient alarm
Decide on priority level
If low priority
If low priority
Blue alarm
Red alarm
Yellow alarm
Device generated alarms
End alarm generation process
Nurses (EMBEDDED)
Receive Care Plan
Set Monitor Alarm Limits
Nurse task list
Receive device generated alarms
Receive nurse notification
Conduct parents alarm training
Decide on notifying RT
Do not notify RT
Notify RT
Decide on notifying UA
Do not Notify UA
Notify UA
Decide on notifying doctors
Do not notify doctors
Notify doctors
Decide on notifying WC
Do not notify WC
Notify WC
Decide on notifying Biomed
Do not notify Biomed
Notify Biomed
Review alarm
Nurse bedside assessment and or intervention
Decide on nurse urgent response
If low urgent
Urgent
Nurse can respond later
Immediate nurse response
No alarm silence
Wait for self corrected condition
Yes
No
Self corrected
Non self corrected
Auto alarm stop
End monitor alarm and/or activate nurse call alert for emergency
Nurses use medical records
Patient records
Nurses silence and or acknowledge alarm
Nurses define further support needed
Nurses request further support


NICU
RT
Set Vent. alarm limits
Start Vent. alarm management process
Receive RT notification
RT walk in
Receive Vent. alarms
RT initial assessment
Decide on RT urgent response
If low urgent
Immediate RT response
RT can respond later
Wait for self corrected vent. alarm
RT bedside assessment and or intervention
Non self corrected vent. alarm
Self corrected vent. alarm
RT silence vent. alarm
Vent. alarm auto stop
RT use medical records
Patient records
End vent. alarm
Ward Clerk
Start support services request process
Receive WC notification
Review notification
Check which support department
Biomed department
IT department
TC department
Maintenance dep.
Notify Biomed
Send NICU-IT ticket
Notify TC
Notify maintenance
WC to follow up requests
WC to assure problem is fixed
Notify Nurses
Unit Aid
Start equipment cleaning/check up process
Receive UA notification
Review Notification
Notify central distribution for supply
WC notify Biomed
UA to follow up requests
UA to assure equipment problem fixed
UA to notify nurses
End equipment cleaning/check up process
Neonatologist
Neo start care plan process
Receive proposed care plan from HS
Receive Neo notification
Neo walk in
Neo receive device generated alarms
Decide on urgent response
If low urgent
Immediate Neo response
Neo can respond later
Neo bed side assessment and or intervention
Fine tune care plan
Neo silence and or acknowledge alarm
Delegate HS to initiate Med. consultation
Neo initiate Med. consultation request
Neo receive consultant report
Consultant report
Formulate final care plan
Send final care plan to HS
Patient records
Neo notify nurses
Nurse task list
End care plan process
House Staff
HS start care plan process
Receive HS notification
HS walk in
HS receive device generated alarms
Decide on HS urgent response
If low urgent
Immediate HS response
HS can respond later
HS bed side assessment and or intervention
HS silence and or acknowledge alarm
Initiate care plan
Propose Neo intervention
Propose HS intervention
Propose nurse tasks
Delegated to initiate Med. consultant request
HS receive consultant report
Consultant report
Send proposed care plan to Neo
Receive final care plan from Neo
Formulate proposed care plan
Patient records
HS notify nurses
Nurse task list
End care plan process
Nurses
Arrive
Attend nurse alarm education upon first arrival
Wait for
Visual alarms
Audible alarms
Anything abnormal with their baby
Heard
Notify nearest available staff



Appendix A. | NICU | Clinical Alarm Workflow | Open-Bay Care Setting |

APPENDIX B.

Terminology	Description as agreed during NICU task force meetings
Primary Alarm	Primary alarm is an alarm produced at bedside monitor and/or overview station monitor and/or central monitor
Secondary Alarm	Secondary alarm is an alarm produced by the middleware and sent to the EUDs
Transferrable Alarm	Transferrable alarm means an alarm that will be transferred from a primary alarm to a secondary alarm to reach EUDs
Waiting Time	Waiting time is the delay time needed to transfer a primary alarm to a secondary alarm which will reach EUDs for the same primary care giver
Response Time	Response time is the delay time needed until auto escalation to the next level occurs
Auto Escalation	Auto escalation to the next level occurs at the end of the response time for this level
Reminders	Reminders take place within the time frame of the response time for this level (N.B. Reminders are not counted while calculating total delay time before risk mitigation)
Total Delay Time	Total delay Time is equal to sum of delays due to primary alarm waiting time plus all delays due to different response times for secondary alarms for all the 3 levels before escalation to the risk mitigation (level 4)

Appendix B. | Final Project Deliverables | Clinical Alarm Configuration Terminology |

APPENDIX C.

Assignment Roles to EUDs	Description as agreed during NICU task force meetings
PN	Primary Nurse
SN	Secondary Nurse
NT	Neighborhood Team
CN	Charge Nurse
ET	Emergency Team
NC	Nurse Call
RT	Respiratory Therapist
HS	House Staff
NEO	Neonatologist

Appendix C. | Final Project Deliverables | Assignment Roles to EUDs |

APPENDIX D.

Device Details				Alarm Configuration Details												
													Smart Delay			
Device	Manufacturer	Model	Location	Parameter	Priority Level	Color	Audible Y/N	Can be disabled Y/N	Able to connect to EUDs Y/N	Lower Limit	Upper Limit	Customized Y/N	Modest Delay (sec)	Y/N	Short Med Long	Averaging Time (sec)
Patient Monitor	Philips	800	Bedside	Tachy	High	Red	Y	Y	Y		210	Y				NA
Patient Monitor	Philips	800	Bedside	Brady	High	Red	Y	Y	Y	80		Y				NA
Patient Monitor	Philips	800	Bedside	High Sat	Med	Yellow	Y	Y	Y		100%	Y	20	Y	Long	5
Patient Monitor	Philips	800	Bedside	Low Sat	Med	Yellow	Y	Y	Y	88%		Y	20	Y	Long	5
Patient Monitor	Philips	800	Bedside	Desat	High	Red	Y	Y	Y	80%		Y	10	N		5
Patient Monitor	Philips	800	Bedside	ABP mean extreme high	High	Red	Y	Y	Y		>60	Y				NA
Patient Monitor	Philips	800	Bedside	ABP mean extreme low	High	Red	Y	Y	Y	<20		Y				NA
Patient Monitor	Philips	800	Bedside	High temp	Med	Yellow	Y	Y	Y		>35.0	Y				NA
Patient Monitor	Philips	800	Bedside	Low temp	Med	Yellow	Y	Y	Y	<33.0		Y				NA
Patient Monitor	Philips	800	Bedside	No central monit	Low	Blue	Y	N	Y	NA	NA	N				NA
Patient Monitor	Philips	800	Bedside	Leads off	Low	Blue	Y	N	Y	NA	NA	N				NA
Patient Monitor	Philips	800	Bedside	Asystole	High	Red	Y	N	Y	NA	NA	N				????
Patient Monitor	Philips	800	Bedside	V. fib	High	Red	Y	N	Y	Wave pattern	Wave pattern	N				NA
Patient Monitor	Philips	800	Bedside	V. tach	High	Red	Y	N	Y	Wave pattern	Wave pattern	N				NA
Patient Monitor	Philips	800	Bedside	INOPs	Low	Blue	Y	N	Y	Revisit/some need to be red	Revisit/some need to be red	N				
Ventilator	Maquet	Servo -i	Bedside	Apnea	High	Red	Y	Y	Y	Do not transfer to Monitor	Do not transfer to Monitor	Y				NA
Ventilator	Maquet	Servo -i	Bedside	PAW high	High	Red	Y	NA	Y	Adult/peds 16 cwp	Adult 120 cwp/ peds 90 cwp	Y				NA
Ventilator	Maquet	Servo -i	Bedside	Minute ventilation high	High	Red	Y	N	Y	Do not transfer to Monitor	Do not transfer to Monitor	Y				
Ventilator	Maquet	Servo -i	Bedside	Minute ventilation low	High	Red	Y	Y	Y	Do not transfer to Monitor	Do not transfer to Monitor	Y				
Ventilator	Maquet	Servo -i	Bedside	Vent failure	High	Red	Y	N	Y			N				
Ventilator	Maquet	Servo -i	Bedside	Vent check tube	High	Red	Y	N	Y			N				
Ventilator	Maquet	Servo -i	Bedside	Pressure limited TV	Med	Yellow	Y	N	Y	Do not transfer to Monitor	Do not transfer to Monitor	Y				
Ventilator	Draeger	VN500	Bedside	Airway pressure high	High	Red	Y	NA	Y	Ask Tim	Ask Tim	N				
Ventilator	Draeger	VN500	Bedside	Airway pressure low	High	Red	Y	NA	Y	Ask Tim	Ask Tim	N				
Ventilator	Draeger	VN500	Bedside	Minute ventilation high	High	Red	Y	NA	Y	Do not transfer to Monitor	Do not transfer to Monitor	Y				
Ventilator	Draeger	VN500	Bedside	Minute ventilation low	High	Red	Y	Y	Y	Do not transfer to Monitor	Do not transfer to Monitor	Y				
Ventilator	Draeger	VN500	Bedside	Pressure limited ! VT not reached	Med	Yellow	Y	NA	Y	Do not transfer to Monitor	Do not transfer to Monitor	N				
Ventilator	Draeger	VN500	Bedside	Mean airway pressure high	High	Red	Y	NA	Y	Ask Tim	Ask Tim	Y				
Ventilator	Draeger	VN500	Bedside	Mean airway pressure low	High	Red	Y	NA	Y	Ask Tim	Ask Tim	N				
Ventilator	Draeger	VN500	Bedside	Disconnection	High	Red	Y	NA	Y			N				
Ventilator	Draeger	VN500	Bedside	Airway obstructed	High	Red	Y	NA	Y	Do not transfer to Monitor	Do not transfer to Monitor	N				
Ventilator	Draeger	VN500	Bedside	Device failure	High	Red	Y	NA	Y			N				
Ventilator	Draeger	VN500	Bedside	Vent check device	High	Red	Y	NA	Y	Ask Tim	Ask Tim	N				

Appendix D. | Final Project Deliverables | NICU | New Standard Alarm Configuration |

APPENDIX E.

Alarm Configuration Details				Primary Alarm Philips Monitors			Level 1 Secodary Alarm | Primary Care Giver | EUDs										
									Manual Escalation	Auto Escalation	1st Reminder		2nd Reminder		3rd Reminder		
Parameter	Priority Level	Color	Audible Y/N	Primary Care Giver	Waiting time (sec)	Transferrable	Primary Care Giver	Response time (sec)	Y/N	Y/N	Y/N	Response Time (sec)	Y/N	Response Time (sec)	Y/N	Response Time (sec)	Escalatable
Tachy	High	Red	Y	PN	0	Y	PN	60	Y	Y	Y	30	N		N		Y
Brady	High	Red	Y	PN	0	Y	PN	60	Y	Y	Y	30	N		N		Y
High Sat	Med	Yellow	Y	PN	0	Y	PN	300	Y	Y	Y	120	Y	240	N		Y
Low Sat	Med	Yellow	Y	PN	0	Y	PN	180	Y	Y	Y	60	Y	120	N		Y
Desat	High	Red	Y	PN	0	Y	PN	60	Y	Y	Y	30	N		N		Y
ABP mean extreme high	High	Red	Y	PN	0	Y	PN	60	Y	Y	Y	30	N		N		Y
ABP mean extreme low	High	Red	Y	PN	0	Y	PN	60	Y	Y	Y	30	N		N		Y
High temp	Med	Yellow	Y	PN	0	Y	PN	180	Y	Y	Y	60	Y	120	N		Y
Low temp	Med	Yellow	Y	PN	0	Y	PN	180	Y	Y	Y	60	Y	120	N		Y
No central monit	Low	Blue	Y	PN	0	Y	PN	300	Y	Y	Y	120	Y	240	N		Y
Leads off	Low	Blue	Y	PN	0	Y	PN	300	Y	Y	Y	120	Y	240	N		Y
Asystole	High	Red	Y	PN	0	Y	PN	300	Y	Y	Y	120	Y	240	N		Y
V. fib	High	Red	Y	PN	0	Y	PN	300	Y	Y	Y	120	Y	240	N		Y
V. tach	High	Red	Y	PN	0	Y	PN	300	Y	Y	Y	120	Y	240	N		Y
INOPs	Low	Blue	Y			Y											
Apnea	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
PAW high	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Minute ventilation high	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Minute ventilation low	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Vent failure	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Vent check tube	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Pressure limited TV	Med	Yellow	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Airway pressure high	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Airway pressure low	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Minute ventilation high	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Minute ventilation low	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Pressure limited ! VT not reached	Med	Yellow	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Mean airway pressure high	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Mean airway pressure low	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Disconnection	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Airway obstructed	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Device failure	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y
Vent check device	High	Red	Y	PN	0	Y	PN	120	Y	Y	Y	60	Y	90	N		Y

Appendix E. | Final Project Deliverables | NICU | Primary Alarms | Level 1 Escalation |

APPENDIX F.

Alarm Configuration Details				Level 2 Escalation | Secondary Care Giver | EUDs										
						Manual Escalation	Auto Escalation	1st Reminder		2nd Reminder		3rd Reminder		
Parameter	Priority Level	Color	Audible Y/N	Secondary Care Giver	Response time (sec)	Y/N	Y/N	Y/N	Response Time (sec)	Y/N	Response Time (sec)	Y/N	Response Time (sec)	Escalatable
Tachy	High	Red	Y	SN	60	Y	Y	Y	30	N		N		Y
Brady	High	Red	Y	SN	60	Y	Y	Y	30	N		N		Y
High Sat	Med	Yellow	Y	SN	300	Y	Y	Y	120	Y	240	N		Y
Low Sat	Med	Yellow	Y	SN	180	Y	Y	Y	60	Y	120	N		Y
Desat	High	Red	Y	SN	60	Y	Y	Y	30	N		N		Y
ABP mean extreme high	High	Red	Y	SN	60	Y	Y	Y	30	N		N		Y
ABP mean extreme low	High	Red	Y	SN	60	Y	Y	Y	30	N		N		Y
High temp	Med	Yellow	Y	SN	180	Y	Y	Y	60	Y	120	N		Y
Low temp	Med	Yellow	Y	SN	180	Y	Y	Y	60	Y	120	N		Y
No central monit	Low	Blue	Y	SN	300	Y	Y	Y	120	Y	240	N		Y
Leads off	Low	Blue	Y	SN	300	Y	Y	Y	120	Y	240	N		Y
Asystole	High	Red	Y	SN	300	Y	Y	Y	120	Y	240	N		Y
V. fib	High	Red	Y	SN	300	Y	Y	Y	120	Y	240	N		Y
V. tach	High	Red	Y	SN	300	Y	Y	Y	120	Y	120	N		Y
INOPs	Low	Blue	Y											
Apnea	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
PAW high	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Minute ventilation high	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Minute ventilation low	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Vent failure	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Vent check tube	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Pressure limited TV	Med	Yellow	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Airway pressure high	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Airway pressure low	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Minute ventilation high	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Minute ventilation low	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Pressure limited ! VT not reached	Med	Yellow	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Mean airway pressure high	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Mean airway pressure low	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Disconnection	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Airway obstructed	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Device failure	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N
Vent check device	High	Red	Y	SN + RT	120	Y	Y	Y	60	Y	90	N		N

Appendix F. | Final Project Deliverables | NICU | Secondary Alarms | Level 2 Escalation |

APPENDIX G.

Alarm Configuration Details				Level 3 Escalaltion | Tertiary Care Giver | EUDs													
						Manual Escalation		Auto Escalation		1st Reminder		2nd Reminder		3rd Reminder		
Parameter	Priority Level	Color	Audible Y/N	Tertiary Care Giver	Response time (sec)	Y/N	To ...	Y/N	To ...	Y/N	Response Time (sec)	Y/N	Response Time (sec)	Y/N	Response Time (sec)	Escalatable
Tachy	High	Red	Y	NT + CN	60	?	?	?	?	Y	30	N		N		Y
Brady	High	Red	Y	NT + CN	60	?	?	?	?	Y	30	N		N		Y
High Sat	Med	Yellow	Y	NT + CN	300	?	?	?	?	Y	120	Y	240	N		Y
Low Sat	Med	Yellow	Y	NT + CN	180	?	?	?	?	Y	60	Y	120	N		Y
Desat	High	Red	Y	NT + CN	60	?	?	?	?	Y	30	Y	30	Y	30	Y
ABP mean extreme high	High	Red	Y	NT + CN	60	?	?	?	?	Y	30	Y	30	Y	30	Y
ABP mean extreme low	High	Red	Y	NT + CN	60	?	?	?	?	Y	30	Y	30	Y	30	Y
High temp	Med	Yellow	Y	NT + CN	180	?	?	?	?	Y	60	Y	120	N		Y
Low temp	Med	Yellow	Y	NT + CN	180	?	?	?	?	Y	60	Y	120	N		Y
No central monit	Low	Blue	Y	NT + CN	300	?	?	?	?	Y	120	Y	240	N		Y
Leads off	Low	Blue	Y	NT + CN	300	?	?	?	?	Y	120	Y	240	N		Y
Asystole	High	Red	Y	NT + CN	300	?	?	?	?	Y	120	Y	240	N		Y
V. fib	High	Red	Y	NT + CN	300	?	?	?	?	Y	120	Y	240	N		Y
V. tach	High	Red	Y	NT + CN	300	?	?	?	?	Y	120	Y	120	N		Y
INOPs	Low	Blue	Y													
Apnea	High	Red	Y													
PAW high	High	Red	Y													
Minute ventilation high	High	Red	Y													
Minute ventilation low	High	Red	Y													
Vent failure	High	Red	Y													
Vent check tube	High	Red	Y													
Pressure limited TV	Med	Yellow	Y													
Airway pressure high	High	Red	Y													
Airway pressure low	High	Red	Y													
Minute ventilation high	High	Red	Y													
Minute ventilation low	High	Red	Y													
Pressure limited ! VT not reached	Med	Yellow	Y													
Mean airway pressure high	High	Red	Y													
Mean airway pressure low	High	Red	Y													
Disconnection	High	Red	Y													
Airway obstructed	High	Red	Y													
Device failure	High	Red	Y													
Vent check device	High	Red	Y													

Appendix G. | Final Project Deliverables | NICU | Secondary Alarms | Level 3 Escalation |

APPENDIX H.

Alarm Configuration Details				Total Delay Time		Level 4 Escalation | Risk Mitigation	
Parameter	Priority Level	Color	Audible Y/N	Sec	Minutes	Escalate To ...	Notes
Tachy	High	Red	Y	180	3.0	ET	Maybe via NC
Brady	High	Red	Y	180	3.0	ET	Maybe via NC
High Sat	Med	Yellow	Y	900	15.0	ET	Maybe re-loop
Low Sat	Med	Yellow	Y	540	9.0	ET	Maybe re-loop
Desat	High	Red	Y	180	3.0	ET	Maybe via NC
ABP mean extreme high	High	Red	Y	180	3.0	ET	Maybe via NC
ABP mean extreme low	High	Red	Y	180	3.0	ET	Maybe via NC
High temp	Med	Yellow	Y	540	9.0	ET	Maybe re-loop
Low temp	Med	Yellow	Y	540	9.0	ET	Maybe re-loop
No central monit	Low	Blue	Y	900	15.0	ET	Maybe re-loop
Leads off	Low	Blue	Y	900	15.0	ET	Maybe re-loop
Asystole	High	Red	Y	900	15.0	ET	Maybe re-loop
V. fib	High	Red	Y	900	15.0	ET	Maybe via NC
V. tach	High	Red	Y	900	15.0	ET	Maybe via NC
INOPs	Low	Blue	Y	0	0.0		
Apnea	High	Red	Y	240	4.0	TBD	
PAW high	High	Red	Y	240	4.0	TBD	
Minute ventilation high	High	Red	Y	240	4.0	TBD	
Minute ventilation low	High	Red	Y	240	4.0	TBD	
Vent failure	High	Red	Y	240	4.0	TBD	
Vent check tube	High	Red	Y	240	4.0	TBD	
Pressure limited TV	Med	Yellow	Y	240	4.0	TBD	
Airway pressure high	High	Red	Y	240	4.0	TBD	
Airway pressure low	High	Red	Y	240	4.0	TBD	
Minute ventilation high	High	Red	Y	240	4.0	TBD	
Minute ventilation low	High	Red	Y	240	4.0	TBD	
Pressure limited ! VT not reached	Med	Yellow	Y	240	4.0	TBD	
Mean airway pressure high	High	Red	Y	240	4.0	TBD	
Mean airway pressure low	High	Red	Y	240	4.0	TBD	
Disconnection	High	Red	Y	240	4.0	TBD	
Airway obstructed	High	Red	Y	240	4.0	TBD	
Device failure	High	Red	Y	240	4.0	TBD	
Vent check device	High	Red	Y	240	4.0	TBD	

Appendix H. | Final Project Deliverables | NICU | Secondary Alarms | Level 4 Escalation | Risk Mitigation |