Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Design

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How to Improve the Clinical Delivery of Neonatal Resuscitation at Birth with a Human-Centred Design Approach

Master's thesis in Master in Interaction Design
Supervisor: Giovanni Pignoni
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Preface

This is a master thesis of the master program in Interaction Design at the Department of Design at Norwegian University of Science and Technology (NTNU). The thesis was in collaboration with Laerdal Medical in Stavanger and Stavanger University Hospital (SUS). The project planning and literature review in the background chapter was finished in the autumn semester of 2020, while the rest of the thesis was finished in the spring semester of 2021.

Jiaxin Li
2021/06/08

Acknowledgement

I would like to thank the following people for their great help for my thesis:

My supervisor Giovanni Pignoni for your continuous support and encouragement along the thesis, for giving me guidance when I struggle, and giving me valuable feedback on how to improve my work.

My co-supervisor Siren Irene Rettedal for showing interest in my project, helping me apply for hospitant and conduct research in Stavanger University Hospital (SUS). Thank you for helping me get in contact with other participants and provide background knowledge on neonatal resuscitation.

Laerdal Medical in Stavanger for giving me this thesis topic and great advice.

Joanna Haynes for your great help on recruiting participants for my interview.

Heidi Killingberg, Torhild Dragsten and Kristin Brobakken Eig for helping me get in contact with the medical and nurse students at NTNU.

Jon Sverre Langaker for helping me translate the survey questions into Norwegian with your insight as a nurse, and publishing it on the nurses' Facebook page.

Sondre Benjamin Aasen for helping me fix the LaTex problems and your support and encouragement.

All the participants for your participation in this study.

Abstract

While most babies can breathe independently within the 30s of birth, around 10% need some assistance to establish a successful respiratory transition. And due to the lack of neonatal resuscitation skill and knowledge and the high cognitive workload, studies show a high percentage of non-adherence to the guidelines and high error rates when healthcare professionals (HCPs) resuscitate the newborn.

This research aims to understand how HCPs in Norway provide neonatal resuscitation, what are the barriers and enablers for providing a high-quality resuscitation, and finally using this information to develop an effective solution to support the healthcare professionals through the process and improve their performance.

In order to fulfil the research objectives, a human-centred design approach has been chosen, and both qualitative and quantitative methods have been applied. In the initial stage, survey, field study and individual interview have been used to empathize and have a deeper understanding of the HCPs and healthcare system. Multiple data analysis methods(e.g. persona, journey map) have been used to discover the insights. 2 HCPs have been invited to confirm the insights and to generate design solutions with the author in co-creation workshops. A storyboard which illustrates the final solution together with a medium-fidelity prototype have been tested in a testing workshop with 2 HCPs.

Outcome and contributions from this study include an in-depth understanding of the current practice of neonatal resuscitation in Norway and the related health ecosystem, and provides a better understanding of the barriers and enablers to a high-quality resuscitation, and what expectations and requirements the HCPs have for the solution. Finally, it suggests a tool, when implemented together with Monivent Neo 100 and NeoBeat, which can improve the understanding of the situation for the healthcare professionals during a neonatal resuscitation, and have the potential to improve their performance and adherence to the Norwegian newborn resuscitation guideline. Future work will be to refine the storyboard, to further develop this prototype to include all the planned functions and the interactive

components, and to test the usability issues and efficacy of the prototype.

Contents

Figures

Acronyms

CO_2 Carbon Dioxide. 52, 53, 54, 57
ECO_2 Expired Carbon Dioxide. 14, 56, 57, 66, 67, 69, 74, 75
FiO_2 Fraction of Inspired Oxygen. 10, 11, 13, 60
$PaCO_2$ Partial Pressure of Carbon Dioxide. 57
SpO_2 Peripheral Capillary Oxygen Saturation. 10, 11, 13, 33, 39, 41, 47, 60, 66, 67, 69, 72, 74, 75, 78
V_t Tidal Volume. 13, 14, 54, 56, 57, 58, 67, 68
V_{te} End Tidal Volume. 58, 66, 67, 74, 75

AHA American Heart Association. 6
AIR Augmented Infant Resuscitator. ix, 26, 57, 58
ANZCOR Resuscitation Councils in Australia and New Zealand. 6

BPM beats per minute. 10, 11, 60

CC chest compression. 2, 12, 13, 33, 38, 41, 60
CLC closed loop communication. 42, 55, 65, 66, 72, 78, 79
CPAP continuous positive airway pressure. 33, 48

DST decision support tool. 2, 13, 60
DSTs decision support tools. v, 5, 13, 79

ECG electrocardiogram. 10, 39, 41, 47, 55, 56, 57, 59, 71

GA gestational age. 8, 11, 31, 38, 73, 77, 82

HCP healthcare professional. 58, 60, 79, 82
HCPs healthcare professionals. iii, 1, 2, 5, 12, 13, 14, 22, 34, 35, 36, 37, 42, 50, 51, 53, 57, 59, 60, 61, 63, 67, 68, 69, 71, 77, 78, 80, 82, 84, 85, 86
HF health trust. 31, 32
HFs health trusts. 31
HR heart rate. 9, 10, 11, 12, 13, 33, 41, 52, 53, 54, 56, 59, 60, 63, 66, 68, 69, 71, 74, 75, 78

ILCOR International Liaison Committee on Resuscitation. 1, 6, 7

NICU neonatal intensive care unit. viii, ix, 23, 28, 33, 34, 41, 42, 43, 44, 46, 47, 48, 49, 51, 53, 71, 72, 73, 79, 82, 86

NRR Norwegian Resuscitation Council. viii, 6, 8, 39, 67, 86
NSD Norsk Senter for Forskningsdata. 29, 83, 84

PEEP positive end expiratory pressure. 12, 13, 58, 66, 68
PIP positive inspiratory pressure. 13, 58, 66, 68
POV positive pressure ventilation. ix, 24, 50, 52, 53, 54
PPV positive pressure ventilation. 2, 12, 13, 33, 60

REK Regional Komiteer for Medisinsk og Helsefaglig for Forskningsetikk. 29, 83, 84
RFM respiratory function monitor. 86
RFMs respiratory function monitors. v, 5, 13, 14, 79
RHF regional health trust. 31, 32
RR respiratory rate. 66, 67

SUS Stavanger University Hospital. i, ii, ix, 22, 28, 31, 33, 38, 39, 40, 56, 72, 73, 77, 82, 83

Chapter 1

Introduction

Each year in the world, around 136 million babies are born and need assessment of breath and simple care such as drying and skin-to-skin with the mother. Between 5-10% of newborn babies require simple helps, such as rubbing, airway clearing or head positioning (Palme-Kilander 1992; Kattwinkel 2000), and around 3-6% of babies require basic resuscitation, such as bag-and-mask ventilation (Zhu *et al.* 1997). Approximately 2% of the babies who do not breathe after birth (less than 1% of all babies), require advanced interventions, including endotracheal intubation, chest compression and medicine (Zhu *et al.* 1997; Deorari *et al.* 2001; Kattwinkel 2000; Perlman and Risser 1995).

According to the ILCOR statement, an assessment of whether a baby needs resuscitation should be based on the existence of initial cry, breathing, muscle tone, heart rate, and response to stimulation (John Kattwinkel *et al.* 1999).

The number of healthcare professionals (HCPs) attending the resuscitation varies depending on the resource setting and how complicated the situation is, normally it involves at least one midwife. In Norway's setting, the team may consist of several midwives, assistant nurses, pediatrician, pediatrician nurses, neonatologists, anesthesiologist and anesthesia nurse.

1.1 Research Problem

Studies have shown that neonatal resuscitation training for the birth attendants may prevent 30% of intrapartum-related mortality (Lee *et al.* 2011). This data indicate the importance to ensure that the birth attendants have adequate knowledge and skills for performing resuscitation. However, a cross-sectional evaluation of around 1500 skilled birth attendants in 5 countries found out that only half of these participants were competent in using bag-mask device (Harvey *et al.*

2007). Some studies (Thomas *et al.* 2006) indicate a 16–55% error rate in adherence to the Neonatal Resuscitation Program (NRP) guidelines during newborn resuscitation. Some of the resuscitation errors are the inability to accurately assess heart rate, clinically significant delays in initiating positive pressure ventilation (PPV), performing chest compression (CC) prior to or in the absence of PPV, and providing CC for an insufficient amount of time (Chitkara *et al.* 2013; MITCHELL *et al.* 2002). A delay in giving a non-breathing newborn ventilation may cause hypoxia, increase the need for more intrusive interventions (Kattwinkel *et al.* 2010), or lead to neonatal morbidity and mortality (Wall *et al.* 2009).

One common solution is to provide more frequent training to increase their knowledge and skills. A study in Nepal shows that the resuscitation skills were able to retained after six months of training (Kc *et al.* 2017), while another study shows that despite the regular training after a formal NRP couse, rapid deterioration of the sufficient knowledge and skill for successful neonatal resuscitation still happened (Carbine *et al.* 2000). Therefore, instead of focusing on the training, in Fuerch *et al.* (2015) the HCPs were provided with NeoCue (a decision support tool (DST)) that gives auditory and visual prompts to guide them during simulation training. The results shows that with the help of NeoCue, the subjects showed significantly more compliance to the Neonatal Resuscitation Program algorithm compared to those relied on their memory alone. By reducing the errors, the clinicians' performance was improved. However, the contribution of this study is limited to individual subject, the results may not be applicable in a team setting.

In another study with 8 midwives in rural Tanzania (Moshiro *et al.* 2018), researchers found that proper labor monitor, preparation of equipment before the delivery, good teamwork and frequent training are important factor for enabling effective ventilation. Barriers to effective ventilation are as follows:

- Anxiety and/or fear of failing to save the baby;
- Difficulties in assessing the baby's responses can lead to a delay in initiating actions;
- Midwives' opions were not heard by the doctors;
- Confusion, interference and interruptions within the team.

To overcome these barriers, midwives, nurses and doctors need to receive more training in teams on how to make joint decisions. Moreover, it's important to simulate real life situations in the training as much as possible, so that they can have a sense of urgency. Having a brief before resuscitation and debrief session after the event can also improve performance. The purpose of debrief is to reflect on the strengths and weaknesses and discover areas for improvement. Although there is evidence that brief and debrief can improve teamwork and clinical performance (Cho 2015), they are often neglected in the delivery room (Edwards *et al.*

2015).

With all of these in mind, this research aims to understand how healthcare professionals in Norway provide neonatal resuscitation, what are the barriers and enablers for providing a high quality resuscitation, and finally using this information to develop an effective solution to support the healthcare professionals through the process and improve their performance with a human centred design approach.

1.2 Human Centred Design

Human centred design is an innovative approach to solve problems. It emphasizes on the focus of human's needs and problems, and producing solutions that meet their needs. The human centred design process can be visualized with a double diamond model (*What is the framework for innovation?* 2015), usually involving several stages, starting from empathizing with the users, and then clearly defining the problem, and reaching to the next step to generate a large number of ideas, then implementing the ideas, lastly testing on the users and iterating. The whole process is not linear, which means it's always possible to go back to the previous steps if needed. Human centred design has been used and proved effective on creating innovative solutions in many areas, especially around issues of health. Considering the academic background and personal interest of the author, human centred design method was chosen in this study.

1.3 Research Questions

This research aims to answer following research questions:

- What are the barriers and enablers to provision of timely, safe and effective newborn resuscitation for the healthcare professionals?
    - Can the barriers, such as difficulty to assess the baby's condition and their resuscitation performance, and enablers, such as training, brief and debrief, found in the literature, be identified during a later observation and interview?
    - Which barriers or problems should be focused on and be solved?
- What are the needs and expectations of the healthcare professionals related to improving the quality of newborn resuscitation?
- How can we support the healthcare professionals in the complex resuscitation process?
    - How can the solutions be proved to be effective?
    - What are the requirement of implementation?

1.4 Thesis Structure

The rest of this paper will follow the structure as:

- In **Chapter 2** the researcher introduces some findings from the literature review.
- In **Chapter 3** the researcher lists the methods that have been used in this study and structures them in a double diamond model. The researcher also talks about ethical consideration when conducting the research.
- In **Chapter 4** the researcher presents all the results, including the early insights from the users, and how to use those insights to develop the final solution and testify it with users.
- In **Chapter 5** the researcher discussed about the methods and the results, and reflects on some limitations.
- And lastly in **Chapter 6** the research draws the conclusion and plans for the next step.

Chapter 2

Background

This chapter presents different theoretical backgrounds and literature that serve as building blocks for my study.

- Section 2.1 introduces different resuscitation algorithms and procedures.
- Section 2.2 explains some barriers to provide high quality neonatal resuscitation, such as the high error rates and low compliance with guidelines, and the limitation of working memory and short term memory.
- Section 2.3 explains some enablers for a high quality neonatal resuscitation. decision support tools (DSTs) and respiratory function monitors (RFMs) which can give real time feedback to healthcare professionals (HCPs) and reduce their workload. Brief and debrief can improve team cooperation and communication.
- Section 2.4 Gives an overview of Human centred design methods.

2.1 Neonatal Resuscitation

Before birth, the fetus exchanges gas from the placenta. Immediately after birth, the pulmonary respiration transition happens and the infant clears lung liquid through spontaneous breaths. Most babies can breathe independently within 30s of birth, while around 10% need some assistance. The majority of those in need response to drying, stimulation and head positioning, few of them need bag-and-mask ventilation (3%), intubation(2%), and very few of them, under 0.1%, need chest compression and medications. The first sign of a successful resuscitation is the increasing heart rate (Mildenhall 2016; Schmölzer, Morley and O. C. Kamlin 2019).

2.1.1 Guidelines

Different Resuscitation Councils around the world have created their own neonatal resuscitation guidelines or algorithms based on the International Liaison Committee on Resuscitation (ILCOR) recommendations. The differences among these guidelines are in the areas of research where strong evidence lack. The Norwegian Resuscitation Council (NRR) has created a guideline for 2015 version(Appendix A.1) based on the ILCOR 2010 (Wyllie, Perlman, Kattwinkel, Atkins *et al.* 2010) and 2015 (Wyllie, Perlman, Kattwinkel, Wyckoff *et al.* 2015) guidelines, but also took other guidelines into account, including European Resuscitation Council Guidelines for Resuscitation 2015 (Wyllie, Bruinenberg *et al.* 2015), the guidelines from Resuscitation Councils in Australia and New Zealand (ANZCOR) (*Australian Resuscitation Council (ARC)* 2020) as well as recommendations from the American Heart Association (AHA) (*CPR & ECC Guidelines* 2020) (NRR 2015). Figure 2.1 shows the action plan which was used in Helping Babies Breathe (HBB) program for birth attendants in resource-limited settings (Kamath-Rayne *et al.* 2018). This action plan briefly illustrates the procedures of newborn resuscitation and equipment in a way that's easy to understand.

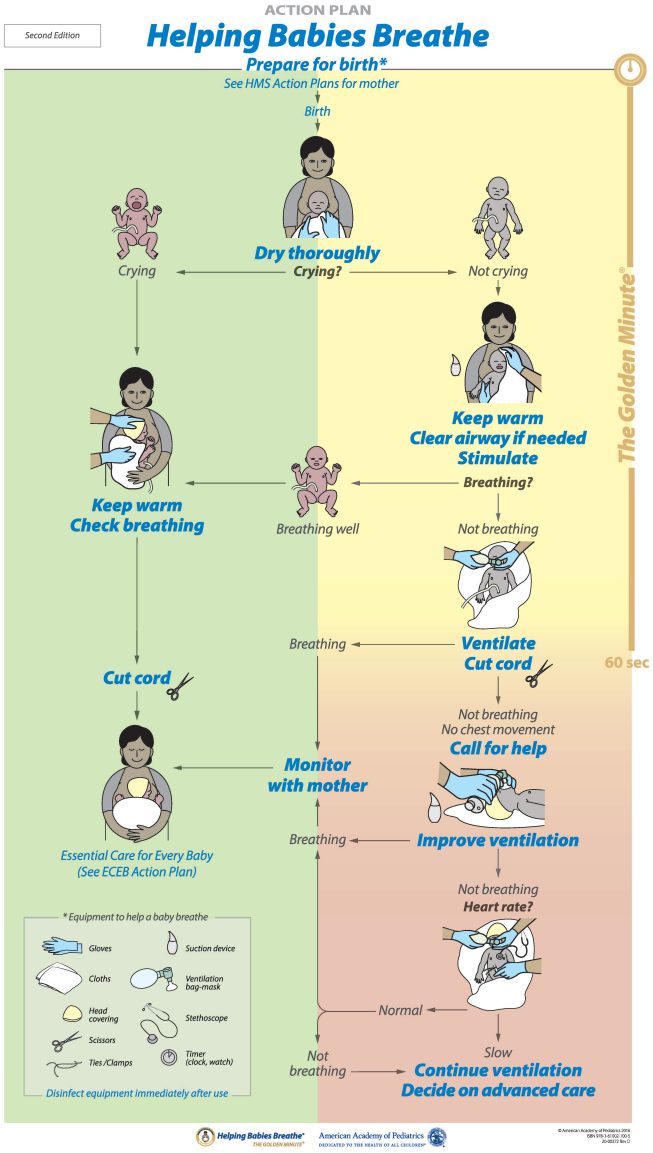


Figure 2.1: HBB Wall Poster Second Edition

In the following sections the researcher will describe steps of performing neonatal resuscitation (Figure 2.2) mainly based on the 2015 Norwegian newborn resuscitation guideline(NRR 2015), but also partly based on the ILCOR 2010 and 2015 guidelines (Mildenhall 2016).

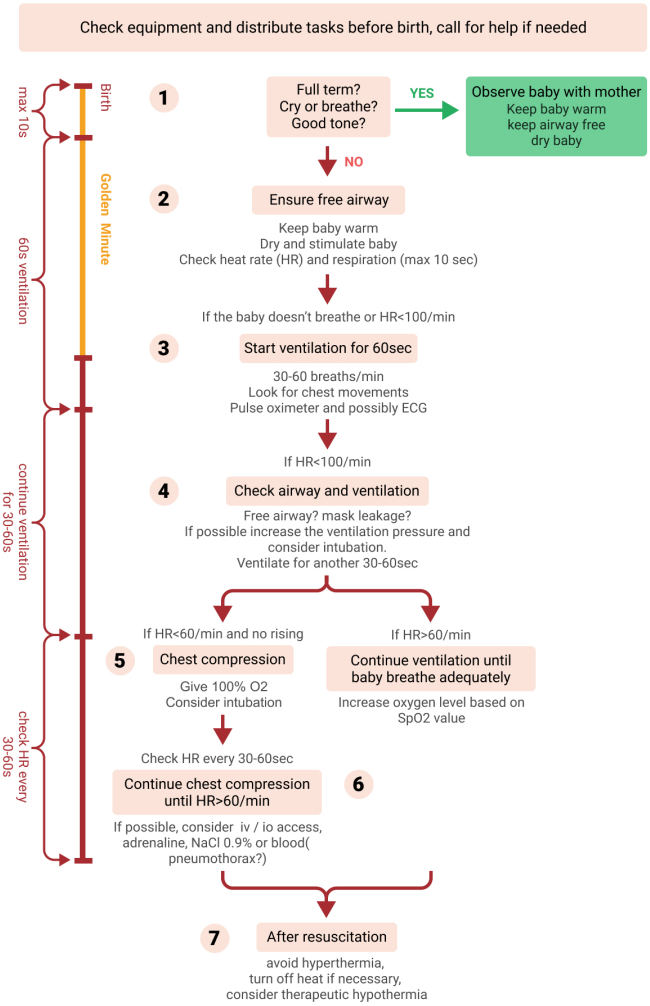


Figure 2.2: Resuscitation guideline modified and translated from the NRR 2015 Newborn Resuscitation Guideline

Step 1. Initial assessment

If a newborn is expected to have problems, a team of different personnel should be summoned and tasks should be distributed, and necessary equipment should be prepared before birth. Immediately after the infant is born, the baby should be assessed based on the following questions: a. full term baby (gestational age (GA) $\geq$ 35 weeks)? b. crying or breathing? c. good muscle tone and no signs of meconium in the amniotic fluid? A good muscle tone means a flexed posture with moving arms and legs, whereas a bad muscle tone can be indicated by a floppy baby with still limbs.

If the answers to all these three questions are yes, then the baby should be dried, wrapped in a warm towel and put on the mother's chest (skin to skin) and under observation. However, if any answers for these three questions are no, then the following measures should be taken in sequence: ensure free airway, ventilation, chest compression, medication or volume expansion. Proceeding to the next action is based on the HR and respiration.

Step 2. Ensure free airway

The baby should be moved to a resuscitation bed or trolley (Figure 2.3). The radio heater should be turned on the keep the temperature between 36.5-37.5° C. The baby should be dried and stimulated by rubbing at the back. The airway should be opened by correctly positioning the head with chin lift or jaw thrust. Most babies will give a positive response after all these actions have been done. The baby's respiration and HR should be assessed in less than 10 sec after birth. HR can be assessed by listening with a stethoscope for 6 seconds and multiply by 10 to get the HR per minute, or by palpating in the umbilical cord. "Routine suctioning to clear amniotic fluid or other secretions from the oropharynx is now strongly discouraged." (Mildenhall 2016)

A preterm newborn (< 32 weeks) should be wrapped in a plastic wrap/bag for both body and head without drying. Assessment and resuscitation can be performed through the wrap (Mildenhall 2016; NRR 2015).

Figure 2.3: Newborn Resuscitation Bed

Step 3. Ventilation

If there is apnea, gasping or the HR is below 100 beats per minute (BPM), a positive pressure ventilation for 30–60 breaths/min with bag-mask or T-piece resuscitator (eg.Neopuff) should be given for 60 seconds. One important sign is chest movement, which means that the baby is getting air into the lungs. Another critical sign is the rising heart rate. The baby should be given ventilation for one minute without taking a break to check the heart rate. If more than one person is present, another team member can auscultate in the meantime. or put a pulse oximeter on the baby's right hand and possibly ECG.

The ventilation should be started with room air, for babies:

- $\geq$ 32 weeks, start with 21% O_2;
- $<$ 32 weeks, start with 30% O_2.

Then the oxygen level should be adjusted based on the expected preductal Peripheral Capillary Oxygen Saturation (SpO_2) after birth (as shown in the algorithm).

Step 4. Check airway and ventilation

After ventilating for one minute and if the heart rate is still below 100 bmp, the airway should be checked to make sure that it is open and the mask is not leaking. If possible, the ventilation pressure can be increased and intubation can be considered. The health personnel should ventilate for another 30-60s and check the heart rate. For babies requiring ongoing resuscitation or respiratory support, pulse oximetry should be used to assess SpO_2 (Mildenhall 2016).

Step 5 Chest Compression

If HR is above 60 BPM, the ventilation should be continued until the baby can breathe adequately, and the oxygen level should be increased based on the SpO_2 value.

If HR fails to rise and is still below 60 BPM, the baby should be given chest compression. For most cases, the cardiac arrest is caused by asphyxia, then the ration of 3:1 for the chest compression is suggested, that is, 90 compression and 30 ventilation per minute. However, if cardiac aetiology is suspected, a higher compression-ventilation ratio of 15:2 is suggested. "It is essential that an adequate airway has been established prior to the commencement of chest compression as the heart rate will not respond unless the compression is delivering oxygenated blood to the ascending aorta."(Mildenhall 2016) The two-thumb, with hand encircling the chest is the preferred method and has been proved better than two-finger(Christman *et al.* 2011). Meanwhile, the oxygen concentration, Fraction of

Inspired Oxygen (FiO_2) should be increased to 100%. If competent personnel are present, intubation should be considered.

Heart rate should be checked every 30-60 seconds. The chest compression should be continued until the heart rate is higher than 60 BPM stably and the oxygen supply should be gradually adjusted based on SpO_2 reading from the pulse oximetry or according to the increasing HR.

Step 6 Medication

If there are adequate lung inflations during the chest compression, but HR is still below 60 BPM, medicine should be considered. Fluids and medications should be provided through the intravenous vascular(iv) access or intraosseous(io) access. The recommend dose of 0.1mg/ml adrenaline is 0.01-0.03 mg/kg (0.1-0.3 ml/kg) in the umbilical cord. The amount of adrenaline varies based on the GA. Repetitive doses can be given every 3 minutes.

If a baby has blood loss or symptoms of shock (pale, poor central perfusion) or does not respond to adequate resuscitation, volume replacement with $NaCl$ 0.9% or blood can be given. The dose can be repeated as needed.

Step 7 After resuscitation

After the resuscitation, the heater should be turned off to avoid hyperthermia. The newborn should be returned to the mother if everything is fine or transferred to intensive care unit. Newborn term or near term infants(GA $\geq$ 36 weeks) with moderate to severe hypoxic-ischaemic encephalopathy(HIE) should be offered hypothermia therapy, with a core temperature of approximately 33.5°C, for 72 hours.

Delay Cord Clamping

It's recommended to delay the cord clamping for at least one minute after birth for a preterm or term baby, which can increase the blood volume. However, for a child who needs resuscitation the optimal time to remove the umbilical cord lacks enough data.

Discontinuing Resuscitation

If a child after 10-15 minutes of resuscitation and has no heart rate, or a child has detectable heart rate but has a prognosis of severe disabilities after 15-20 minutes of resuscitation, the resuscitation should be considered to end. This decision should be consulted with a chief physician if possible (NRR 2015).

2.2 Barriers to High Quality Neonatal Resuscitation

2.2.1 High Error Rates and Low Compliance with Guidelines

Some studies (Thomas *et al.* 2006) indicate that HCPs show a 16–55% error rate in adherence to the Neonatal Resuscitation (NRP) Program guidelines . Common errors in the resuscitation including clinically significant delays in initiating positive pressure ventilation (PPV), performing CC before or without establishing an airway and ventilation support and giving naloxone before PPV (MITCHELL *et al.* 2002). Although auscultation and palpation are recommended as methods to assess the heart rate in many guidelines, studies (Chitkara *et al.* 2013) found that it's very common that the health personnel assessed the heart rate (HR) inaccurately through these methods and the errors in HR determination are related to 48% of all the errors happened in resuscitation. For the rest cases even though HCPs accurately assessed the HR, 62% of the omission errors (lack of appropriate interventions) and 45% of the commission errors (inappropriate interventions) still occurred. One reason for causing these mistakes can be deficit in knowledge. Another possible reason can be the stress and sense of time pressure making it difficult for HCPs to remember the steps in the guidelines, skip certain steps or to proceed to the following steps without indication (Chitkara *et al.* 2013). Similar result was found by Yamada *et al.* (2015), an average error rate of 23% was recorded in the resuscitation procedures, among which 28% was omission errors and 72% commission errors. Many errors were repetitive and can cause adverse outcome. The most common omission error was not having an available cap (52.2%), while the most repeated error was failure to assess heart rate/or breath sounds, which happened up to 4 times in one single resuscitation. The most common commission error is late removal of wet linens (78.2%), following low peak inspiratory pressures and inadequate positive end expiratory pressure (PEEP) during ventilation, interruption of PPV to stimulate or check the heart rate, prolonged intubation attempt, improper CC technique, administration of CC without PPV and CC not coordinated with PPV.

2.2.2 Working Memory and Short Term Memory

As mentioned in Schmölzer, Morley and O. C. Kamlin (2019), "The major challenge to neonatal resuscitation in the DR (delivery room) is the lack of direct feedback about the effectiveness of the interventions that are employed". Very often, the resuscitators don't realize their techniques are not correct. Furthermore, the repeated errors in the same resuscitation indicate a team failure rather than an individual failure. The team members failed to detect and correct the mistakes, which might be due to the high cognitive load and technical load on the whole teams. Cognitive load refers to the amount of working memory resources that are occupied. Working memory is the amount of mental work that is required to recall and act on stimuli and make decisions under time pressure. And the technical load refers to the the mental and physical energy required to complete the steps

of a technical task such as intubation (*Cognitive load* 2020; Yamada *et al.* 2015). Research has shown that human have limited ability to identify, process, and act upon multiple, simultaneous stimuli. The capacity of visual short term memory is constrained by two factors, the number of objects should be kept within four or five, and the information load per item (Alvarez and Cavanagh 2016). Studies (Pashler 1994) show that the psychological refractory period indicate a bottleneck effect including the process of choosing actions, retrieving memory and other cognitive operations. Other factors that limit human's performance such as task preparation, sensory-perceptual processes and time. There's limit capacity of working memory, when both input and output process need to retrieve working memory at the same time, interference may occur (Luck and Vogel 2001). These inherent limitations in human's performance can result in delays or mistakes in either understanding or taking action in high intensity activities such as neonatal resuscitation.

2.3 Enablers for High Quality Neonatal Resuscitation

2.3.1 decision support tools (DSTs) & respiratory function monitors (RFMs)

In healthcare, variant DSTs "are designed to decrease the cognitive load of HCPs, improve quality of care, and decrease human errors by linking health observations with health knowledge" in different domains (Zehnder *et al.* 2019), such as quality improvement (Conway *et al.* 2012), medication safety (Waitman *et al.* 2011), intensive care unit patient (Egan 2006), implementation and monitoring of mental health care guidelines (Chorpita *et al.* 2007), and patient wellness (Kailas *et al.* 2010).

In an area as complex as neonatal resuscitation, DSTs include visual display and auditory reminders to trigger interventions, which can reduce part of the cognitive load for HCPs and save more capacity for other tasks (Zehnder *et al.* 2019). Fuerch *et al.* (2015) assessed the impact of a visual and auditory decision support tool and reported significantly improved adherence to the Neonatal Resuscitation Program algorithm in a simulation setting. The intervention group performed PPV 94-95% of the time correctly compared to 55–80% in the control group who depended on memory alone ($p < 0.0001$). The intervention group also demonstrated better performance in the CC, with a correct rate of 82-93% compared to 71-81% in the control group ($p < 0.0001$). With respect to the Fraction of Inspired Oxygen (FiO_2) adjustment, FiO_2 was addressed three times more frequently in intervention group compared to control group ($p < 0.0001$), which indicates that the intervention group were more sensible to the patient's SpO_2 and might adjust FiO_2 based on their needs (Fuerch *et al.* 2015). There are many other physiologic variables such as HR, oxygen saturation, temperature, airway pressure, gas leakage, positive inspiratory pressure (PIP), PEEP, gas flow, Tidal Volume (V_t),

Expired Carbon Dioxide (ECO_2) that can be measured and monitored during resuscitation, these functions allow the resuscitator to discover problems and adjust their technique to improve neonatal resuscitation outcomes (Visvanathan and Jayasekara 2011). Many studies have shown that using RFMs to measure V_t and leakage around the mask or endotracheal tube allows HCPs make a better clinical assessment and improve their techniques (Wood, Morley, Dawson and Davis 2008; Wood, Morley, Dawson, C. O. F. Kamlin *et al.* 2008a; Wood, Morley, Dawson, C. O. F. Kamlin *et al.* 2008b; Schmölzer, O. C. O. F. Kamlin, O'Donnell *et al.* 2010; Poulton *et al.* 2011; Kaufman *et al.* 2013; Li *et al.* 2014; Schmölzer, O. C. O. F. Kamlin, Dawson *et al.* 2010; Schmölzer, Morley, Wong *et al.* 2012; Schmölzer and Roehr 2011; Schilleman, Witlox *et al.* 2010; C. O. F. Kamlin *et al.* 2013).

With the development of technology, more and more variables are possible to measure now, what data should be displayed and how to display, as well as human factor issues should be considered to ensure the optimal cognitive load and improve the performance for the HCPs (Chitkara *et al.* 2013).

2.3.2 Briefing and Debriefing

Resuscitation in the delivery room requires a team of HCPs from different disciplines (Weinstock and Halamek 2008). To coordinate and work efficiently in a team manner, it's very important that the individuals know who should be present, each team member's role and responsibilities, and what skills theses roles require (G *et al.* 2010). Studies show that briefing, debriefing and checklist can improve team communication, facilitate teamwork (Edwards *et al.* 2015; Mitchell *et al.* 2012; G *et al.* 2010), and are associated with better resuscitation outcome (Edwards *et al.* 2015; Morey *et al.* 2002).

Briefing

Briefing can get everyone on board for the following event and is essential for an effective resuscitation team (Mitchell *et al.* 2012; G *et al.* 2010). According to American Academy of Pediatrics (Poulin n.d.), a team briefing requiring following actions:

- Determine the leader, announce the objective, assign the roles, responsibilities and tasks;
- Check the availability and examine the equipment;
- Discuss the treatment plan with the parents if not already done;
- Ask the obstetrician the plan for delayed cord clamping.

If any risk factors for resuscitation is identified, more qualified personnel will be summoned before the delivery. In this case, there's more time to do a team briefing. While in other cases, a resuscitation need is unexpected until the baby is born,

therefore the resuscitation team is assembled in an emergency situation and has little time for brief.

Debriefing

Debriefing normally happens after a simulated or clinical event. The goal of debriefing is to improve the future performance. It requires all the team members to gather together to share and reflect on the experience and identify their weaknesses and strengths. Debrief has been proven to improve clinical outcomes, patient safety and the teaching of teamwork and communication in pediatrics (Couper and Perkins 2013; Greif *et al.* 2015), but fell short in both policy documentation and practice (Edwards *et al.* 2015).

Debriefing can be defined as hot debriefing and cold debriefing based on the time when it is performed (Cho 2015). Hot debriefing often happens immediately after a certain event, led by a resuscitation team member and probably data-driven (e.g. use of feedback devices on cardiac compression metrics). It focuses on the team performance, including equipment availability and how fast the resuscitation team gathers (Percarpio *et al.* 2010). Hot debriefing can identify and rectify latent resuscitation errors and is the most popular form of debriefing because it's easy to gather everyone right after the resuscitation. However, their recall on the performance errors is often poor, even when they had real-time feedback for shallow chest compressions (McInnes *et al.* 2012). Hot debriefing possibly has little impact on CPR quality without the immediate data summary.

Cold debriefing, or structured post-event performance focused debrief, has some advantages over hot debriefing. Because the meetings normally happen some time after the resuscitation, there's time to download the performance data, analyse and incorporate the data into the debrief. Also, cold debriefing can be shared to all members of the clinical team, thereby allowing them to learn from other's experiences even though they haven't attended the event. The cold debriefing can be in a form of written feedback and their performance summary. Data sources are mostly from video recording and defibrillator downloads. Video recordings can be used to check if they followed the guidelines or algorithms, and calculate cardiac arrest performance elements such as chest compression rate, flow fraction and intervention timings. Research on cold debriefing has shown an improvement on CPR delivery (Wolfe *et al.* 2014; Edelson *et al.* 2008), however, the optimal way of debriefing and the interval between actual cardiac arrest and the debriefing event is yet to be determined (Greif *et al.* 2015).

Table 1. Comparison between strategies for delivery of hot and cold debriefing in the clinical setting

	Hot/immediate debriefing	Cold/delayed debriefing
Format	Verbal	Verbal
		Written
		Performance summary
Staff	Immediate team	Immediate team
		Larger team
		Managers
Data	Clinician recall	Clinician recall
	Automatic performance summary	Download of defibrillator CPR data
		Video-recording

CPR, cardiopulmonary resuscitation.

Figure 2.4: Comparison between strategies for delivery of hot and cold debriefing in the clinical setting (Cho 2015)

2.4 Human Centred Design

Drawn from the research in human computer interaction, industrial design and cognitive psychology, human centred design (HCD), or user centred design (UCD), offers a collection of design methods to create useful products that are tailored to the users' needs. Three key principle of HCD are an early focus on users, empirical measurement of how users use prototype and iterative design (Gould and Lewis 1985). The main focus on empirical measurement is usability, i.e. effectiveness, efficiency and satisfaction. Figure 2.5 summarizes common HCD methods with strengths, weaknesses and optimal usage. Figure 3.1 demonstrates a modified double diamond model connected with the methods planned to be used in this study.

Table A1
Overview description of HCD methods, their intended uses, and potential weaknesses.

Method	Description	When to use (design phase)/purpose	Result	Weaknesses
Contextual inquiry [52,53,54,55]	Interviews about and observations of the user's work practices in real-world contexts.	Early stages of the design process when project requires a deep, qualitative understand of the user and their working environment.	Detailed descriptions of the user's behaviour and work practices, including communication flows, task sequences, artifacts, tools, work culture, and physical environment.	Observation can affect user behaviour, interviews are subject to recall bias, time-consuming, expensive.
Task analysis [53,56]	Interviews about and observations of the user's specific tasks in real-world contexts.	Early stages of design process when project requires a deep, qualitative understanding of the user's specific tasks as they happen in the user's working environment along with predictive models of user task performance.	Flowcharts (or similar visuals) that depict user's tasks, subtasks, decision points, and human-system responses.	Does not provide insight into situations where users performs interwoven, continuous, or opportunistic tasks.
Field studies/ethnography [57,58]	Observations, interviews, and document analysis related to people in their natural environments.	Early stages of design process when project requires a comprehensive and empathetic understanding of the users and their world.	Deep insight into user lives, artifacts, and behaviours that influence their needs.	Time consuming, expensive
Competitive analysis [59,60]	User interviews about design landscape including user experiences, competitors, best practices, trends, and user demographics.	Early stages of design process when researcher needs to make informed decisions about own product or design strategy.	Improved understanding of the landscape in which a design will compete. This includes a comparison of strengths and weaknesses of the design with that of the competition.	Process is lengthy and ongoing as landscape changes when new competitors emerge.
Iterative design [53,58]	Repeated redesign of some or all system components in consultation with users and stakeholders.	Applicable throughout new product development process but preferably used in the earliest stages of development when a design needs refinement to improve its usability and quality.	A design or process that is the best solution for the task.	Process is lengthy since ongoing, no set endpoint.
Participatory prototyping [61]	Creating iterative prototypes by involving users in the design and review process.	As a check-back with target user groups to ensure that key feedback is accurately incorporated.	Visual and textual feedback related to content, usability, workflow integration, context, word choices, or any other part of the prototype.	Requires a collaborative environment to solicit both positive and negative participant feedback.
Prototyping [13]	Creating approximations of a design idea, initially low fidelity (e.g. paper, props) and later in the target medium.	To explore design ideas before committing significant resources to system development.	Feedback from representative users, stakeholders, and other designers.	If a prototype is mistaken for the final product, it may lead stakeholders to believe an incomplete system is ready to go.
Focus groups [62]	Facilitating a guided discussion with a group of target participants regarding their opinions, attitudes, and experiences.	Early in the HCD process when the project depends upon knowing the experience of the target user groups.	Thematically analyzed audio and video transcripts to bring forward to new iterations.	If the focus group environment is too formal, analysis may yield biased feedback.
Interviews [56]	Meeting directly with a participant to gather information about opinions, attitudes, and experiences.	Used for exploratory research. Can be used prior to or after design/development for input.	Thematically analyzed audio and video transcripts to bring forward to new iterations.	The interviewer needs to guide the session with the appropriate questions so interviewee can understand them.
Formative usability testing [63]	Continuous testing of prototypes to identify interface problems, quickly fix them, then retest with more participants.	Used early in the design process between changes in prototypes before a high-fidelity prototype. To evaluate a design ahead of real-world use to verify that design decisions (e.g., color choices, language, interactivity, layout, flow, content) do not cause the user any use difficulties.	Ongoing identification of problems that block users from completing a task.	Does not give statistically valid, repeatable metrics. Number of testers cannot be planned in advance.
Expert review/heuristic evaluation [64]	Team members with different disciplines and varying expertise on the subject matter conduct an informal usability inspection based on a set of agreed principles.	Done before user testing begins. Can be done with low-fidelity prototypes in middle phases of the design process.	A report that identifies features that are both consistent and inconsistent with heuristic principles.	Rarely identifies opportunities for major advances in design. When evaluators do identify problems, they are not always able to provide solutions.

Table A1 (*continued*)

Method	Description	When to use (design phase)/purpose	Result	Weaknesses
Summative usability testing [65,66,67]	Observing and recording a participant using a digital application to complete a task.	Use when need to identify problems for end users that prevent them from completing a task. Can be done early or late in design process.	Thematically analyzed audio and video transcripts to bring forward to new iterations.	Requires experienced evaluators to design tasks that will detect problems and a sufficient number of participants to reach saturation with problem detection.
Cognitive walkthrough [57]	Give a user a task to evaluate whether an interface is easy to learn.	Use when evaluating "walk up and use" systems that should not require detailed explanations to operate (e.g. cash withdrawal machine, parking metre, train ticket kiosk).	Description of design issues and usability problems.	May not be as effective if user will use system more than once.
User requirements analysis [68,69]	Study of actions and cognitive processes required for a user to achieve a task.	Use when project requires an understanding of the current system, the information flows within it, problems for people, and opportunities that indicate user needs.	Detailed descriptions of high-level tasks, flow chart of system organization, logic model showing inputs and outputs, description of sequence of human activities.	Requires experienced evaluators to design tasks that will detect problems and a sufficient number of participants to reach saturation with problem detection.
Surveys [57,69]	Either a questionnaire or interview administered by the user designer or designer.	Use earlier in design process to gain large volumes of information from user groups to facilitate in-depth focus groups or interviews.	Self-reported personal characteristics of user group.	Self-report instruments don't always yield accurate reflection of true thoughts and feelings.
Card sorting [57]	Give small groups of users (3 – 5 people) cards to sort (30 – 100) and observe how they organize content.	Use when project requires an understanding of how users group things into categories.	Understanding of how users group things into categories and relate things to one another.	Complicated to moderate, rigour of method depends on rigour of analysis
Personas [18]	Takes information gathered from user studies (e.g., interviews, designer's own experiences, and other sources) to create a composite user.	Defined in early stages of a project and used throughout the design process. Use when direct user involvement is not always appropriate, complex, or demographic features create barriers (e.g., children).	Provides a concise description of a user's characteristics and what their goals are. Helps designers, developers, and stakeholders understand and focus efforts to suit each persona's needs.	Can include an excess of assumptions or biases if real user data is not readily available. Sometimes limits real-user input into designs until far into the project.
Journey Mapping [70]	Add a time dimension to personas, showing a user's experience with a product/business/workflow over time. Maps the user's needs, expectations, thoughts across many phases.	Used in early stages of a project to understand the user's context, define product touch points and opportunities.	A visual representation (map) of a user's experience with persona (and other) elements integrated.	A map is only as good as the data it is based on, and so can be subject to assumptions and biases.

Figure 2.5: Overview description of HCD methods, their intended uses, and potential weaknesses. (Babione *et al.* 2020)

Chapter 3

Methods

In order to answer the research questions listed in Chapter 1, multiple research methods including qualitative and quantitative were used. Here's a modified double diamond model (*What is the framework for innovation?* 2015), including methods that the author had used for data collection and analysis. Appendix A.13 demonstrates the research project plan in 5 months for a single person.

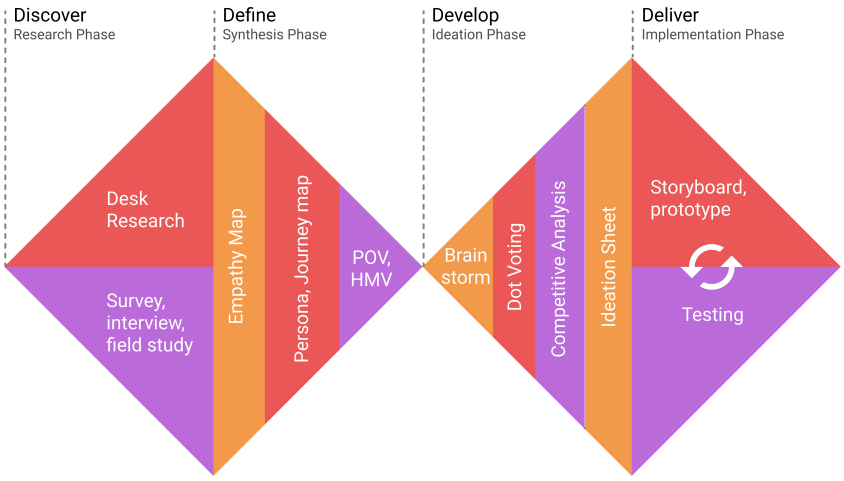


Figure 3.1: Modified double diamond model

3.1 Sampling Methods

There are three samples included in this study. Sample 1 includes midwife, paediatrician, paediatrician nurse, neonatologist, obstetrician, anesthesiologist, anesthesiologist nurse, and other medical staff who have received newborn resuscitation training and have clinical experience in newborn resuscitation. Sample 2 includes medical students who have received newborn resuscitation training and possibly with clinical experience. Sample 3 includes some colleagues from Laerdal Medical in Stavanger. The sample has been collected using convenience sampling, snowball sampling and purposive sampling methods. Convenience sampling, also known as grab sampling or accidental sampling, means that participants are recruited if they are available and willing to participate without any criteria (Leedy and Ormrod 2015; *Convenience sampling* 2020). Purposive sampling means people are chosen for a particular purpose or criteria (Leedy and Ormrod 2015), in this case, the criterion will be having relevant knowledge and experience of newborn resuscitation. Purposive sampling and snowball sampling method have been used on sample 1 and sample 2. The researcher has posted advertisement on facebook page, NTNU bulletin board and St.Olavs hospital intranet. The researcher has also contacted several program leaders at different universities, department managers at different hospitals and asked them to recruit participants. The researcher has also asked some participants to recommend other relevant participants. Incentives of gift card have been added as motivation for people to join the study. Convenience sampling has been applied to recruiting some colleagues from Laerdal Medical for the initial prototype testing.

The number of participants required varies among different methods. Ideally, data collection should continue until it reaches a saturation point at which no more new insights emerge, however, in reality it is always restricted by the available resources. For the survey, a sample size of more than 60 is recommend, while for the interview it's six to ten for each user group, and for a qualitative usability testing 3-15 (Baxter 2015).

3.2 Discover

3.2.1 Survey

Survey can collect large samples of data in a short amount of time. Therefore, a survey has been considered to discover some patterns before the interview, so that the author can better formulate the interview questions based on the findings from the survey results. The survey was drafted in English on created on Nettskjema [1], and have been sent to Jon Sverre Langaker, a nurse student at NTNU, for collecting feedback, then slightly modified and translated into Norwegian. The

[1] https://www.uio.no/tjenester/it/adm-app/nettskjema/

survey has been slightly modified several times after release. To reach out to the sample, the survey has been shared on facebook page [2], NTNU bulletin board, St.Olavs hospital intranet channel, medical students from NTNU and medical staff from Stavanger University Hospital. Please see Appendix A.2 for the survey questions.

The survey questions can be categorised into three parts, namely demographic characteristics of the participants, clinical experience and simulation training experience. Questions change based on the participant's answers. For example, if a participant indicated that he/she doesn't have clinical experience, then no follow-up questions related to clinical experience will appear.

3.2.2 Individual Interview

The interview has been conducted in a semi-structure way, in this way, a set of questions has been prepared beforehand (Appendix A.4). Semi- structure interview allows the researcher to follow the questions guideline while remains a certainty of freedom. The questions were general at the beginning and then more detailed, and they were adjusted based on different roles of the sample. The interviews have been mostly conducted online considering the restrictions of corona virus, and a few face to face in the hospital. One advantage of doing the interview face to face is that the participant can demonstrate some physical artifacts to the researcher. At the end of the interview, the researcher has drawn an empathy map and journey map with the participants. When there was not enough time to finish empathy map and journey map during the interview, the author finished it alone after the interview.

An empathy map (Figure 3.2) can create a better understanding of the users. A typical empathy map has 4 parts, Says, Thinks, Does, and Feels, with the user or persona in the middle (Sarah 2018a).

[2] https://www.facebook.com/misheky

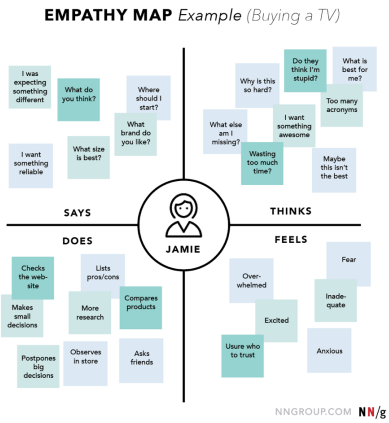


Figure 3.2: Empathy Map example from nngroup.com

According to NNGroup's definition, "a journey map is a visualization of the process that a person goes through in order to accomplish a goal"(Sarah 2018b). In a journey map (Figure 3.3) there are usually five key components, namely actor, scenario, journey phases, actions, mindsets, and emotions, and lastly opportunities. Actor is the persona who experiences the journey. Scenario gives context on how the actor conducts a task and his/her goals. Journey phases describes the different stages in the journey. Actions, mindsets, and emotions are the behaviours, thoughts, and feelings that the actor has throughout the journey. Opportunities are insights gained from mapping.

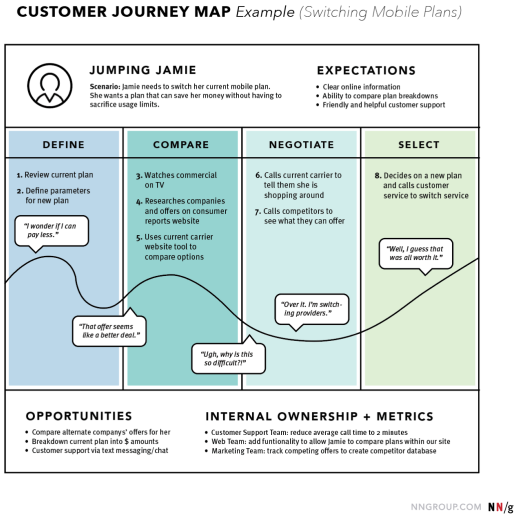


Figure 3.3: Journey Map example from nngroup.com

During the interview, the researcher has recorded the video or audio based on the

participant's agreement. After interviews, the audio record has been transcribed to text, while the body language from the video recording has be analysed, and the original videos have been deleted once they have been transcribed. If it's not allowed to record the video, the researcher has taken the notes herself or asked others to take notes, and the interview notes have been sent back to the participants to see if they want to correct the notes.

Ideally the researcher will continue the interview process until it reaches a saturation stage, which means there are no more new insights of the interests can be found from the interview. However, due to the time limit, the research has to end the interview process so that she still has time to finish the project within the deadline.

3.2.3 Field Study

Field study, also called field research, is to go out of the office or laboratory and observe the users in their natural environment. Field study is a valuable method for the researcher to understand how users interact with the things around when they conduct their tasks (*Field research* 2021; Farrell 2016). However, in this study, due to the difficulty of getting approved by REC and corona restrictions, the researcher was not able to observe the resuscitation in the clinical settings or the simulation training. But the researcher has the chance to visit the resuscitation room at Gjøvik hospital and Stavanger University Hospital (SUS) when she conducted the interviews at the hospitals. During the visits, a doctor or a nurse showed the researcher around the room and briefly introduced the equipment and checklist they used during resuscitation. The researcher was allowed to take pictures of the room and to keep a copy of the checklist.

3.2.4 Data analysis

The survey data was collected through online survey platform Nettskjema and downloaded in excel sheet. The original data was in Norwegian and then translated by the researcher into English.

The answers from the last two open questions in the survey and the interview notes were read through by the researcher several times to obtain an overview. Some categorise were developed based on previous literature review, survey questions and interview questions, such as "how healthcare professionals (HCPs) perform newborn resuscitation","different roles in the clinical event","brief","debrief","training" and so on. More categories and subcategories were developed during coding process, through inductive reasoning. The interview notes were divided into small pieces of meaning units, abstracted and labelled with a code. Similar or related codes were grouped under same subcategories, subcategories were then grouped under categories or themes (Leedy and Ormrod 2015, p. 320). Due to the vagueness nature of language, some meaning units can be given multiple codes(Graneheim

and Lundman 2004). This coding process helped the researcher to retrieve information across different interview notes to create persona, empathy map and journey map.

The researcher has grouped the demographics information from the survey and interview under five user groups. This information was used to create five personas for five user groups. The researcher has grouped "pediatrician" and "neonatologist" into one group "pediatriton", "newborn nurse", "intensive care nurse" and "NICU nurse" into one group "NICU nurse", because their roles are quite similar and neonatologist is only involved in the more complicated case. The researcher has also combined "midwife", "nurse assistant", and "obstetrician" into one group "midwife", the reason is that obstetrician rarely involved in the neonatal resuscitation, and the nurse assistant's role and midwife's role are quite similar during the resuscitation, and the researcher hasn't been able to interview any nurse assistant.

3.3 Define

3.3.1 Persona, Empathy Map and Journey Map

A persona is a fictional individual who describes a group of specific users. It can help the team feel connected to the end-users and focus on the same target during the product development (Baxter 2015). The persona has been build from information extracted from interview notes and survey results.

In the interview, the researcher has already drawn a draft of journey map and empathy map with the interviewee, but these journey maps and empathy maps were created based on each single user, not the persona, which represent a group of users who shares some similar characteristics. So the researcher combined multiple individual empathy maps based on the same roles. Information from the interview and survey was added into the empathy maps.

Based on the interview notes, the researcher has identified 4 different scenarios in neonatal resuscitation and created 4 journey maps for these scenarios. The researcher has included different users in one journey map instead of creating a journey map for each type of user, because in the previous way, it can demonstrate how different roles collaborate with each other to deliver a high quality resuscitation. However, in this way, the researcher felt it more difficult and unnecessary to include the emotion curve and thoughts in the journey map. And the thoughts of each role could be found in the empathy map. Also, during the interview when the researcher asked about their emotion changes in the event, they felt difficult to describe their emotions. The common pattern that they mentioned were that they need to especially concentrated on the tasks and felt stressed. If the baby's health condition improved, they felt relieved and if not, they were sad

and concerned about the baby and wondered if they had done something wrong. Therefore, the researcher decided to only inculde the action part in the journey map, which makes it look similar to a task analysis.

3.3.2 Point of View and How Might We

The researcher has chosen 2 main difficulties to focus based on how frequently it was being mentioned, its possible contribution and the feasibility to solve. Then the researcher framed the difficulites into some actionable problem statements using positive pressure ventilation (POV), which gave the researcher a deeper understanding of the users and their intrinsic needs. To write a POV, the researcher used this template: [User... (descriptive)] needs [Need. . .(verb)] because [Insight. . . (compelling)]. And it should be neither too broad or too narrow(Dam and Siang 2020).

After finishing writing the POV problem statements, the researcher translated 2 POV into 2 How Might We (HMW) questions, which can evoke an innovative thinking and allows finding different answers. HMW questions were served as the launchpad for brainstorming, in this case, it shouldn't be neither too broad or too narrow, so that it is manageable while leave space for wild ideas (IDEO 2015; Dam and Siang 2020).

3.4 Develop

3.4.1 Co-creation Workshop, Brainstorming and Dot Voting

The researcher has invited 2 participants to an online workshop on Microsoft Teams. The goal of workshop was to validate the previous findings, generate some possible solutions and to select the most promising ones for further development.

To prepare for the workshop, the researcher has drafted a plan(Appendix A.6), and created a mural board for co-creation(Appendix A.5). The mural board mainly has three sections, namely problem statement, brainstorming and voting sections. The researcher has mind-mapping to explore different ideas alone before the workshop, and put her ideas into the mural boards. The researcher's ideas were hided from the participants before each brainstorming session. The researcher had briefly demonstrated the workshop with one friend as well as the supervisor beforehand to receive feedback, and some changes were made based on the feedback.

In the workshop, the researcher first shared the four scenarios to the participants and see if they had any disagreements. Then the researcher shared the link of Mural board to the participants and asked them to join. The researcher explained

the first problem statement and how might we questions, and the brainstorming rules(IDEO 2015, p. 95), namely defer judgement, go for quantity, build on ideas of others, stay on topic and encourage wild ideas. Be visual wasn't chosen because the participants don't have sketch experience.

After that, the researcher asked each participant to get a sticky note to write down his/her name, so that they could get familiar with the tools in Mural. And then the researcher set a 5 minutes alarm for a brain storming session. The participants kept writing ideas on sticky notes. After 5 minutes,everyone, including the researcher, shared and explained his/her ideas to the rest of group. Then the second problem statement and HMW question was introduced and participants were asked to brainstorm solutions for 4 minutes and then share ideas. Due to the time limit, there was not enough time for a second round of brainstorming for each problem statement and HMW question. And the researcher will group similar ideas together after the workshop.

After the brainstorming, the next step is to reduce the amount of ideas. Dot voting is a great tool to quickly reach agreement in a group. Before the vote, the rules of voting were introduced. The voting followed three criteria: new, useful and feasible, which is also called NUF test(Gray *et al.* 2010, pp. 244–245). Each person had up to 5 votes for each category represented with different colours, they voted for ideas that matched the criteria most. There were two voting sessions since there were two groups of ideas, and each round of voting had 5 minutes. Timer will be set during the voting, however, since the participants were not familiar with the voting, more time was given until all votes were used. During the voting, the participants lost track of how many votes each of them used, which means, some used more than 15 votes while some used less. The reason might be that the rules were not clearly explained before the voting. Again due to the time limit, the participants didn't pick 3-5 ideas with the most votes and share the reasons why they liked about them (Idean 2019, pp. 76–77).

The workshop session was recorded, and consents were collected before recording. After the workshop, the video recording was transcribe into text for analysis.

3.4.2 Bundle ideas

Since lots of ideas have been generated from the brainstorming workshop, the researcher used bundle ideas method to group some similar ideas together, and combined groups into more complex concepts. Then the researcher chose the groups that had more votes and combined them into more complex concepts or solutions. In the process different combination can be experimented. The essence is to take the best part of each idea and leave the bad parts (IDEO 2015, p. 97).

3.4.3 Competitive Analysis

Looking at existing similar products can give us inspiration. After the idea was built up from dot voting and bundling ideas, the researcher has chosen several competitors for a competitive analysis. Two kinds of competitors have been included in this analysis, namely primary competitors and secondary competitors. Primary competitors share the most common features and compete directly against your product, such as Liveborn (from Laerdal Medical) (*Liveborn* 2021) and Laerdal newborn resuscitation monitor(Linde *et al.* 2017), while secondary competitors are those that have fewer features in common and don't compete directly, such as some respiratory monitors (Baxter 2015, p. 33).

The author has included the features, strengths, weaknesses, user base and anything that can be learned from the competitors, as shown in the sheet in the book (Baxter 2015, p. 34). The author has experienced the product Liveborn app directly, because it's free to download on iPad and iPhone. But this was not possible for all of the remaining competitors, as some are not commercially available, like the Laerdal newborn resuscitation monitor, Augmented Infant Resuscitator (AIR) (Patterson *et al.* 2020), NeoCue(Fuerch *et al.* 2015) and MedNav(Duffy *et al.* 2017), others were too expensive and unnecessary to buy, like Monivent Neo100(*Monivent Neo100* 2021) and NeoBeat(Patterson *et al.* 2020), therefore most of the information were obtained from research papers and online websites.

3.4.4 Ideation Sheet

The final idea was articulated with ideation sheet methods. An ideation sheet has been used to specify ideas by describing them in detail and even with illustration. On an ideation sheet, the researcher wrote down the opportunities that the idea could create, problems that were solved as well as the requirement for implementation(Opsahl *et al.* 2019). In this way, an ideation sheet demonstrated clearly how the products will be used in an actual scenario.

3.5 Deliver

3.5.1 Mind map and the Application Structure

Mind map is a very useful tool to showcase the relations between different pages and the contents within an application (*How to Create Information Architecture for Web Design* 2018). It takes little time and effort to draw, and it's very easy to make changes, it's like a simplified site map [3]. The structure of the application was inspired by some competitors, and using a tool called Xmind [4]. It helped the

[3] https://en.wikipedia.org/wiki/Site$_m ap$
[4] https://www.xmind.net/

researcher to clarify the pages and contents before making the wireframe.

3.5.2 Storyboard

Storyboard is a quick way to visualize the concept, to help refine your idea and understand your users, and how they will use your product (IDEO 2015, p. 113). Before drawing a storyboard, the researcher has written down a scenario, describing people who are involved, when, where and how they will use the new solution. From the previous research the researcher has found 4 main scenarios, however, the differences between expected case and unexpected case were quite prominent, therefore, the researcher decided to focus on the most common one first, which was the expected case in the delivery ward, and then explore the opportunities to adapt it to the other scenarios. To draw the storyboard, firstly the researcher divided the scenario into several scripts, then she sketched them on iPad, and finally arranged them one after one like a waterfall in Figma [5], so the user can focus on one scene and scroll vertically to look at the next one. The researcher has also included some questions that the researcher wanted to clarify with the users in the storyboard.

The storyboard is a useful and efficient tool to validate your idea with stakeholders and users, especially when your idea involves complicate products or a service. The storyboard makes it easier for the users to imagine how your products can become a part of their lives (**noauthor_show_2018**; Spalton 2019). The storyboard has been tested together with a prototype in a workshop with some medical staff.

3.5.3 Wireframe and Medium-Fidelity Prototype

Wireframe is a low-fidelity prototype. It is the skeleton of a design that contains the most essential elements and contents of a website or app, including the page layout, navigation system and functions (Mkrtchyan 2018). It is a very valuable and low-cost tool to test out the idea before developing a high-fidelity prototype. The researcher decided to draw the wireframe by hands first because it's much faster and easier. When drawing a wireframe, the researcher focused mainly on the navigation, layout and functionality, and didn't spend much time on color, styling or graphics because these were the tasks in high-fidelity prototype (HANNAH 2021). The page layout was designed based on the information architecture diagram, which shows the priority of different elements on each page. Page was divided into large blocks and then filled with details. The process of drawing wireframe helped the researcher establish the user flow of the solution (*What is Wireframing?* 2021).

However, a wireframe, which contains too little information about the solution,

[5] https://www.figma.com/

was not appropriate to be tested with end users because it will require lots of explanation from the researcher and imagination from the users (Babich 2018). Therefore, after finishing the wireframe, the researcher created a medium-fidelity prototype using a prototype tool called Figma. The aim of a medium-fidelity prototype was to test it in a workshop with users in order to collect their thoughts of the possible solution. A medium-fidelity contains slightly more details than a low-fidelity prototype and looks closer to the final product, but fewer details than a high-fidelity prototype, therefore it takes less time to make it and cause less pain when big changes are needed to make (Dam and Siang 2021). When making the prototype, the author tried to limit the use of color and icons so that the users can focus more on the functions instead of visual aesthetics. And since the goal of the prototype was to validate the idea and collect feedback for improvement, a too good looking prototype can hide the flaws and discourage the users for giving honest feedback (McKay 2013, p. 271).

Prototype was designed based on the apple design guidelines (*Themes - iOS - Human Interface Guidelines - Apple Developer* 2021). The content was inspired by some competitors and the registration form of newborn transferred to NICU in SUS (Appendix A.3.2). The whole brief page and checklist were designed based on the checklist in Katheria *et al.* (2013) and S. C. Bennett *et al.* (2016).

3.5.4 Testing workshop

The researcher has drafted a plan(Appendix A.7) for the preparation of the workshop and had briefly run the testing workshop with a classmate to test some practical issues.

Two participants from the previous brainstorming workshop, one neonatologist and one anesthesiologist, participated in a testing workshop where the researcher shared the storyboard and key interfaces of the prototype and asked for feedback. When drawing the storyboard, the researcher had questions about how different people stood around the resuscitation bed, when they weighted the baby, the reason that they needed to give iv. access to the baby and so on. And when the researcher were making the prototype, the researcher had different ideas and created multiple versions for some pages. Therefore, the goal of the testing workshop was to answer the questions in the storyboard, and to figure out which version of the pages they prefer. Besides, the researcher also wanted to know which part of the solution they liked and which part they disliked, what could be the potential problems that the solution can cause.

The testing workshop with the neonatologist was conducted in the main entrance of SUS. The researcher chose to do the testing face to face was because in this way, the researcher can present the prototype on the iPad to the user, which was closer to the final product. Another consideration was to prevent the possible tech-

nical problems with remote testing. The participant was presented with the storyboard first, and then the prototype. And considering the goal was to validate the concept, the researcher didn't make everything clickable in the prototype. Because of the limited interactive elements, the researcher clicked through the prototype and showed them the interfaces instead of letting them to explore the prototype. Questions related to specific pages were asked when showing the prototype. Afterwards, more questions were asked regarding the whole design concept. The procedures in the testing workshop with the anesthesiologist were similar, except that it was conducted online with Microsoft Teams. The anesthesiologist has been informed about the technical requirements, a PC with internet connection, before joining the workshop.

Both workshop sessions were recorded, and consents were collected before recording. After the workshop, the recordings were transcribed into text for later analysis.

3.6 Ethical and Legal Considerations

The researcher has applied for a project evaluation at Regional Komiteer for Medisinsk og Helsefaglig for Forskningsetikk (REK) [6] and has received answer stated that the current study did not need to apply for approval from REK, please see Appendix A.14 for the assessment. The researcher has applied fro approval from Norsk Senter for Forskningsdata (NSD) [7] for collecting personal data and have been granted the approval. No health information or human biological material have be collected in this study.

Personal data have be collected through interview, survey, workshops and testing through image, audio and video recording. Nettskjema[8] from UiO is an anonymous online survey platform and has be used to create the survey form and collect response. The personal data have only be used for the purpose of the master thesis. The data have be processed confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act). Participants will not be identified in any reports on this study. The personal data have be anonymised after collecting and been stored in strict confidentiality, in an encrypted drive. The consent form will be stored in a locker at NTNU, only the researcher and supervisor have access to the data. All data have been stored and process only in Norway. The persona data, except for the consent form, will be deleted after the project is over, at 22.06.2021. But the consent form with the signature will be deleted at the latest 31st December 2023.

All participants have been informed of the study and asked to sign a consent form

[6] https://rekportalen.no/
[7] https://www.nsd.no/
[8] https://www.uio.no/tjenester/it/adm-app/nettskjema/

before data collection (Appendix A.8). Participation is voluntary and participants can withdraw at any time without giving a reason. There will be no negative consequences for participants if they choose not to participate or later decide to withdraw. The participant has the right to change, withdraw and view his own personal information at any time.

The possible risk for the participants might be the leak of personal data. If any data leakage happened, the researcher will notify the data controller to minimize the damage. Some questions about the previous resuscitation experience during the interview might cause stress or uneasy to the participants, but the participants have been notified that they didn't need to answer any questions if they didn't feel comfortable. The potential benefits for the participants are the contribution to a solution that have the potential to improve the clinician's neonatal resuscitation performance.

Chapter 4

Results

In this chapter the researcher will present the results and main findings from the methods previously applied in this study.

4.1 Discover

4.1.1 Survey

The researcher has received 60 valid submissions, among these 47 (78.33%) submissions came from doctors or nurses at various hospitals in Norway, 13 (21.67%) submissions from medical students or nurse students at NTNU. Since the data from the medical students haven't been used in the later study, therefore, the researcher decided not to show them here.

Demographics

Demographic characteristics of the doctors and nurses are shown in Figure 4.1, including titles, working experience and which health trust (helseforetak in Norwegian) they belong to. health trust (HF) is a health enterprise in Norway, one health trust is responsible for one or more hospitals (*Health trust* 2014). 34.04% (16) of participants have working experience for more than 12 years. 42 out of 46 participants work in a hospital that can treat infant with gestational age (GA) less than 28 weeks. 3 work in a hospital that can treat infant with GA between 28-35 weeks, 2 work in a hospital that can treat infant with GA more than 35 weeks. The majority of participants come from two HFs, St. Olavs Hospital and Stavanger University Hospital (SUS), given a reason that the survey was mainly distributed in these two HFs, it's not surprising that we got this resutls. 12 people were from Helse Midt-Norge regional health trust (RHF). Based on the list of all HFs in Nor-

way [1], Helse Midt-Norge RHF is actually a RHF, the same as Helse Sør-Øst RHF. The author assumes that some participants from St. Olavs Hospital HF might mix the concepts of HF and RHF and gave the wrong answers. If so, then it means half (25, 53.19%) of the participants come from St. Olavs Hospital.

Characteristic	Participants (n=47)
Title	
nurse	8
intensive care nurse	8
nurse assistant	5
Pediatrician	4
LIS 1	4
midwife	3
anesthesia nurse	3
newborn nurse	2
NICU nurse	2
Neonatologist	2
anesthesiologist	2
obstetrician	2
doctor	1
ENT resident	1

(a)

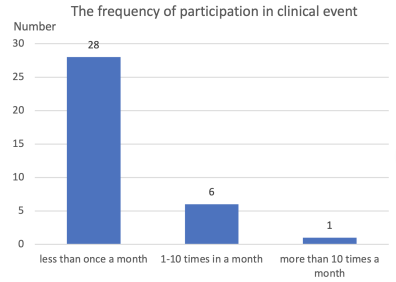
Characteristic	Participants (n=47)
Working experience	
more than 12 years	16
0-3 years	13
4-7 years	13
7-12 years	5
Health Trust	
Helse Stavanger HF	13
St. Olavs Hospital HF	13
Helse Midt-Norge RHF	12
Oslo universitetssykehus HF	2
Helse Bergen HF	1
Helse Møre og Romsdal HF	1
Helse Nord-Trøndelag HF	1
Helse Sør-Øst RHF	1
Sykehuset Innlandet HF	1

(b)

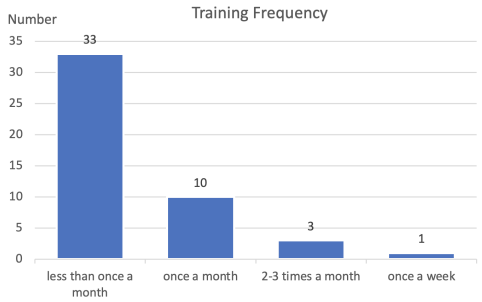
Figure 4.1: Demographic characteristics of participants

Figure 4.2 shows the number of participants with different frequencies participating in the clinical event and simulation training. There are 47 doctors or nurses, all of them have received simulation training. 33 (70%) participants train less than once a month. 74.47% (35) of all the doctors and nurses have clinical experience, among this group, 80% (28) perform newborn resuscitation less than once a month.

[1] https://www.regjeringen.no/no/tema/helse-og-omsorg/sykehus/innsikt/oversikt-over-landets-helseforetak/id485362/



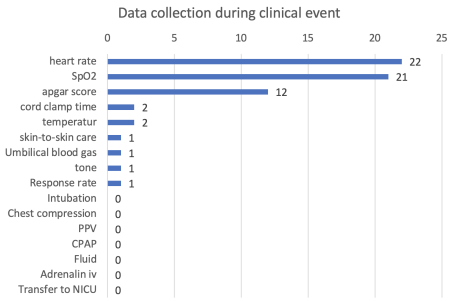
(a) The sample distribution based on the frequency of participation in clinical event



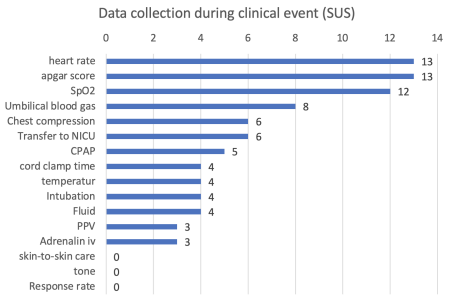
(b) The sample distribution based on The frequency of participation in a simulation training

Figure 4.2

Figure 4.3 shows different data they collected during the resuscitation. Since there were some changes to the options in the version distributed in SUS, the researcher has separated the results into two graphs. Figure 4.3a shows the results from hospitals other than SUS, while Figure 4.3b shows the results from SUS. In the SUS version, options of "temperature", "intubation", "CC", "positive pressure ventilation (PPV)", "continuous positive airway pressure (CPAP)", "umbilical blood gas", "fluid", "adrenaline IV" and "transfer to neonatal intensive care unit (NICU)" were newly added, while "skin to skin" was deleted. From these two graphs, we can see that "heart rate (HR)", "Peripheral Capillary Oxygen Saturation (SpO_2)" and "apgar score" are the three most collected data during the resuscitation.



(a) Data collection during clinical event in hospitals other than SUS



(b) Data collection during clinical event in SUS

Figure 4.3

Following are some demographic data that are grouped based on 5 user groups. These data have been used for creating personas.

Title	age	num	working experience	num	frequency of clinica event	num	frequency of training	num
Neonatologist, pediatrician (n=6)	31-40	3	0-3 years	1	less than once a month	1	less than once a month	1
	51-60	2	4-7 years	1	1-10 times in a month	5	once a month	4
	61-70	1	7-12 years	1	more than 10 times a month	0	2-3 times a month	1
			more than 12 years	3			once a week	0

Figure 4.4: Demographic characteristics of pediatrician and neonatologist

Title	age	num	working experience	num	frequency of clinica event	num	frequency of training	num
nurse assistant, midwife, obstetrician (n=10)	18-30	2	0-3 years	2	less than once a month	7	less than once a month	9
	31-40	5	4-7 years	3	1-10 times in a month	0	once a month	1
	41-50	2	7-12 years	1	more than 10 times a month	1	2-3 times a month	0
	51-60	1	more than 12 years	4			once a week	0

Figure 4.5: Demographic characteristics of nurse assistant, midwife, and obstetrician

Title	age	num	working experience	num	frequency of clinica event	num	frequency of training	num
intensive care nurse, newborn nurse, NICU nurse(n=12)	18-30	2	0-3 years	0	less than once a month	11	less than once a month	9
	31-40	4	4-7 years	4	1-10 times in a month	0	once a month	2
	41-50	5	7-12 years	2	more than 10 times a month	0	2-3 times a month	1
	51-60	1	more than 12 years	6			once a week	0

Figure 4.6: Demographic characteristics of intensive care nurse, newborn nurse and NICU nurse

Title	age	num	working experience	num	frequency of clinica event	num	frequency of training	num
anesthesiologist (n=2)	18-30	1	0-3 years	1	less than once a month	2	less than once a month	2
	41-50	1	4-7 years	0	1-10 times in a month	0	once a month	0
			7-12 years	0	more than 10 times a month	0	2-3 times a month	0
			more than 12 years	1		0	once a week	0

Figure 4.7: Demographic characteristics of anesthesiologist

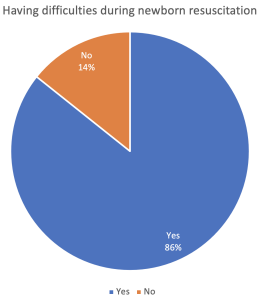
Title	age	num	working experience	num	frequency of clinica event	num	frequency of training	num
anesthesia nurse(n=3)	31-40	2	0-3 years	0	less than once a month	2	less than once a month	1
	41-50	1	4-7 years	2	1-10 times in a month	0	once a month	1
			7-12 years	0	more than 10 times a month	0	2-3 times a month	1
			more than 12 years	1		0	once a week	0

Figure 4.8: Demographic characteristics of anesthesia nurse

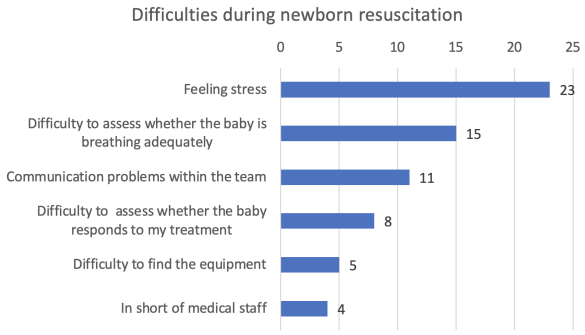
Difficulties in Clinical Events and Simulation Training

34 HCPs who have clinical experience were asked if they have difficulties during newborn resuscitation, 30 (86%) said yes, while 5 (14%) said no (Figure 4.9a).

Figure 4.9b shows the distribution of different difficulties they have during newborn resuscitation, the biggest difficulty is feeling stressed.



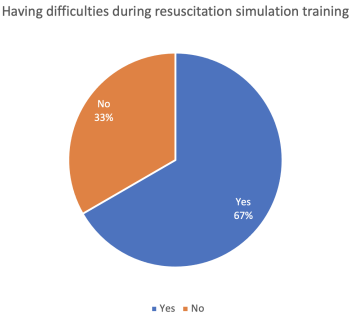
(a) Percentage of HCPs having difficulties during newborn resuscitation



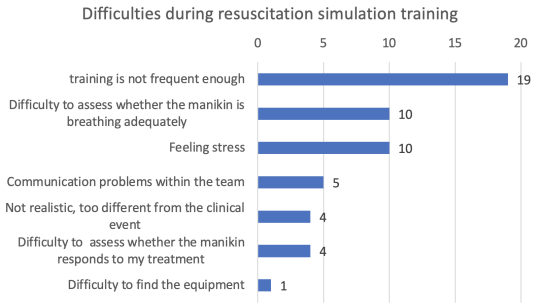
(b) Difficulties that HCPs have during newborn resuscitation

Figure 4.9

Of all 47 HCPs who have received simulation training, 67% answered that they had difficulties during newborn resuscitation simulation training (Figure 4.10a), which was lower than the percentage of HCPs who have difficulties during clinical event. Figure 4.10b shows the distribution of the difficulties during training, which is also slightly different than difficulties in clinical events, with most people mentioning that "training was not frequent enough", and fewer people reported that they felt stressed.



(a) Percentage of HCPs having difficulties during newborn resuscitation simulation training

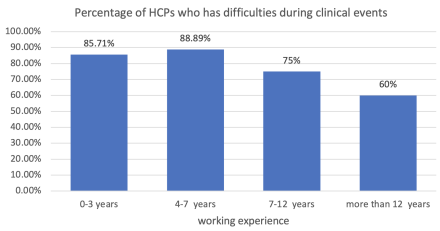


(b) Difficulties that HCPs have during newborn resuscitation simulation training

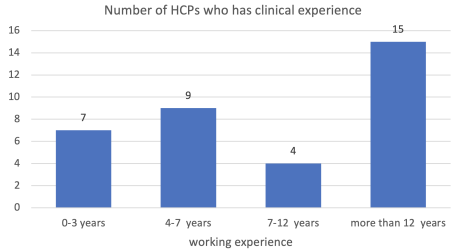
Figure 4.10

When analysing the survey data, two hypotheses emerged. The first one is if a clinician has more working experience, then the likelihood of having difficulty in clinical event is lower. From Figure 4.11a we can see that there is a decreasing

trend that when HCPs have more working experience, then the percentage of having difficulty is lower. However, the numbers of participants in these four groups are quite different. But if we combine the group of "0-3 years" together with "4-7 years", "7-12 years" together with "more than 12 years", then the sample is more evenly distributed. However, due to the small number of sample, we can only infer that there might be a relation between working experience and the the likelihood of having difficulty in clinical event, and this should be further investigated.



(a) Percentage of HCPs who have difficulties during clinical events



(b) Number of HCPs who has clinical experience

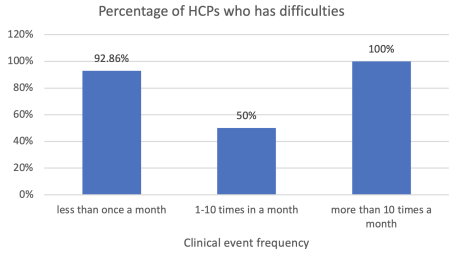
Figure 4.11

The second hypothesis is if a clinician has higher frequency of participating in a clinical event or simulation training, then the likelihood of having difficulty in clinical event is lower. Data of "clinical event frequency", "training frequency" and "whether have difficulty" were coded as shown in Figure 4.12a, and then Kendall's tau correlation analysis was conducted in IBM SPSS [2]. The result (Figure 4.13) shows that there's a weak correlation between the frequency of participating in a clinical event and the likelihood of having difficulty, but no correlation between training frequency and the likelihood of having difficulty. If we look at Figure 4.2a, we can see that most (80%) participants participate in clinical event less than once a month, and 92.86% of this group reported difficulties. Due to the small number of participants who train more than once a month, the researcher decided to reject this hypothesis until further investigation.

[2]https://www.ibm.com/analytics/spss-statistics-software

	Item	Code
clinical event frequency	less than once a month	1
	1-10 times in a month	2
	more than 10 times a month	3
training frequency	less than once a month	1
	once a month	2
	2-3 times a month	3
	once a week	4
having difficulties	yes	1
	no	2

(a) Coding clinical event frequency, training frequency and having difficulty



(b) Percentage of HCPs who have difficulties in clinical event when they have different frequency of clinical event

Figure 4.12

Correlations

			clinical event frequency	training frequency	having difficulties
Kendall's tau_b	clinical event frequency	Correlation Coefficient	1.000	.305*	.385*
		Sig. (1-tailed)	.	.032	.012
		N	35	35	35
	training frequency	Correlation Coefficient	.305*	1.000	.142
		Sig. (1-tailed)	.032	.	.196
		N	35	35	35
	having difficulties	Correlation Coefficient	.385*	.142	1.000
		Sig. (1-tailed)	.012	.196	.
		N	35	35	35

*. Correlation is significant at the 0.05 level (1-tailed).

Figure 4.13: The correlation between the frequency of participating in clinical event, training frequency and likelihood of having difficulties in clinical event

Suggestions for Clinical Event and Simulation Training

When asked about their suggestions on how to improve the newborn resuscitation, the most mentioned suggestion is to have more training individually or in teams (Figure 4.14). As one stated, "regular simulation, makes you feel safer when you get into the situation." The second suggestion is having better team cooperation, namely be clear on the roles and expectation, clear communication and secure team culture. Besides, they also want to have objective feedback and to brief in advance more often.

When asked about their suggestions on how to improve the newborn resuscitation training, the most mentioned suggestion is to have more frequent training (not specified in team or individual). One participant answered:"the important thing is the frequency of simulation. Must simulate often enough to be confident in the algorithm." The second suggestion is to have training cases that are more realistic, to receive more background information about the child and delivery, and to have

tranings on things other than mask ventilation and CC, such as giving fluids and blood gases. The third most popular suggestion is to have more frequent training in a team setting.

Name	Files	References
Suggestions for clinical event	1	29
training	1	14
team	1	7
Objective feedback	1	3
Brief in advance more often	1	2
automatic data collection	1	1
check equipment more frequently	1	1
Debrief more often	1	1
Suggestions for simulation training	1	28
frequent simulation training	1	15
real cases	1	4
frequent simulation training in team	1	3
equipment	1	2
simulate in the actual resuscitation room	1	2
feedback on progression	1	1
more time for training	1	1

Figure 4.14: Frequency of suggestions for clinical event and simulation training being mentioned in the survey

4.1.2 Field Study

Based on the description of one midwife at the Gjøvik Hospital, the Gjøvik Hospital has around 650 deliveries annually, and is a hospital that only treat healthy mothers, and infant with GA more than 35 weeks. Mother with high risk factors or infant with GA less than 35 weeks will be transferred to Lillehammer Hospital or Oslo Hospital. And they only have pediatrician for emergency during the day time, when the pediatrician is not available, they get help from anesthesiologist.

SUS has around 4600 deliveries annually, and can treat infant with GA $\geq$ 23 weeks. The department of obstetrics has a low-risk delivery unit run by the midwife, a general labour ward and two operation theatres. Each of the places mentioned above has a resuscitation room, during c-section, the resuscitation room is right next to the operation theatre, while in the normal delivery, the distance between resuscitation room and the delivery ward is between 3 and 20m (Bjorland, Øymar *et al.* 2019; Bjorland, Ersdal *et al.* 2020).

Figure 4.15 and Figure 4.16 show the resuscitation room in Gjøvik Hospital and SUS respectively. The main equipment in the resuscitation room is a resuscitation bed, which has basic functions like light and radiant heater. In Gjøvik Hospital they

use Lifetherm resuscitation units [3] while in SUS they use Panda bedded warmer [4]. The Panda bedded warmer is more advanced, which has a digital screen, timer, control panel for suction, ventilation pressure and oxygen blender other than light and radiant heater. It can also measure electrocardiogram (ECG) and SpO_2. Here are two videos showing how to use Panda warmer [5].

Other than the resuscitation bed, there are ECG monitor, T-piece (Neopuff) and bag-mask ventilator, oxygen blender, equipment trolley, registration form or checklist (Appendix A.3), Norwegian Resuscitation Council (NRR) guideline poster, stethoscope, and NeoBeat (in SUS).

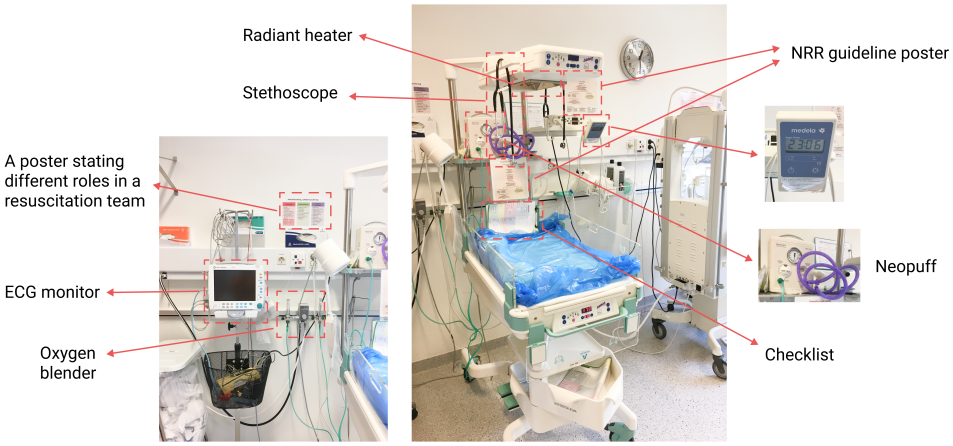


Figure 4.15: Resuscitation room in Gjøvik Hospital

[3] https://hul.de/uk/produkt/lifetherm-resuscitation-units-2/
[4] https://www.fusionhealthcare.com.au/files/PandaFamilyBrochure.pdf
[5] https://www.youtube.com/watch?v=boDGbnfAHn8, https://www.youtube.com/watch?v=0pDCNg9q7d4

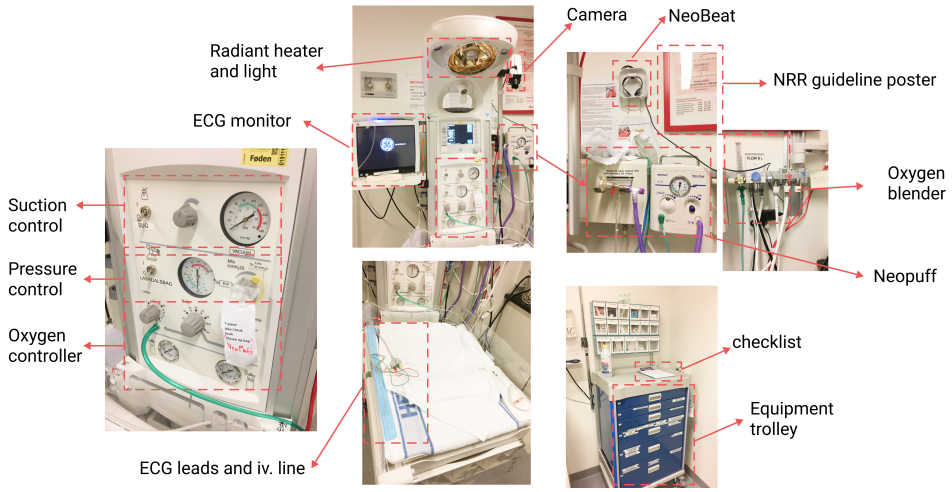


Figure 4.16: Resuscitation room in SUS

4.1.3 Interview

The researcher has conducted 11 interviews with doctors and nurses from different hospitals, most of these participants were from SUS, except one intensive care nurse from the St.Olavs Hospital in Trondheim, one anesthesiologist from Tromsø University hospital, and two midwives from the Gjøvik hospital. The interviews with two midwives from the Gjøvik hospital were conducted in the early exploratory stage.

Difficulties in Clinical event

The researcher has ranked different categories of difficulties in the clinical event by the frequency (as shown in Figure 4.17).

Name	Files	References
difficulties in the clinical event	10	77
difficult to get sufficient air into the lung	8	30
communication difficulty within the team	7	18
feeling stress	7	16
difficulty to find the equipment	3	5
in short of medical staff	2	3
difficulty to gather objective information	2	2
too few practice	1	2
not familiar with the equipment	1	1

Figure 4.17: Frequency of different difficulties in clinical event being mentioned in the interview

Following are the three main difficulties:

1. Difficult to get sufficient air into the lung or provide sufficient ventilation

To provide sufficient ventilation or getting enough air into the lungs is the most important but most challenging part. The main reason causing this difficulty is the difficulty to assess the baby's condition and thus make adjustments. To look at the chest movement is a fast but not an easy way, because the baby is very tiny, and it's not always lying still when people around are trying to stimulate the baby and to put on ECG leads and SpO_2 monitor. Another way is to use a stethoscope to see if they can hear air going back and forth into the lungs. But sometimes it's very difficult, especially if there's lots of fluid in the lungs. As one neonatologist mentioned, "It's easy when you hear the sound of lung, but maybe sometimes you cannot be quite sure. But that for me is then it means that it's not enough." So if they can't hear the sound, they just accept that the ventilation is not good enough. One more measure is to look at HR and SpO_2 number, the rising numbers usually indicate an effective ventilation. However, it's not easy to attach ECG electrodes or SpO_2 monitor to the baby, and it takes several minutes for ECG and SpO_2 monitor to provide reliable numbers. Airway blockage and mask leakage can lead to little air going into the lungs. Too low ventilation pressure is also not able to inflate the lungs. And it's very difficult to discover the mask leakage since there's no feedback from Neopuff or bag mask.

2. Communication Difficulty

The second main difficulty is communication problem within the team, which is mainly caused by the unwell defined roles or tasks. Very often, a pediatrician will start to ventilate the baby right away, and forget to assign tasks to the people around, which can cause confusion and stress in the team. In most cases this won't necessarily lead to a bad outcome for the baby, because most babies just need ventilation for several minutes, so as soon as the pediatrician is giving adequate ventilation, then the outcome will be good. Also, some tasks are closely binded to the roles, for example, the pediatrician or more experienced person will be in charge of airway. NICU nurse or nurse assistant are in charge of putting on the ECG and SpO_2 monitor. But anything other than this varies based on the case, therefore if the task is not given clearly, time might be wasted on doing something unnecessary. As one NICU nurse said:"It could be just little tiny things like that where you end up opening something that he doesn't want."

However, when the situation escalates and more treatments are needed, a good collaboration in the team is crucial to the final outcome. As one neonatologist mentioned:"But as soon as it's chaotic if you don't get to ventilate, and the newborn is not responding and you have to start with CC and iv access and so on,

then it's chaos. and the most of the simulations I attended are those situation." Some participants suggest that the pediatrician let other people, such as anesthesiologist, NICU nurse or midwife to handle the ventilation, so the pediatrician can stand aside to observe the situation and assign tasks to different people. But since the pediatrician is so used to the role of ventilation and not sure about other people's competence, and ventilation is the most important part in the resuscitation, they feel reluctant to let others ventilate. A neonatologist mentioned another difficulty that it's not easy to assign role because after a while more experienced people will come in and maybe take over the role as a team leader.

Another main reason causing the communication difficulty is that the messages are not given loud enough or given to the right person, and there is not always a closed loop within the communication. No one realized that something has been done when it's not been verbalized, and this makes it more difficult for them to follow the guidelines. The lack of closed loop communication (CLC) happens more often with the less experienced fellow, especially under a very stressful situation. In this case, a highly dedicated team leader is needed to administrate the messages.

3. Feeling stressed

In a highly intense situation like neonatal resuscitation, it's no wonder that so many people feel stressed. A little stress increase focus on the task. Too much stress, however, can make the HCPs lose the overview of the situation, and make sub-optimal choices. The reason causing stress is the high expectation that there should be no delay or no mistakes. And they feel more stressed in an unexpected case when they are less prepared or if they haven't attended a resuscitation for a long time. Other reasons are various challenges in the resuscitation, for example, the difficulty to provide sufficient ventilation and team communication problems.

Factors that can contribute to a good outcome or a bad outcome

Figure 4.18 shows the list of different factors that can contribute to a good outcome or a bad outcome of clinical event.

Name	Files	References
factors contribute to a good outcome	9	46
good team cooperation	7	18
preparation beforehand	4	11
data	4	7
training	4	4
prompt and adequate ventilation	3	3
a little stress is positive	2	2
seeing lots of newborns increase the confidence of assessing the breathing of newborn	1	1
factors contribute to a bad outcome	6	16
Fail to provide adequate ventilation	4	5
people lack of the skill, not familar with the roles, equipment and environment	1	4
uncontrollable factors	3	4
insecure team atmosphere	1	1
not able to plan beforehand	1	1
they try to prolong the nighttime delivery to daytime, which can make it worse	1	1

Figure 4.18: Factors mentioned in the interview that can contribute to a good outcome or a bad outcome

1. **Good team cooperation:** To help each other out, switch roles when it's needed, be clear about the roles and expectation, calm and secure atmosphere, clear leadership and good communication.
2. **Preparation beforehand:** Have people ready when a baby is expected to be ill, prepare the equipment and assign roles.
3. **Data:** Objective real-time feedback and automatic data collection.
4. **Training:** Regular training in team or individually.
5. **Prompt and adequate ventilation.**

Here is a list of highlighted bad outcomes.

1. Fail to provide adequate ventilation.
2. People lack of the skills, not familar with the roles, equipment or environment.
3. **Uncontrollable factors:** Severe brain damage or disease.

4.2 Define

4.2.1 Empathy Map, Persona and Journey Map

Persona and Empathy Map

Here are the 5 main personas involved in the neonatal resuscitation, namely pediatrician, NICU nurse, midwife, anesthesiologist and anesthesia nurse, and their corresponding empathy map (Figure 4.24, for clear version please see Appendix A.9).

Name	Anne
Age	45
Title	Pediatrician
Working experience	10 years
Hospital	SUS

> **You stand there and think you ventilate the baby, but actually very little air goes into the lungs, maybe the airways are blocked, or maybe you don't have applied enough pressure to actually inflate the lungs.**

Roles

- Take care of the baby from after it was born until it is discharged
- Team leader, assign roles or tasks to other people
- In charge of airway, eg. ventilation, intubation

Behavious

- Paticipate in a clinical event once or twice a month
- Paticipate in training once a month

Goals

- Provide sufficient ventilation, make sure the baby is healthy and can return to mother as soon as possible
- Be a good team leader, make sure everyone knows their roles or tasks and can work well together. make sure they follow the guideline, make them feel safe in the team.
- Have a objective record of the event, to know what has exactly happened and can review later

Bio

My typical day will be to have a meeting in the morning. When a baby is expectedly ill, we will wait in the resuscitation room and check the equipment. Sometimees the baby is fine and we just leave. Around 1/3 of the cases we have encountered are unexpected, then we are called by the pager and then rushed to the room. In this case, it can be a bit chaotic and stressed. I will take over the airway, try to understand the situation as quickly as possible, and assign roles to other people at the same time.

Pain Points

- Difficult to give sufficient ventilation
- Difficult to take care of the airway and assign roles at the same time
- There are always new people come to help, which makes it difficut to assign roles
- Often forget to stimulate before ventilation
- When they call us on phone, sometimes they call the wrong team
- No objective data showing minute by minute, only narrative description of the event
- Very little training on team leadership

Photo: Colourbox.dk/#228350

Figure 4.19: Persona of pediatrician

Name	Kari
Age	40
Title	NICU Nurse
Working experience	10 years
Hospital	SUS

> **It could be just little tiny things like that where you end up opening something that he doesn't want. So there are some things you know you should do like put on the monitor. but anything other than that, varies from time to time.**

Roles

- Take care of the baby from after it was born until it is discharged.
- Help attach ECG and SpO2 moniter, monitor temperature, find equipment for the pediatrician
- If it's an unexpected case, called by the phone and rush to the resuscitation room with the pediatrician
- Bring the baby to NICU, moniter or give treatments until it's safe to go back to the mother

Goals

- Save the baby, and maske sure the baby is healthy and can return to mother as soon as possible
- Finish my tasks well, assiss the team leader and the team
- Have a objective record of the event, know what has exactly happened and can review later

Behavious

- Paticipate in a clinical event less than once a month
- Paticipate in training once or twice a year

Bio

My working day varies a lot. There are different parts of my department, highly intensive, intermediate intensive and one is close to discharge. I might take care of several babies at the same time, giving them treatments, CPAP, medicine, respirator or feeding. Sometimes I go to the birth ward and do assessment with the doctor, if the baby is not doing well, then we will take it to NICU.

Pain Points

- It can be chaotic with an unexperienced team leader, don't know what to do and get confused
- Don't know what others are doing when they don't verbalise loudly
- Difficult to give sufficient ventilation
- Feels very stressed
- When the baby was born in some rare locations, it's difficult to find the equipment
- Training happens rarely in a year, especially the training with a team

Photo: Colourbox.dk/Sergey Novikov

Figure 4.20: Persona of NICU nurse

> **Probably it's just stressful situation, that involved many people comes at one time and wants to help and the roles of each person is maybe not clear and then it could be a bad communication, who's going to do what in this situation.**

Name	Inger
Age	35
Title	Midwife
Working experience	7 years
Hospital	SUS

Roles

- Take care of the mother from the time she gets pregnant til she is discharged.
- If it's an expected case, pass the baby to pediatrician, and assist the team if it's needed.
- If it's an unexpected case, dry, stimulate and ventilate baby until the pediatrician arrives, and call for help

Goals

- Save the baby, and maske sure the baby is healthy and can return to mother as soon as possible
- Finish my tasks well, do as what the leader tells me to do, assisst the team
- Help the mother give birth, and take care of the mother

Behavious

- Paticipate in a clinical event less than once a month
- Paticipate in training once or twice a year

Pain Points

- Difficult to give sufficient ventilation
- Feels very stressed
- It can be chaotic with an unexperienced team leader, don't know what to do and get confused
- Time consuming to record the event, everything happens every fast, difficult to write down everything
- Training happens rarely in a year, especially the training with a team

Bio

We will do risk assessment with gynecologist, obstettrician before labour. If a baby is expected to be ill, we will inform the NICU department ahead of time. And they will take care of the baby after it's born. I will either take care of the mother or assist the baby team if they need me. When a baby is born and unexpetedly needs help, then barnepleier and me will take the baby and rush to the resuscitation table. The NICU team usually arrives after several minutes and take over the baby. I either stay there to help them or go back to take care of the mother.

Photo: Colourbox.dk/Anatoly Tiplyashin

Figure 4.21: Persona of midwife

> **We all try to follow the algorithm or the flow chart, but not always easy to do that when you don't know who's doing which.**

Name	Jacob
Age	45
Title	Anesthesiologist
Working experience	10 years
Hospital	SUS

Roles

- If I arrive before the pediatrician, especially in c-sections, I will assess the baby and start ventilation, very often the baby starts to breathe by the time the pediatrician comes, otherwise the pediatrician takes over the ventilation
- If I arrive after the pediatrician, I will assist the team, ventilation, help with getting iv access or other tasks.
- Give general or regional anesthesia to the patients

Goals

- Save the baby, and maske sure the baby is healthy and can return to mother as soon as possible
- Finish my tasks well, assiss the team
- make sure the patients don't feel pain in the surgery, and can wake up afterwards.

Behavious

- Paticipate in a clinical 5-6 times a year
- Paticipate in training less than once a month

Bio

A typical day for me will be to have meeting in the morning and discuss about the patients. Then we will go to each ward and give anesthesia, either general or regional anesthesia. We have some theaters for obstetric surgery, mainly c-section. The majority are planned c-sections, but sometimes there are emergencies. We also go back and forth to labour ward for labour epidurals. Normally we are not involved in an expected ill baby, but if there's an alarm we will go to help them.

Pain Points

- It can be chaotic with an unexperienced team leader, don't know what to do and get confused
- Don't know what others are doing when they don't verbalise loudly
- Difficult to give sufficient ventilation
- At the first year, I found it difficult to find the equipment, and sometimes people use the equipment without putting back to the original place
- Training happens rarely in a year, especially the training with a team

Photo: Colourbox.dk/#290938

Figure 4.22: Persona of anesthesiologist

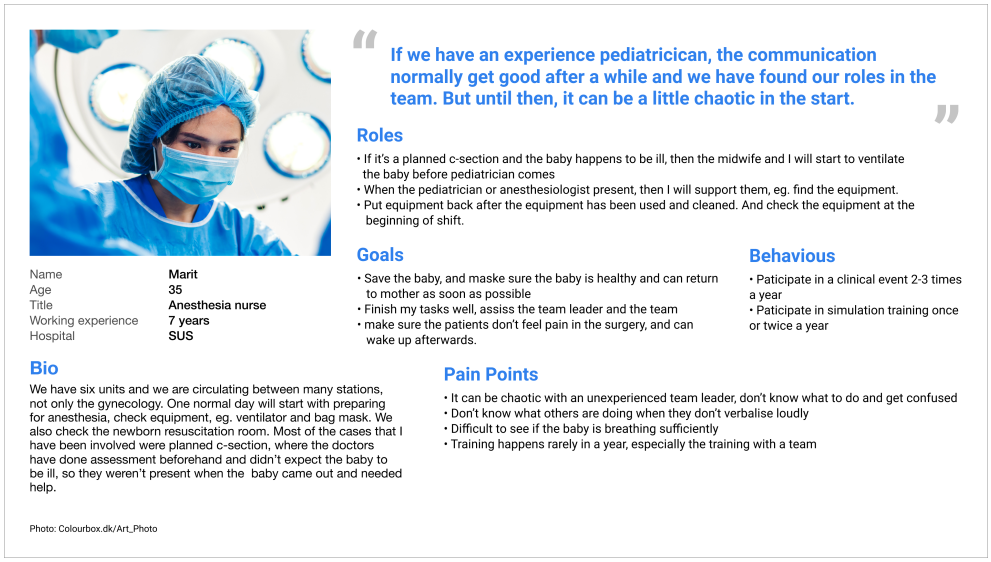


Figure 4.23: Persona of anesthesia nurse

(a) **(b)** **(c)** **(d)** **(e)**

Figure 4.24: Empathy maps for pediatrician, NICU nurse, midwife, anesthesiologist and anesthesia nurse

Scenario and Journey Map

Following are 4 common different scenarios in neonatal resuscitation, namely expected case in the delivery ward, emergency c-section in the operation theatre, unexpected case in the delivery ward, planned c-section in the operation theatre. Each scenario has a journey map, as shown in Figure 4.25,Figure 4.26,Figure 4.27,Figure 4.28.

1. Expected case

Before the labour, midwife, gynecologist, obstetrician, pediatrician and NICU nurse will have a risk assessment, to see if there are any underlying risk factors of the mother or infant that can cause the infant trouble of breathing. And if there is difficulty during labour, for example, the delivery has caused too much bleeding, or they have used vacuum or forcep to get the baby out. Then they will inform the NICU department, and the pediatrician will make a judgement to see if he/she

needs to bring a neonatologist, who is only involved in a more serious case. Usually one pediatrician with one NICU nurse, or 2 pediatricians with 2 NICU nurse will go to the resuscitation room next to the labour ward and wait for the baby to come. While they are waiting they often brief. During brief, they might discuss the background history, check and prepare the equipment. They make sure the clock is on 0 so they can start the clock as soon as they hear the baby is born. They turn on the radiant heater. They turn the gas flow on, make sure the pressures is set correctly, 30/5cm H2O for term babies and 20-25/5cm H2O for preterm babies. They set the oxygen at 21%, check self-inflation bag, temperature and light, suction catheter, iv access, make sure ECG and pulse oximeter are in place and so on. The pediatrician may assign roles to the team.

When the baby is out and doesn't breathe, they start the clock. The midwife cut the umbilical cord, dry the baby and take it out to the resuscitation room. In most cases, the pediatrician will take over the airway and be the team leader. As a team leader, the pediatrician will assign roles or tasks to people around. The midwife will dry and stimulate the baby, order blood gas test. The pediatrician will open the airway, use Neopuff (T-piece ventilator) to ventilate the baby, while the NICU nurse or nurse assistant will attach the ECG and SpO_2 monitor, and maybe NeoBeat if they have(a device that can display the baby's heart rate immediately), check the chest movement, monitor the temperature, find any equipment that the pediatrician needs, eg. iv line. If there's extra personnel, one will writes down the apgar score, temperature and other things on a whiteboard on the wall.

If the case is more serious, they will raise the alarm to call for help. Then more experienced pediatrician, anesthesiologist, anesthesia nurse, more midwife, nurse assistant, NICU nurse and maybe neonatologist will come. The neonatologist will take over the team leader role, take over the ventilation if the pediatrician couldn't manage it. The neonatologist is also responsible for intubation if it's needed. The anesthesiologist will find the equipment, help with iv access, but can also ventilate the baby. More people than needed will come with the alarm, so they just wait to be assigned tasks.

They usually ventilate the baby for 1.5 - 3 minutes before it starts to breathe itself, if it doesn't scream, then they will let it breathe against the NeoPuff for another 5-6 minutes, and then assess him within 5-10 minutes if it should be brought to NICU or sent back to parents.

If the baby breathes fine with no need of oxygen, no severe retractions and looks fine, then the baby can be sent back to the parents. They will go to check the baby within maybe 30 to 60 minutes and see how it is doing and check their blood sugars.

If the baby is not breathing and is still in need of oxygen or has severe retractions,

they suspect that it will need CPAP treatment for some time, so they take it to NICU and observe it there. The baby will be sent back if it is reacting fine. According to a survey(cite the paper), almost 2/3 of all ventilated newborns go back to their parents right away after the resuscitation, about 1/3 of the babies were transferred to the NICU. And most of them leave NICU after one day.

After the resuscitation, the pediatrician might have a quick summary with the midwife or nurses who is taking note, and try to recall what has happened in the event.

Other than the delivery scenario, an expected case can also happen when there's an need of an emergency c-section, then there will be another alarm which goes to the NICU department. And pediatrician and NICU nurse will rush to the resuscitation room and do the same thing as described above. The main difference is that in this case the anesthesiologist and anesthesia nurse will be present at the start, so the anesthesiologist can ventilate the baby if the pediatrician trusts her, or if the anesthesiologist is more experienced than the pediatrician.

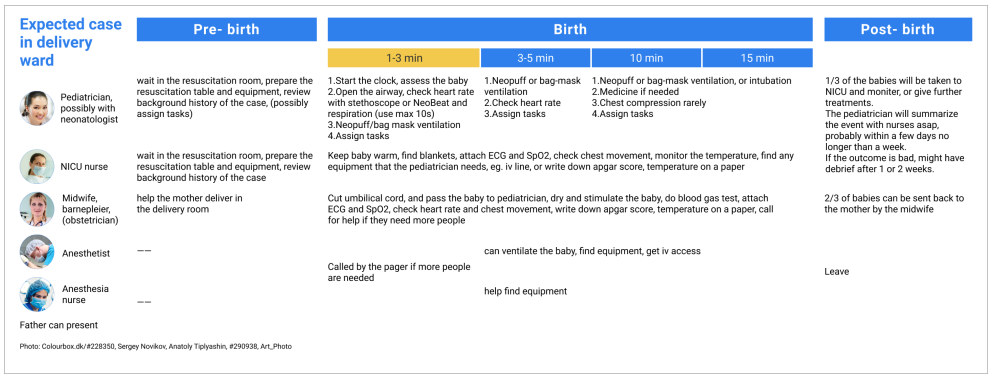


Figure 4.25: Journey map of expected case in delivery ward

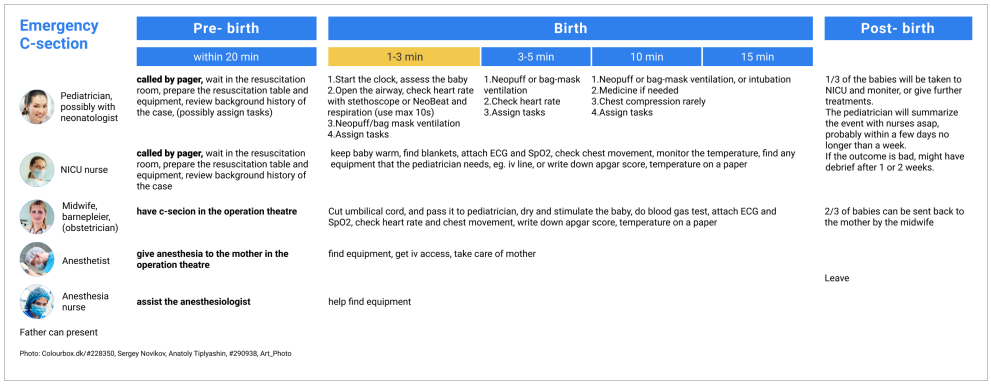


Figure 4.26: Journey map of emergency c-section case

2. Unexpected case

An unexpected case is when a baby is born and to their surprise needs help. This consists of 1/3 of all the cases. This can either happen in a delivery room or c-section theatre. If it's in a delivery room, after the obstetrician make an assessment, they will cut the umbilical cord, rush to the resuscitation room with nurse assistant, and possibly obstetrician. After they dry the baby, stimulate, open the airway, the midwife will start to ventilate. If the baby is very sick, then the other people present will call the NICU department by phone. Anesthesiologist and anesthesia nurse will also come with the alarm. If anesthesiologist arrives earlier than the pediatrician, then he/she will likely take over the ventilation and the team leader role until the pediatrician arrives. If this happens in a c-section theatre, it is usually a planned c-section, in which case they assume the baby would be healthy but in reality it's not. In this case, the anesthesia nurse and midwife, and possibly anesthesiologist are the first persons there, so the midwife, or if anesthesiologist is present, will start to ventilate and act as team leader until pediatrician arrive. The anesthesia nurse will support the team. It usually takes several minutes before the pediatrician arrives, so in many cases, the baby will start to breathe in the meanwhile. However if not, the pediatrician will take over the ventilation and team leader role. The rest of the resuscitation is the same as what has been described in the expected cases.

After the resuscitation, they rarely do debrief. They either do it when the midwife or pediatrician need it or something serious happen, either the baby turns out to be much worse then expected, or has passed away. This happens usually several weeks after and it's usually led by the birth department. During debrief, everyone will go through the event and share their experience. They might use some record if it's available, however, there's rarely objective data of the ventilation or timeline. And due to the lack of data, there might be disagreement on what has really happened during the event.

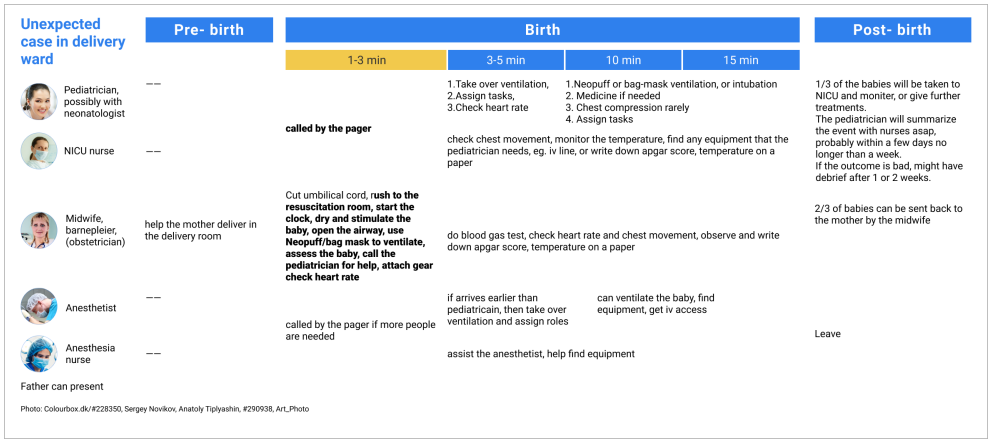


Figure 4.27: Journey map of unexpected case in delivery ward

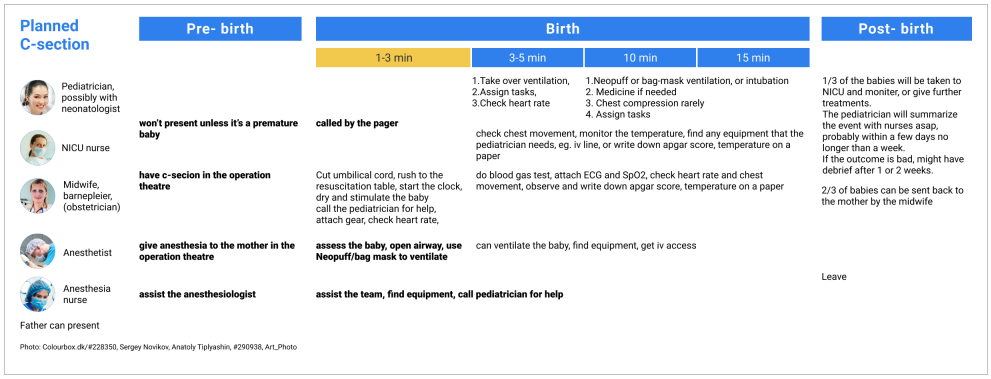


Figure 4.28: Journey map of planned c-section case

4.2.2 Point of View and How Might We

Two of the most frequently mentioned difficulties were chose for being written as positive pressure ventilation (POV), namely "difficult to get sufficient air into the lung or provide sufficient ventilation" and "communication difficulty". Although "feeling stress" is a very common problem, it hasn't been chose because it's not easy to be solved directly, and by solving the two other problems, it can make the situation less stressful for the HCPs to some extent. POV and HMW as shown as following:

1. **[The HCPs who participate in a newborn resuscitation]**
   need to
   [provide sufficient ventilation to the baby]
   because
   [they want to save the baby's life].

2. **[The HCPs who participate in a newborn resuscitation]**
   need to **[have better communication in the team]**
   because
   [they want to have a better understanding of the situation, and contribute to helping].

1. How might we [make it easier for the HCPs who participate in a newborn resuscitation to know if they manage to give sufficient ventilation and possibly give them guidance on the next step]?
2. How Might We [provide an overview of the situation and help the HCPs find their tasks]?

4.3 Develop

4.3.1 Brainstorm and Dot Voting

Two participants joined the workshop, one neonatologist and one anesthetist, both were recruited from the previous interview. The workshop took more time than expected, for around 1.5 hour, because there were some technical problems. One participant joined with a mobile phone and needed to switch to computer later to use the mural board. Also due to the poor internet, one participants needed to quit and join the meeting. Other than the technical problems, the participants enjoyed the workshop very much, and have generated many ideas and provided valuable feedback.

At the beginning of the workshop, they reviewed the four journey maps and provided some feedback:

- The pediatrician tries to summarize the event with the nurses as soon as possible, usually within several days and no more than one week.
- They start with Neopuff or bag-mask ventilation.
- In a resuscitation, usually midwife or nurse assistant calls for help.
- Pediatrician and NICU nurse are always called by pager, there are different pager codes based on different cases.
- In an emergency c-section, the baby usually should be out within 20 minutes from the alarm sounds, so the pediatrician and NICU nurse have enough time to get prepared.
- The main attention of anesthesia personnel is on the mothers, they don't usually ventilate the baby when there are two pediatricians.
- Pediatrician won't present in a planned c-section case unless the baby is premature, and the midwife usually doesn't ventilate the baby, instead he/she asks anesthesiologist for help, since anesthesiologist is the closest one. And they will send pager to the pediatrician.

Minor changes were then made based on their feedback, and the changes were marked by bold font as shown in the pictures above(Figure 4.25,Figure 4.26,Figure 4.27,Figure 4.28)

After the journey map review sessions, it was the brainstorming and voting session. Figure 4.29 shows the results from the brainstorming session and voting session.

Figure 4.29: Brainstorming and voting results from the workshop

Ideas for the first POV and HMW were mainly about to provide various feedback on ventilation, eg. HR, Carbon Dioxide (CO_2), volume, pressure and so on. The neonatologist mentioned that there's a recent study which shows that CO_2 feedback is more sensitive on telling whether you ventilate the baby well compared to HR. But HR remains a very valuable signal and the changes of HR can indicate how successful the ventilation is. The increase in saturation is not as obvious as CO_2 and HR feedback, but still helpful. They also look the chest movement and auscultate to hear the sound of air entering into the lungs, but it can be difficult and requires multiple personnel to check that. If you can't succeed in getting air into the lungs, check if the airway is blocked and try intubation. Otherwise, think about if the baby has other disease, eg.pneumothorax, which makes it extremely difficult for the baby to get improved.

After they shared their ideas on first POV and HMW, they were asked for feedback on competitors like Laerdal newborn resuscitation monitor(Linde *et al.* 2017),

Neocue(Fuerch *et al.* 2015) and Monivent Neo 100(Monivent 2020). Generally they were positive about these monitor digital devices and thought that these would be the trend in the future. The neonatologist mentioned that they were already using the Laerdal newborn resuscitation monitor in practice, but they used a more modern HR device, which was NeoBeat, and they didn't have the CO_2 sensor. However, they covered the screen because they just wanted to collect the data for after-event analysis instead of getting the real time feedback during the resuscitation. Apart from the positive response, they also expressed their concern on how much information is too much. Too much information can increase their workload, and take away attention from the baby. They also commented that the audio prompts from NeoCue can be difficult to be caught by the HCPs during resuscitation since the environment is quite noisy, if the HCPs doesn't catch the messages, then it only creates more noise in that situation instead of providing guidance. They suggested that there should be studies on how much information they can effectively absorb, and what kind of effect this audio feedback will have on their performance. And the information at the beginning should be simple, and can increase the complexity as more people come to the help, and help the team leader to assess the situation.

The second POV and HMW focused on how to improve the team communication and leadership. Ideas include:

- Give clear messages and avoid unnecessary noise.
- They mentioned that the main problem about the communication is that there is no close loop. They need more practice to learn and get used to the close loop communication.
- It's difficult to choose whether to let the most experienced personnel handle the airway or be the team leader, since both jobs require highly experienced people. But they agreed that if other people, like anesthesiologist, can handle the ventilation well, then the most experienced person should take a step back and be the team leader.
- Spending some time to do a timeout, summary of the situation is very helpful, so they can reflect on whether they have made some mistakes and plan for the next step.
- It's important to have self-introduction when everyone enters the resuscitation room, so people know what they can expect from their teammates. One participant mentioned that they once mistook a NICU nurse as pediatrician and only discovered it when they need someone to intubate the baby.

4.3.2 Bundling ideas

Figure 4.30Figure 4.31 shows how similar ideas were grouped together using bundling ideas method.

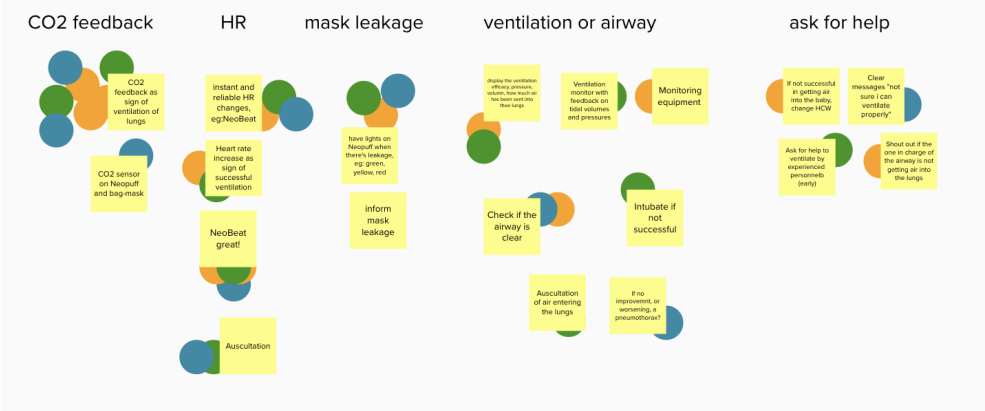


Figure 4.30: Bundling ideas for the first POV and HMW

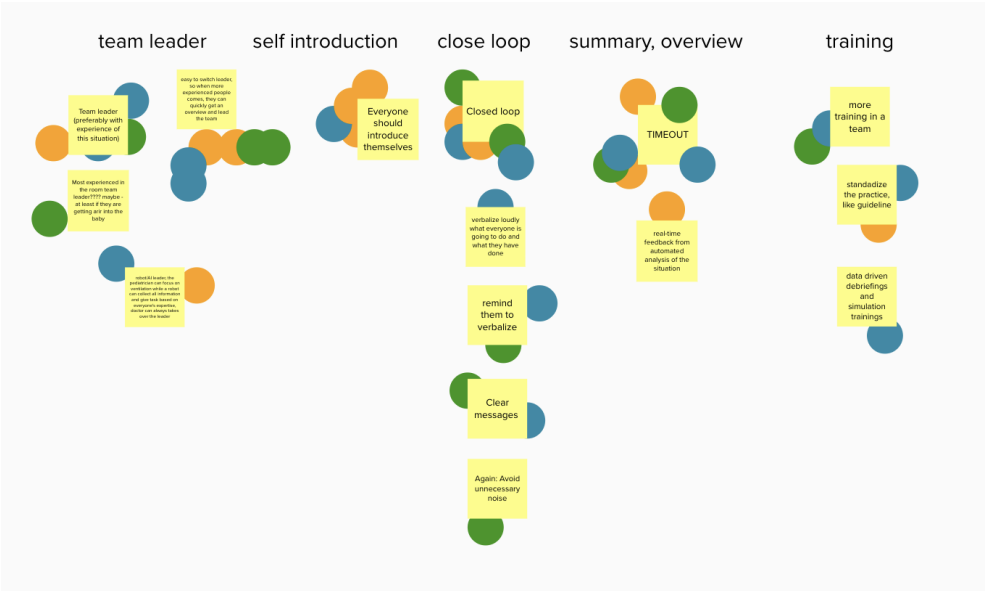


Figure 4.31: Bundling ideas for the second POV and HMW

Here are the groups of ideas that have more votes and chosen to be further developed:

- Provide CO_2 feedback on how much air has entered the lungs.
- Provide instant and reliable HR changes.
- Provide indication on whether the mask has leakage.
- Provide feedback on ventilation techniques, such as pressure, V_t, frequency and so on.
- The most experienced one in the team should be the team leader, and let

others handle the ventilation if they have competence.
- The communication should have a closed loop, everyone should verbalize loud what they are doing and what they have done.
- Everyone should introduce themselves then they enter the resuscitation room.
- There should be a short timeout session during the resuscitation, so everyone, especially the team leader can have a overview of the situation and plan for the next step. And this makes it easier for the newly joined team leader to take over the situation and lead the team.

Strategies to Improve Team Communication

Since CLC has been addressed by the several participants in the co-creation workshop and interviews, the researcher have reviewed some literature on this topic. A classic CLC requires 3 steps (Härgestam *et al.* 2013; Burke *et al.* 2004):

- **call-out:** the sender send out a message;
- **check back:** the receiver acknowledges receiving the message;
- **closing the loop:** the sender verifies if the message has been interpreted correctly.

CLC can increase the accuracy of information exchange, the speed and efficiency of task completion, especially in the tasks for administrating meditation, placement of intravenous lines and obtaining blood for laboratory testing(**el-shafy_closed-loop_2018-1**). Despite these benefits, CLC is not frequently used even with explicit training on CLC strategy (Härgestam *et al.* 2013). There are several possible reasons. Firstly, CLC is not common in natural dialogues and takes more time, which makes it especially difficult when they need to do things quickly in an emergency situation. Secondly, verbal confirmation is not necessary when the speaker can see the action being taken, such as putting on ECG electrodes (Marzuki *et al.* 2020).

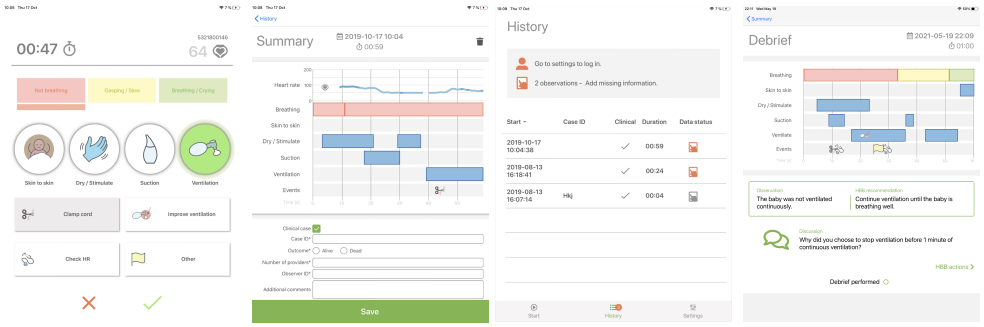
Siassakos *et al.* (2009) found that when a message or command is sent to a specific person, for example with the person's name, it's more likely to be picked up and executed compared to those called out "in the air". To make it worse, when several commands were called out "in the air", it can increase the workload for the team members and decrease the team performance (Andersen *et al.* 2010).

Other than CLC, brief and debrief have also been proved to improve the teamwork and team communication (Edwards *et al.* 2015). Therefore, the researcher decided to include brief and debrief in the solution, and to include some CLC techniques as reminder in the brief, such as the checklist in Katheria *et al.* (2013) and S. C. Bennett *et al.* (2016).

4.3.3 Competitive Analysis

Liveborn

Liveborn(*Liveborn* 2021), as shown in Figure 4.32, is an application that can be used to register newborn's respiratory effort (not breathing, gasping or breathing) and provider's interventions such as dry/stimulate, suction and ventilation in a resuscitation for both simulation and clinical setting. It can connect with NeoBeat through bluetooth and can display HR data continuously. After the event, user can review the case summary and use the report in debrief session. The report provides not only HR, interventions, and breathing status, but also noncompliance with the guideline, recommendation and discussion topic to facilitate the debrief. Liveborn is available on mobile phone, tablet and PC.



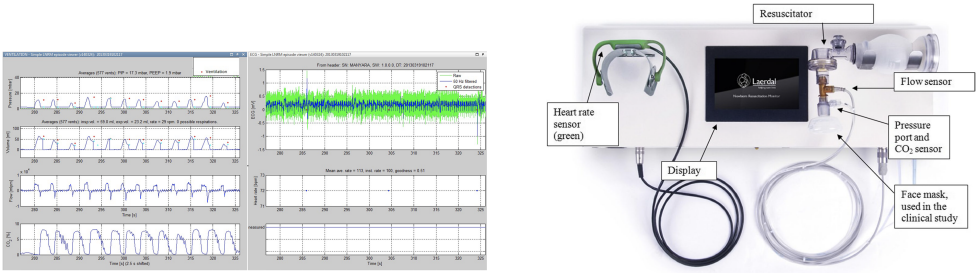
(a) Main screen page **(b)** Case summary **(c)** History page **(d)** Debrief page

Figure 4.32: Liveborn main interfaces (*Liveborn* 2021)

Laerdal Newborn Resuscitation Monitor

Newborn resuscitation monitor(NRM) (Laerdal Global Health, Stavanger, Norway) can continuously display ventilation pressure, V_t, flow, Expired Carbon Dioxide (ECO_2) and HR during ventilation and store this data for later analysis(Figure 4.33a). It can be used to "study if measurements and feedback to the provider will facilitate more objective assessments and thus improve decision making and quality of care during newborn resuscitation"(Linde *et al.* 2017).

Figure 4.33b demonstrates different parts of NRM. The HR sensor can collect ECG through dry electrodes, and HR was calculated from ECG using an proprietary algorithm (Kohler *et al.* 2003). On Figure 4.33b the HR sensor and the main cabinet are connected through a cable, but from the last workshop with 2 doctors from SUS, the researcher was told that the HR sensor has been replaced with a more modernised NeoBeat and can transfer the data through wireless.



(a) Example ventilation and ECG data from a piglet.

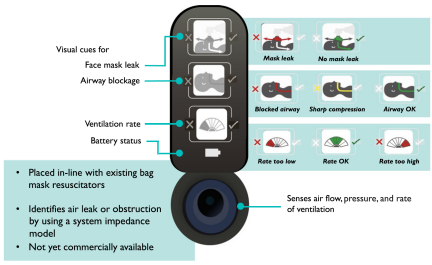
(b) The composition of newborn resuscitation monitor.

Figure 4.33: The newborn resuscitation monitor(Linde *et al.* 2017)

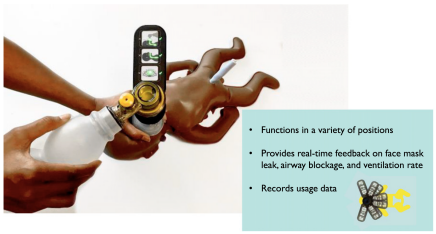
The rest of data are measured through a flow sensor (MIM Gmbh, Krugzell, Germany), an ISA CO_2 sonsor (Masimo/PhaseIn AB, Danderyd, Sweden) and a pressure sensor (MPXV5010, Freescale Semiconductor Inc, Austin, Tx) put between the endotracheal tube (ETT) and the resuscitator bag. The flow sensor can measure air flow and V_t. The CO_2 sensor can measure ECO_2 from a sample of exhaled air. And the pressure sensor is used for measuring the ventilation pressure. Studies has shown that ECO_2 is a useful indication for lung aeration and pulmonary blood flow, though not as accurate as Partial Pressure of Carbon Dioxide ($PaCO_2$), which is measured by arterial blood gases test (Hooper *et al.* 2013; Linde *et al.* 2017).

Augmented Infant Resuscitator (AIR)

AIR is an add-on device that can be added between a face mask and ventilation bag, and is compatible with almost all existing bag valve mask (BVM) resuscitators. By measuring the air flow, pressure and rate of ventilation, it can provide real-time, objective visual feedback on whether there are ventilation errors that can cause damages to the baby, including mask leakage, airway blockage and incorrect ventilation rate. The AIR device also uses different color coding to communicate the ventilation quality, while green indicate effective ventilation and red indicate errors. This realtime feedback can help HCPs adjust their ventilation techniques, and at the same time able to keep most attention on the baby. Other than the real time data, AIR can store timestamped data on a memory card for future quality improvement. The saved data include “the total ventilation time, time and duration of effective ventilation, duration with a good face mask seal, and duration with a patent airway”(Patterson *et al.* 2020). In the testing of the fourth-generation prototype, AIR showed 100% accuracy in discovering face mask leakage and airway blockage (D. J. Bennett *et al.* 2018).



(a) Key features of AIR



(b) Demonstration of AIR in use during training

Figure 4.34: Key features of AIR and AIR in use.(Patterson *et al.* 2020)

Limitation

AIR doesn't provide information on V_t, and the current version doesn't support you to adjust the desired ranges based on the baby's weight. Also, the AIR has primarily been tested in simulation training and need further validation in the clinical resuscitation, and is not commercially available.

Monivent Neo 100

Monivent Neo 100 is an add-on to existing ventilation equipment, both T-piece and bag-mask ventilators. It measures the airflow through a sensor module integrated in the face mask and can display real-time feedback on a digital screen, including End Tidal Volume (V_{te}), positive inspiratory pressure (PIP), positive end expiratory pressure (PEEP), mask leakage and ventilation rate. It uses different color codes to indicate the quality of the V_{te} on the digital screen, of which green means within the desired range, and red means below the desired range and orange above the desired range. And the LED light on the sensor module has a corresponding color, so that the healthcare professional (HCP) doesn't need to direct his/her attention away from the baby. The desired ranges are calculated based on the weight of the baby that the HCP type in on the screen before ventilation(*Monivent Neo100* 2021; *INVITATION TO SUBSCRIBE FOR UNITS IN MONIVENT AB* 2021).

(a) Sensor module is put between mask and bag

(b) HCP types in the weight to the digital screen before ventilation

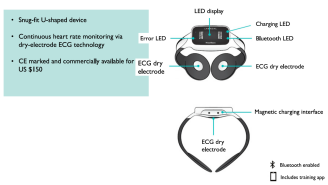
(c) Digital screen displays some parameters of ventilation

Figure 4.35: Use of Monivent Neo 100 in clinical setting (Monivent 2020)

NeoBeat

NeoBeat is a snug-fit U-shaped device that uses dry electrode to pick up an ECG-based signal. It can be easily placed on the upper abdomen of a newborn and can provide an accurate and continuous display of HR within 5 seconds. The device has 2 different sizes for different babies, NeoBeat for newborns 1.5 to 5 kg, and NeoBeat Mini for newborns 0.8 to 2 kg. For easy accessibility, it comes with a charging stand which can hang on the wall(Figure 4.36a). Enabled with Bluetooth Low Energy, the device can be connected with Liveborn app and send the data to the cloud. The trend of HR changes with timestamp can be seen on the Liveborn app or Power BI desktop dashboard after the usage(Patterson *et al.* 2020; *NeoBeat Newborn Heart Rate Meter* 2021).

(a) NeoBeat can hang on the wall with a charging stand.



(b) Key features of NeoBeat

(c) Demonstration of NeoBeat in use

Figure 4.36: Key features of NeoBeat and NeoBeat in use.(*NeoBeat Newborn Heart Rate Meter* 2021; Patterson *et al.* 2020)

Limitation One limitation of this technology is that "when rhythmic changes in electrical activity are difficult to detect, often due to low or no heart rate, NeoBeat may display sporadic numbers that reflect detection of artifacts." This sporadic signal requires training for the HCPs to recognize that it's unreliable and clinical

confirmation is needed(Patterson *et al.* 2020). Also, the feasibility and acceptability of NeoBeat is still under trial study in Nepal and Norway(American Academy of Pediatrics 2020; Helse Stavanger HF 2019).

NeoCue

NeoCue is a tablet-based device which requires HCP's manual input of critical clinical data such as HR, respiratory effort, and chest rise assessment and can give visual and audio prompts for HCP to take actions. Figure 4.37 shows some examples of the auditory prompts. The digital screen displays information such as, current HR, SpO_2, weight, time since delivery, suggested actions from the NRP algorithm based on HR, as shown in Figure 4.38a. The number is color coded to indicate the severity. For example, if the HR is $>$ 100 beats per minute (BPM), then it's green, and HR 60-99 BPM is yellow, and <60 BPM is red. The decision support tool (DST) can be hung next to the resuscitation bed within touch of all HCPs (Figure 4.38b).

Action to be performed	Auditory prompt
Listen to breath sounds and HR	"Evaluate respirations and heart rate."
CPAP/adjust FiO_2	"Clear airway, CPAP, blend O_2."
PPV	"Start PPV" with whooshing noise from metronome to maintain appropriate rate (40/min).
CC	"Start compressions" with clicking noise from metronome to maintain appropriate rate (90/min).

Figure 4.37: Examples of the auditory prompts from NeoCue.(Fuerch *et al.* 2015)

In Fuerch *et al.* (2015) study, the intervention group with the help of NeoCue performed PPV and CC more frequently when they were indicated and adjusted Fraction of Inspired Oxygen (FiO_2) more often compared to the control group that relied on memory alone. In another randomized control study (Roitsch *et al.* 2020), HCPs using NeoCue show more adherence to the NPR guideline performance, and had better performance in both decision making (deciding on which action should be taken) and technical skills compared to the control group without NeoCue. The researchers suspected the reason might be that the DST gave prompts both for the initiation of actions and the guidance of performing actions correctly (eg. a metronome sound for 40 breaths per minute). However, these improvements were not observed in scenario A but only scenario B, which is a more complicated scenario that requires CC and intubation. It's likely that DST is more helpful in a complicated situation or HCPs need some time to get familiarized with the tool. Both studies have showed that NeoCue can improve HCPs' adherence to the resuscita-

tion guideline, and even increase their performance. However, these studies were tested in simulated settings, and in a team size between 1-3 people, it's unclear how it performs in a clinical setting where a more complicated team setting with 5-7 people.

(a) Visual display of NeoCue

(b) NeoCue is mounted above the baby's left foot.

Figure 4.38: Key features of NeoBeat and NeoBeat in use.(Fuerch *et al.* 2015; Roitsch *et al.* 2020)

MedNav

MedNav(Duffy *et al.* 2017) is a desicition support tool that can provide visual and audio prompts based on the latest clinical advice(Figure 4.39) for HCPs during the neonatal resuscitation and can reduce the burden on training. It identies 12 key tasks that can lead to an ideal resuscitation(figure N), and focuses on one task at a time. There's a timer that indicates the appropriate time for the HCPs to spend on each task. Buttons only need to be pressed when a task is finished before the screen automatically moves forward or if a critical choice has to be made for the next step. The timer will go red to indicate the urgency to make a decision. MedNav also comes with a recording function for the individual or team to review after the event, which can be used as audit and medical documentation. The software of MedNav can operate offline, and can be run on mobile phones, tablets and laptops, while the best option is a digital screen which is mounted next to the resuscitation bed.

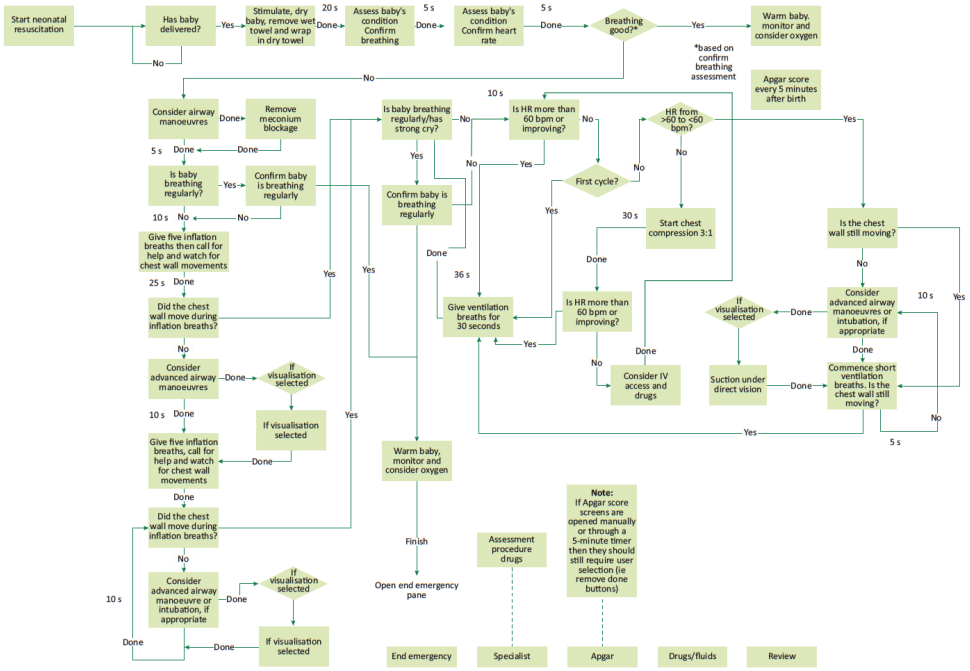


Figure 4.39: MedNav flow chart. IV = intravenous (Duffy *et al.* 2017)

- Call for help
- Start the clock
- Dry and wrap
- Assess respiration
- Check heart rate
- Check colour
- Check tone
- Carry out airway manoeuvre
- Give inflation breaths
- Chest moving
- Reassess Apgar score
- CPR

(a) 12 key tasks of MedNav.

(b) MedNav being tested at Kitovu Hospital, Uganda.

Figure 4.40: MedNav (Duffy *et al.* 2017)

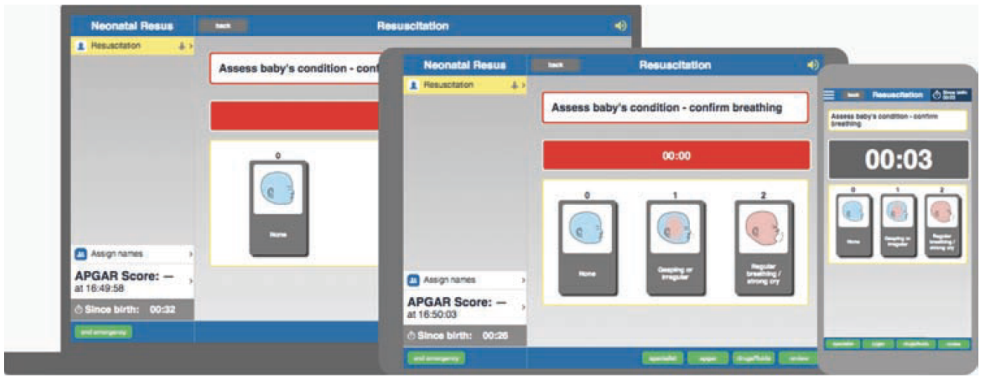


Figure 4.41: MedNav interface on PC, tablet and mobile phone. (Duffy *et al.* 2017)

A 6-month study(Duffy *et al.* 2017) in a resource-limited clinical setting found that the intervention group with the help of MedNav finished much more of these 12 signal tasks compared to the control group(94% vs. 46%), and concluded that MedNav can improve HCPs' performance on neonatal resuscitation. The researchers assumed that MedNav could be more helpful in low-income countries due to the dangerously low staffing level.

4.3.4 Ideation Sheet

The ideation sheet (Figure 4.42) illustrates how an ecosystem, including a resuscitation support tool, can be implemented in a clinical event.

- **Requirements for implementation:** The support tool is designed to run on a tablet, and to make full use of this tool, it requires receiving real-time data from a HR detector such as NeoBeat, a sensor module that can measure various ventilation parameters such as Monivent Neo 100 and a pulse oximeter. And before being implemented in a clinical setting, it should be used in simulation training so that the HCPs can get familiar with the tool and integrate it into their existing work flow.
- **Chanllenges solved:** The problems that this ecosystem aims to solve are that the HCPs don't know if the baby is sufficiently ventilating and they don't what have been done in the event.
- **Possibilities or gains:** HCPs can get instant HR readings and feedback on the ventilation techniques, get an overview of the resuscitation event, which can be recorded for later analysis.

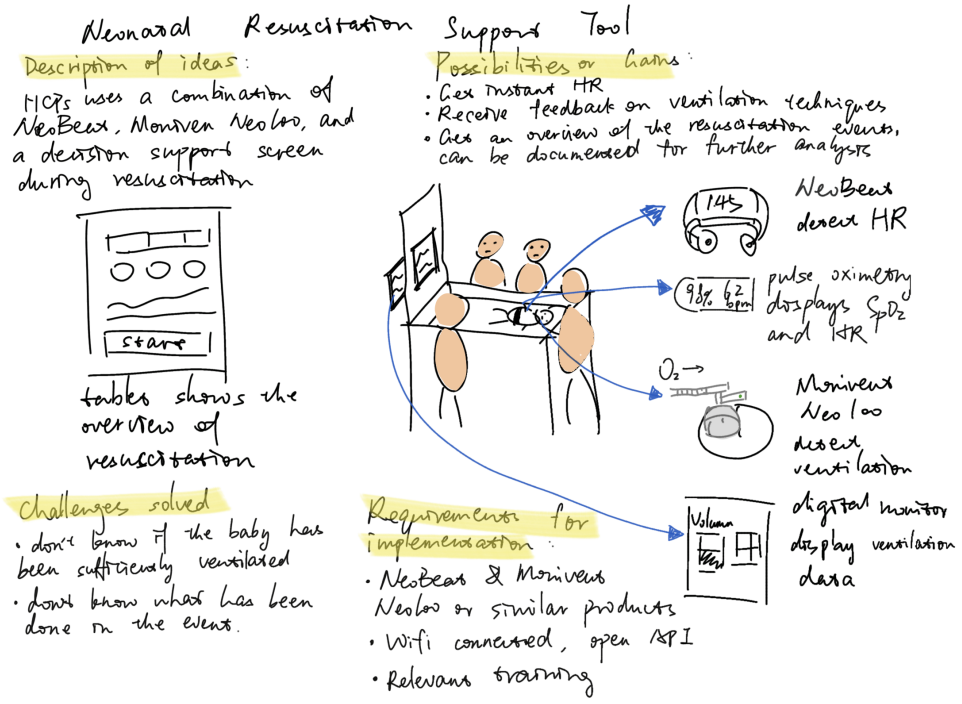


Figure 4.42: Ideation sheet

4.4 Deliver

4.4.1 Mind map and the Application Structure

Figure 4.43 demonstrates the pages and contents of the resuscitation support tool.

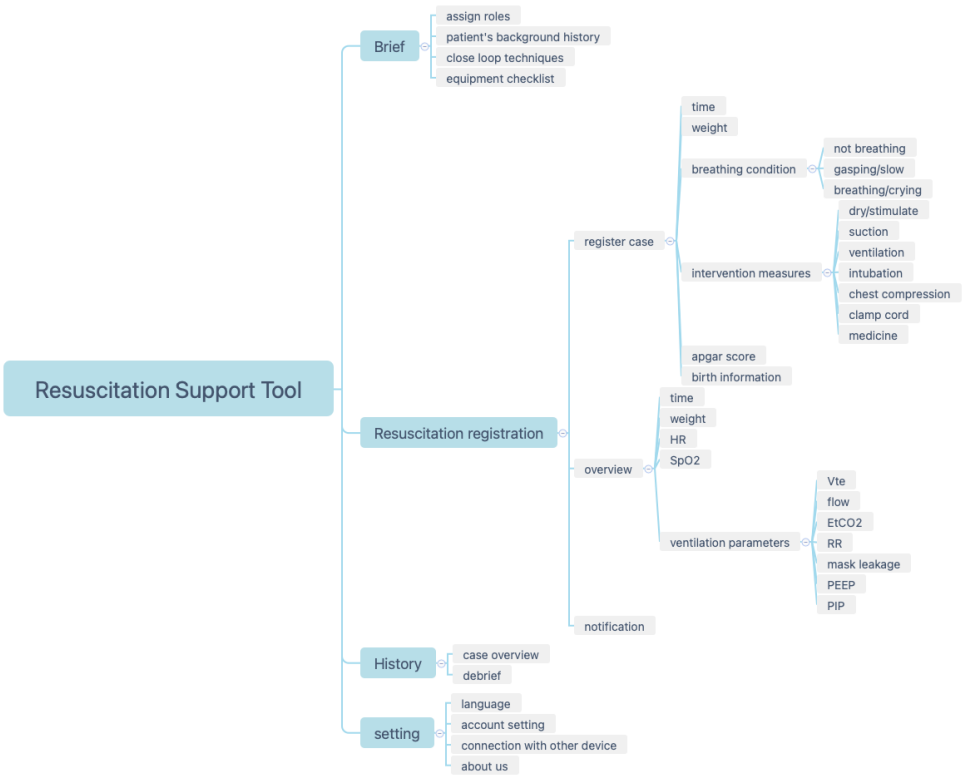


Figure 4.43: The structure of the resuscitation support tool

4.4.2 Wireframe and Medium-Fidelity Prototype

To see the wireframe, please refer to Appendix A.11. Figure 4.44 shows the flow of the prototype. For clear version of the prototype, please look at Appendix A.12.

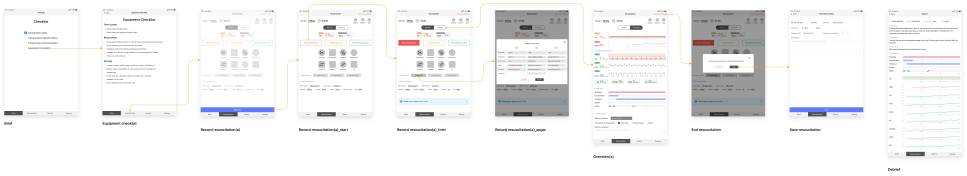


Figure 4.44: Prototype

Brief Pages

On the brief home page, there are four items on the checklist, namely introduction/roles, discussion treatment plan and patient history, CLC techniques and equipment checklist. This checklist serves as a reminder that all these tasks should be finished during brief, when user finish one task, he/she can check one box. The

four items follow a natural order. During brief, users should introduce themselves to each other and the team leader can assign roles. After that, they can discuss patient's history and treatment plan. Then the team leader can express his/her expectation for CLC, for example asking the team mates to call back the orders (eg. "HR is 90"), and ask the team mates to speak up if they have any problems or concerns. The last one is to check the equipment and have the right settings. There's another equipment checklist, which has separate tasks for team leader, resuscitator and nursing personnel. The whole brief page and checklist were designed based on the checklist in Katheria *et al.* (2013) and S. C. Bennett *et al.* (2016).

Record Resuscitation Pages

When you click on the "Resuscitation" button on the navigation bar, and can then switch to the resuscitation page. You can click "baby born" to start to register the resuscitation. On this page, you can see the baby's weight and clock, and the connection status with NeoBeat, Monivent and pulse oximeter. Underneath is a segmented control, which you can switch between record and overview. On the record mode, you can see the HR and SpO_2 values. You can register the baby's breathing status, what kinds of intervention have been taken during the event, apgar score at 1,5,10 minutes and birth information. The intervention buttons are differentiated in round shape and square shape. The square shape means that the measures has a period of duration, such as ventilation and intubation. The user needs to press once to activate it and press again to deactivate it. Then the time period is registered. The round shape intervention button represent measures that don't have a duration, there's only done or not done status. Thus user only needs to press once to register the measure. There will be some notifications at the bottom of the page, they can be warnings of status or to urge certain actions being taken, for example, at one minute there will be a reminder to fill in the one minute apgar score.

Overview of Resuscitation Page

If you switch to the overview page, you can see all kinds of data that can aid the decision making process. You can see the HR and SpO_2 changes over time, and temporary ventilation parameters such as End Tidal Volume (V_{te}), flow, ECO_2, respiratory rate (RR), leakage, PEEP and PIP. You can also see what interventions have been taken at what time for how long. At the bottom you can see the patient history, including delivery method, intervention during delivery and mother's symptoms. The order and form (either wave form or numeric form)of the ventilation parameters were based on a study's results (Katz *et al.* 2019). In the study they found out that generally participants spend more time and more frequently looking at the wave form data compared to numeric data, especially the V_{te}, following by the flow (wave form), respiratory rate (number) and leakage (number). The purpose of this page is to let the observers, especially people who

joined the resuscitation later, to know what has happened and to discover any mistakes or abnormality in a short amount of time.

Following are the explanations of the important data during neonatal resuscitation:

HR and SpO_2

HR is one of the most important indicators for a successful ventilation, which tells whether the lungs are inflated and blood is oxygenated. SpO_2 is another important and direct indicator of a baby's oxygenation state. Monitoring SpO_2 can help the HCPs adjust the oxygen level accordingly (Morley 2018).

Expired Carbon Dioxide (ECO_2)

ECO_2 can indicate the degree of lungs aeration immediately after birth, and can be seen as the first sign of an adequate ventilation (Hooper *et al.* 2013; Mizumoto *et al.* 2015).

End Tidal Volume (V_{te})

V_{te} is used to indicate whether air has been entered into the lung and how much. A recommended value for V_{te} is between 4-8 mL/kg, and varies with the size of baby, time after birth, and the existence of spontaneous breathing. Monitoring V_{te} can make sure it doesn't go too high or too low, because too high can cause irreversible damages to the lungs, too low can effectively inflate the lungs and thus prolongs the trauma and leads to more invasive interventions (Kaufman *et al.* 2013; Wood, Morley, Dawson and Davis 2008; Schmölzer, O. C. O. F. Kamlin, Dawson *et al.* 2010; Schilleman, Siew *et al.* 2012; Schilleman, Pot *et al.* 2013).

Flow and RR

Flow is a set of V_t delivered over time. Flow curve together with the RR can indicate whether the ventilation synchronize with the baby's breathing pattern. If not, it can make it more difficult for the baby to breathe (Morley 2018). NRR guideline recommends a ventilation rate between 30-60/min .

Mask Leakage

Mask leakage is very common and difficult to detect clinically. A mask leakage can lead to inadequate inflations. The main reasons for mask leakage are wrong size of the mask, or holding the mask incorrect, or without lifting the chin during mask ventilation. An accurate way to assess the leakage is by measuring the volume lost between inhale and exhale (Morley 2018).

Positive End Expiratory Pressure

PEEP has been shown to be effective for removing the liquid from lungs for preterm babies. A recommend value is between 5-8cm H2O (*Resuscitation of neonates | Better Safer Care* 2021; Morley 2018).

Peak Inflating Pressure The recommended PIP for preterm babies is usually 20 cm H2O and 30 cm H2O for full term babies, though this might need to be adjusted based on each individual case. "The purpose of PIP is to ensure an appropriate V_t" (Morley 2018). It's important to monitor the PIP to make sure it's too high, because studies found that severe damages to the lungs and brain can be caused with only 5 over large inflations (Björklund *et al.* 1997; Hillman *et al.* 2007; Polglase *et al.* 2012).

Debrief Page

After you finish the observation of resuscitation, you can click at the button "end resuscitation" at the top right corner to end this event. There's a confirmation pop-up window in case you press that button by accident. Once you have confirmed, you need to fill in some extra information before saving it, such as clinical or training case, outcome of the baby, observer ID and the number of providers. After it's saved, you can review it in the history page. You can also choose to debrief immediately.

On the debrief page, you can see the basic information of the case, including date, duration and outcome. There's also a summary of the event, suggestion and discussion topics that are generated automatically by the software. Underneath are some measures that have been taken, and some important data with timelines.

Different Versions of Record Page

The researcher has made two version of the record page, as shown in Figure 4.45. The only difference between these two versions is that instead of showing all the possible intervention measures at one time, they are separated into two groups on the version b, considering at the first 10s or half minute the HCPs only have time to clamp cord, dry/stimulate, check HR and airway. After a certain amount of time, it will switch to the second group of intervention measures automatically. However, they can always click on the two arrows to switch back and forth. The consideration for the design of version b is to reduce the unnecessary contents on the screen in order to reduce the workload for the user.

Figure 4.45: Two versions of record resuscitation page.

Different Versions of Overview Page

The researcher has made three versions of overview page, as shown in Figure 4.46. On version a, ECO_2 is shown in a wave form and refresh every few seconds, while on version b the ECO_2 was shown with the changes in a time line. On version a, the HR and SpO_2 numbers are also added with tabs that states whether the number is normal or abnormal. On version c, the safe or normal areas are highlighted in green color, while on version a and b, the warning areas are highlighted in orange, and danger areas are in red. The reason of having these different variations is that the researcher was unsure about which way of showing the data was more natural and helpful to the HCPs, and would like to figure it out in the testing workshop. Noticed that the patient history part on version a is not shown on version b and c, and this doesn't mean that version b and c don't have patient history, it's just because of the page length and it's redundant to show repetitive contents.

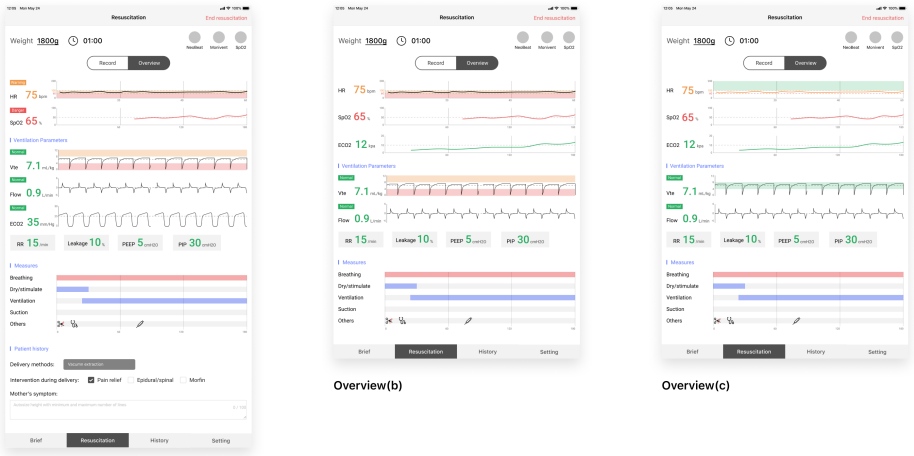


Figure 4.46: Three versions of the overview page.

4.4.3 The Ecosystem of the Resuscitation Support Tool

Source: https://laerdalglobalhealth.com/products/NeoBeat-Newborn-Heart-Rate-Meter/, https://www.monivent.se/, https://verk.store/product-eng-2353-Finger-pulse-oximeter-medical-heart-rate-heart-rate-monitor.html, https://www.youtube.com/watch?v=W2rfQqkpYqo

Figure 4.47: Ecosystem

Figure 4.47 demonstrates how the resuscitation support tool(iPad) interacts with the ecosystem. As mentioned in the subsection 4.3.4, the resuscitation support

tool(iPad) requires to receive real-time data from NeoBeat, Monivent Neo 100 and a pulse oximeter integrated in the Panda warmer.

The resuscitation support tool and Monivent should be connected to a charger and could be mounted on the wall next to the panda warmer with screen bracket. The screen bracket allows HCPs to adjust the positions and angles for both screens. The resuscitation support tool could be easily taken down when in use. The consideration of positions of the screens was based on the findings from a randomized controlled simulation study. In this study, the monitor was put either in the middle of radiant warmer with eye level or mounted on the wall above eye level besides the radiant warmer. The results show that the position of monitor didn't affect situation awareness (SA), visual attention (VA) or protocol adherence. However, participants found that central position was more convenient. And since the study was only tested in 2 people scenario, when more people involved it can cause obstruction for a peripheral monitor (Law *et al.* 2020). Further testing is needed to see when the positions and angles can be adjusted, whether there will be obstruction with more people involved.

If NeoBeat and Monivent are not available, alternatives have been considered. A possible way to receive HR is through the ECG leads integrated in the Panda warmer, and the HCPs can type in HR into the resuscitation support tool manually. The ventilation parameters can be accessed through a flow sensor (MIM Gmbh, Krugzell, Germany) that has been used in many studies (Linde *et al.* 2017).

In the future, when the visual recognition technology is more mature and has been approved in the clinical event, it can be added into this solution so that the time of birth and different intervention measures can be automatically registered, which can reduce the work of the user in a further step and possibly generate more precise data.

4.4.4 Storyboard

The storyboard has a series of illustrations demonstrating how a respiratory monitor (Monivent Neo 100) and a resuscitation support tool (iPad) function in a clinical neonatal resuscitation. Other than illustrations, each scene has also text description to help readers understand the story. Story began with an expected ill baby in the delivery ward, a junior pediatrician and a NICU nurse were informed about the sick baby and waited in a resuscitation room for the baby to come. They used the resuscitation support tool to brief before the baby was out. After the baby was sent to the resuscitation room, they registered and monitored the event with the resuscitation support tool on iPad, and can also see the ventilation techniques on the Monivent digital screen and the sensor module. After the resuscitation, the resuscitation support tool can support them through debrief. For more details, please refer to the storyboard in Appendix A.10. Noticed that the storyboard was

created based on the author's understanding of current procedures in Norway and how the new solution might help improve, so there might be some details that are unrealistic and will be found out in the later testing.

4.4.5 Testing Workshop

Two testing workshops have been conducted, one with a neonatologist at the entrance at SUS, another one with an anesthetist on Microsoft Teams. Both participants were recruited from the previous interview and the first workshop. Both workshops last for almost 1 hour. In the workshop, participants have reviewed the storyboard and prototype, answered the questions and given valuable feedback for the solutions.

Feedback regarding the storyboard

When they reviewed the storyboard, they occasionally gave some positive feedback about the CLC, the apgar score reminder, warning about too low SpO_2 and incorrect ventilation techniques on Monivent monitor and sensor module. The anesthesiologist liked the equipment checklist very much and said it was very realistic and helpful for remembering stuff. More comments were made for what needed to be changed about the storyboard. Here are the summary of the comments.

- The NICU nurses are usually just called when there is a very premature baby(under 30 weeks) or very sick baby. Usually it will be a pediatrician with the help of midwife and nurse assistant.
- During brief they usually check the equipment first in case the baby comes at any time.
- Checklist:
    - The meconium aspirator should be changed to suction sets;
    - They don't draw it up because they hardly ever use. Only around 1.0% of all resuscitations need epinephrine or adrenaline;
    - They don't have chemical mattresses in SUS;
    - The headlines,"resuscitator" and "nursing" can be a bit confusing and is suggested be changed with "pediatrician" and "NICU nurse".
- In SUS, they put NeoBeat on all babies immediately after birth in the delivery room, so the baby has already been put on NeoBeat when it comes to the resuscitation table.
- In their current practice, they don't weigh the baby before resuscitation, so they need to estimate the weight of baby if it's needed.
- The standing position of people: People in charge of the airway is at the end the table, the assistants will be on the sides. Usually they stand against the door, so they can see new people come. Midwife or nurse assistant usually stands at the back to take notes on the white board.

- After ventilating the baby for one minute and it is not improving, they don't call for help immediately. They call only after evaluation.
  In 2/3 of all the cases, the obstetrician estimates if the baby will be sick and call for help if it's needed. Then a young pediatrician, the first level team, will go and prepare in the resuscitation room. If the baby comes out in very bad shape and its skin color is completely white, then a bigger team is needed. In this case, they will call a department on the phone from the resuscitation table. And this department will push a button to raise an alarm, which will go to different people's pagers. After several minutes, a second level team consists of one neonatologist, one NICU nurse and anesthesia personnel and will arrive to help (Bjorland, Øymar *et al.* 2019).
  The cesarion section are categorised into 3 levels of urgency. Level one c-section is the most acute, in which they need to get the baby out immediately, so the second level team, usually neonatologist and NICU nurse, will attend. Level two c-section is less urgent, they have 20 minutes to get the baby out, so the first level team will attend. The third level is elective c-section, usually no pediatrician will attend.
- In SUS, it's common that the pulse oximeter is put on at 2-3 minutes after birth.
- Blood gases test is ordered after birth before they clamp the cord in the delivery room.
- A baby very rarely need fluid, saline or other medicine, during resuscitation. It's more common, but still rare, that it needs some glucose if the blood gases test result indicates that the baby has low blood sugar. So when an anesthesiologist is asked to get iv. access during the resuscitation, the anesthesiologist just put needle inside the baby's arm or foot. The iv. access will be kept if the baby need to be transferred to NICU department. If not, the needle will be pulled out before the baby leaves the hospital and goes to the hotel. Also it's unrealistic to succeed in getting iv. access within 5 minutes of birth. It first takes several minutes for the anesthesiologist to arrive at the scene after the alarm, and then some time for everyone to present themselves and assess the situation. Then they need to find the iv. equipment, and how long it takes to put the needle into the baby varies. As the anesthesiologist said, "if it's easy to see and hit it on the first try it can take like one minute. But if it's difficult it can take 5, maybe up to 10 minutes."
- The neonatologist suggested that before sending back the baby to the parents, there should be another assessment of the baby's situation. Does it qualify the criteria for hypothermia treatment? Does the baby have clear airway and breath well, without nasal flaring or gasping? Does it have a saturation over 95% for one or two minutes without any support? Is the baby under 35 weeks of GA? And the iPad could have such a checklist for assessment.
- After the assessment, if they need to take the baby up to NICU department then they don't have time to debrief. If the baby is healthy, then the midwife

> and nurse assistant should take the baby and leave with the father. Then the rest of the team can then have a short debrief, although it's not a routine in their current practice.

They have also noticed some inconsistencies of the drawing, such as the NeoBeat should be always put on the abdomen of the baby, and there should be always names or titles next to the person.

Feedback regarding the prototype

Generally they gave very positive feedback of the prototype, they thought the prototype looked beautiful, and they liked the overview and debrief page especially.

The neonatologist liked the realistic of the prototype, for example, the SpO_2 wasn't available until 1-2 minute, and they can register checking HR(using stethoscope) in the event. She commented that they used stethoscope very often, not only to check the HR, but also to check for the air going into lungs.

1. Which version of overview page do they prefer?

When they were asked which version of the overview page they liked, both of them said they preferred the version b, which has waveform of ECO_2. They would also like to see HR and SpO_2 in waveform. They gave reasons that waveform is more reliable, as the pediatrician stated:"So it actually is 60 per minute. It's not just because it's only picking up half the paces." While they thought that waveform could allow them easily to see if they have a good signal during resuscitation, they commented that the timelines would be useful in the after event report. And the pediatrician would like to see the HR and SpO_2 in both waveform and timeline on the overview page if it's possible.

While both participants shared the same preference for the waveform data, they disagreed with the background colors of the graphs. While the pediatrician preferred the version with warning and danger areas highlighted, the anesthesiologist preferred the version c, with the normal area highlighted in green.

2. Are there more data that they want to see on the overview page?

Both participants have shown interest in the pressure and airway blockage. However, they both agreed that there has already been lots of information and afraid that too much information can cause overload. Other than the pressure and blockage, the neonatologist wanted to include temperature. The temperature can be measured through the panda warmer. The neonatologist also gave a ranking of the four most important data she thought, HR, SpO_2, V_{te} and lastly ECO_2. She

mentioned that in a recent published study found that ECO_2 can be more preditive than V_{te} on lung aeration (Holte *et al.* 2019).

3. Which version of record page do they prefer?

They both liked the simplicity of version b. The pediatrician gave reason that the first group of measures can suit most of the babies, because only 1.3% of babies require ventilation. Therefore, there's no need to show the more advanced second group, and if they can always switch to the second group of measures. The anesthesiologist supported the version b only if the second group can show up automatically when certain time pass. Otherwise, she was concerned that extra clicking can cause the midwife or nurse assistant confusion.

4. what they like about the solution?

Both of the participants liked about the objective feedback which can inform them what has happened during the resuscitation. The anesthesiologist liked about the idea of having one tablet to register everything and be able to see just the enough number of data in the resuscitation. "And so if someone starts ventilating, then the person with the tablet can just click ventilating or something and it's also connected to the monitoring equipment so you can also get the trend and the exact values in that time. So you have a lot of things you can check out, but it's easy to look at it and it's really not too much information." And they both saw that this solution can make debrief much easier by providing summary, suggestion, discussion topics and data trends. The neonatologist believed that this can increase the transparency of the data, and can help them understand what they have done well and where they could improve."I like transparency. I think it's the right thing to do for the babies, and it's the right things to do for us to learn." And they express the wishes that the information on debrief page could be integrated into the patient journal. Additionally, the neonatologist saw the opportunity of setting up simulation training based on the data. The neonatologist said that she thought the solution have the potential to make it easier for her to assess the baby and improve the ventilation. She also agreed that this solution could improve the communication in the resuscitation because she would be more aware of the steps and things to remember, for example the warnings of low HR or SpO_2.

5. what they don't like about the solution and possible problems that can occur to their workflow.

The neonatologist answered that she didn't like that it required a person to register the intervention measures and wished that it can be automatically registered by visual recognition technology. She also mentioned that they clamped the cord in the delivery ward and they didn't currently have a resuscitation bed in the delivery ward. Therefore, if the iPad is in the resuscitation room, then the registration of

time on iPad for birth and cord clamp might be delayed. However, if the iPad is put in the delivery room, then a person will need to register everything on iPad and take it to the resuscitation room. The anesthesiologist raised concern about the need of typing weight into the system, and suggested that the name should be changed to "estimated weight". The researcher found out later that the newest version of Panda bedded warmer [6] support integrated weight scale. Which means it's possible to weigh the baby before resuscitation, however, this needs to be adjusted based on different settings. The anesthesiologist commented that as long as it has be implemented into the simulation training, and everyone has been familiar with the tablet, she couldn't think of any problems, because they have been using liveborn in their current practice as well.

[6] https://www.fusionhealthcare.com.au/files/PandaFamilyBrochure.pdf

Chapter 5

Discussion

The purpose of this research is to find out how healthcare professionals (HCPs) in Norway perform neonatal resuscitation, what difficulties do they have and what contributes to a high quality resuscitation, and explore the possibility of developing an effective solution to support HCPs in the decision making progress, and to improve their performance. A human center design approach with both quantitative and qualitative methods have been chosen in this research. The research process can be illustrated in a double diamond model with four stages, namely discover, define, develop and deliver.

In the discover stage, the researcher has conducted an online survey and received 60 valid responses from both HCPs and medical students. The researcher has also interviewed 11 HCPs from different hospitals in Norway and visited the observation rooms in Gjøvik Hospital and Stavanger University Hospital (SUS). Quantitative data from the surveys were analyzed with Microsoft Excel[1] and IBM SPSS [2]. Answers from the open questions in the survey and the interview notes were coded with Nvivo [3], and analyzed with a thematic approach.

The survey results show most of the participants have working experience of more then 12 years and work in a hospital that is able to treat infant with gestational age (GA) less than 28 weeks. In fact, they mainly came from SUS and St. Olavs Hospital in Trondheim. Considering the survey was mainly distributed through SUS and St. Olavs Hospital in Trondheim, it's no surprise that we got these results. The majority (74.47%) of the HCPs have clinical experience. Most(80%) of the participants in this group perform newborn resuscitation less than once a month. We can infer that the frequency of participation in clinical event is quite rare. Besides,

[1]https://www.microsoft.com/en-us/microsoft-365/excel
[2]https://www.ibm.com/no-en/products/spss-statistics
[3]https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

their training frequency is relatively low, the majority(70%) train less than once a month, and 21% train once a month. Based on the interview, most participants who chose less than once a month claimed that they only received training once or twice a year. Therefore, we can infer that the training is not frequent enough. However, due to the lack of more detail options, it's hard to how many of them train less than every other month or so. While asked about what data were collected during resuscitation, most participants gave answers as heart rate (HR), Peripheral Capillary Oxygen Saturation (SpO_2) and apgar score. This looks also very normal because in most guidelines, HCPs are required to give different interventions based on the values of HR and SpO_2 (NRR 2015). And to record apgar score is also a very common practice in neonatal resuscitation (Apgar 1953). Apart from collecting demographics data, another main purpose of the survey is to find out the prevalence of having difficulty in the resuscitation and what difficulties they have. Results show that 86% (n=30) of the HCPs who have clinical experience have difficulties during the clinical event. The most chosen difficulty is "feeling stressed", followed by "the difficulty to assess whether the baby is breathing adequately", "communication problems within the team" and "the difficulty to assess whether the baby responds to my treatment". While in the interview, the most frequently mentioned difficulty is the difficult to get sufficient air into the lung or provide sufficient ventilation, followed by the communication difficulty and feeling stressed. When they were asked to explain in the interview about their chosen options of difficulty, based on their answers the researcher suspected that the options "the difficulty to assess whether the baby responds to my treatment" and "the difficulty to assess whether the baby is breathing adequately" might have caused some confusions to the participants, and thus suggested combine these two options and name it as "the difficulty to provide sufficient ventilation". In this way the results from the survey will more comply to the results from the interview. From the interview, the researcher also found out that the difficulty to assess the baby's condition and the ventilation techniques are the main reasons to the difficulty to provide sufficient air into the lungs. Many studies show that HCPs' clinical judgement on the mask leakage, ventilation volume, rate, pressure, airway blockage is very often inaccurate (Schmölzer, O. C. O. F. Kamlin, O'Donnell *et al.* 2010; Schmölzer, Dawson *et al.* 2011; Schmölzer, Dawson *et al.* 2011). Although chest movement observation is recommended in the current neonatal resuscitation guidelines, studies show that it's a very subjective and unreliable indication for aeration of lungs (Poulton *et al.* 2011). And regarding the communication difficulty, the main problem is that very often a pediatrician is in charge of the airway and at the same time a team leader. Being a team leader needs to assign tasks and confirm the execution of tasks. However, this can be difficult while he/she needs to keep the main focus on the ventilation. When the pediatrician couldn't fulfill the responsibility as a team leader, the other team members don't know what they should do, and this can cause confusionin the team. The participants also commented on the absence of a closed loop communication (CLC) in the team, which is also reported in another study (Härgestam *et al.* 2013). The consequence of

lacking a CLC is that people doesn't know what has already been done by others and thus make it difficult to follow the guidelines. Other than the difficulties in the resuscitation, the participants have also mentioned some factors that could contribute to a good outcome, such as having good collaboration within the team, preparation before the event, objective real time feedback, more frequent training (both as individual and as a team) and a prompt and adequate ventilation, which aligne with another study (Moshiro *et al.* 2018).

During the analysis of the survey data, two hypotheses emerged. The first hypothesis is if a HCP has more working experience, then the likelihood of having difficulty in a clinical event is lower. The second hypothesis is if a HCP has higher frequency of participating in a clincal event or simulation training, then the likelihood of having difficulty in a clinical event is lower. Due to the small sample, both hypotheses have been rejected until further investigations.

In the define stage, a series of data analysis methods have been used to analyze the enormous amount of data and to generate insights for the next stage. Findings from survey and interview were then used to develop persona, empathy map and journey map. The researcher has created five personas (pediatrician, neonatal intensive care unit (NICU) nurse, midwife, anesthesiologist and anesthesia nurse) and corresponding empathy maps, and four main journey maps, expected case in the delivery ward, emergency c-section in the operation theatre, unexpected case in the delivery ward and planned c-section in the operation theatre. Persona, empathy map and journey map are effective ways of visualizing the data and creating empathy with the users. The journey maps is especially helpfu as it helped the researcher understand how different roles work in a team in four main scenarios. Two main difficulties, namely "difficult to provide sufficient ventilation" and "communication difficulty", have been written as Point of View and How Might We and served as the basis for brainstorming in the co-creation workshop session.

In the develop stage, one neonatologist and one anesthesiologist were invited to a co-creation workshop to validate the 4 journey maps, to generate ideas for the 2 main difficulties and then to vote out some ideas. The researcher has also presented three competitors to the participants in the workshop and has received generally positive feedback . However, concern about the information overload has been raised. After the workshop, the researcher have grouped similar ideas and further developed them. The researcher has analyzed several competitors, mainly respiratory function monitors (RFMs) and decision support tools (DSTs), tried to learn from their advantages and disadvantages to improve the solution. The researcher has also reviewed some literature on closed-loop communication. At last, the researcher visualized the final solutions with the ideation sheet. The ideation sheet helped the researcher to consider the implementation of the resuscitation support tool in a clinical setting.

In the deliver stage, the researcher used a mind mapping tool to conceive the structure of the prototype , which served as the input for wireframe and medium-fidelity prototype. A storyboard was also created to visualize how to implement the resuscitation support tool in an expected case in the delivery ward and how it would function. The prototype and storyboard have been tested with 2 HCPs in the testing workshops. Since the anesthesiologist wasn't involved in this scenario very much, the majority of the feedback on storyboard were given by the neonatologist. Some measures in the storyboard contradict to their current practice, for example, they put on NeoBeat in the delivery ward and they don't weigh the baby until it's stable. And since the cord clamping happens in the delivery ward, the iPad might need to be in the delivery ward. And they gave some suggestions on what more functions should be added to this solution. Other than these, they gave very positive feedback about the whole solution, and commented that the objective data and prompts could increase their awareness of the situation, adherence to the guidelines, and improve their performance and possibly team communication. They expected that the data could facilitate the debrief session, be used to set up simulation training targeting on their weaknesses, and could be integrated into the patient's journal. These benefits of objective data were also mentioned in Morley (2018). The reason that the solution has received so much positive feedback is possibly due to the co-creation session, which can generate the feelings of involvement, and in return, enables the solution to have higher chances of acceptance(citation:co-creation). Also, the storyboard demonstrated how the solution can be adapted to their existing work flow and integrated into the whole ecosystem, which could also increase their acceptance (Patterson *et al.* 2020). As one participant commented, they have been using a similar application (Liveborn) on a tablet in their daily practice. Therefore, the resuscitation support tool wouldn't be a totally new thing for them. Another possible reason is that the aesthetic of the prototype could reduce their willingness to give negative feedback.Tthe participants have commented that the prototype was beautiful for several times in the workshop. Also, unlike a usability testing, where the user will be given a task and need to finish the task alone, in which way it easier to discover some usability problems when the user misunderstands a button or make a mistake. However, in this study, the researcher was the person who clicked through the prototype and explained different contents on the pages, therefore the participants would have a better understanding of the prototype. Besides, the goal of this testing workshop wasn't to discover any usability issues, instead, its purpose was to know their acceptance of the solution before the researcher plan to invest more effort on it. This was the first time that the researcher tried to use storyboard and prototype in a testing session with users, the original thought was to save time but then figured it out that the combination of storyboard and prototype was a very good tool for testing a complex service or product. Since the whole solution includes not only the resuscitation support tool(iPad), but also Monivent Neo 100 and NeoBeat, the storyboard could easily demonstrate how the resuscitation support tool interacts with the other products, and how the solution could

be implemented in their current practice and have positive impact (Spalton 2019; Bridgeable 2018). Further study is needed to investigate the best practice for combining storyboard and prototype in a testing.

5.1 Research Ethics

5.1.1 Validity

Validity can be classified as internal validity and external validity. The internal validity is to what extent a researcher can draw accurate conclusions based on the data generates from a study (Leedy and Ormrod 2015, p. 103). To ensure or increase the validity, the researcher has used following measures. The researcher will use mixed-methods design and triangulation (Leedy and Ormrod 2015, p. 104), which means the researcher will collect data from both quantitative and qualitative methods, such as online survey, individual interview, workshops and so on, so that all the data can converge to support each other.

Other than the mixed-methods and triangulation, the researcher has validated the data and findings with the respondents in different ways through the whole project (Leedy and Ormrod 2015, p. 105). Firstly, if the interview wasn't recorded, then the researcher will send the notes back to the participants, so that they can correct the notes if there are any mistakes. Secondly, researcher have invite a small number of participants to a workshop where they can validate the finding. Last but not the least, the researcher will testify the prototype with the participants and iterate it based on their feedback for several times until a satisfied result is achieved. Moreover, the researcher will conduct extensive literature review to see how other researchers effectively used the methods. The researcher will show the instruments like survey questions, interview guides and so on to more experienced colleagues for feedback and conduct some pilot studies to discover the weaknesses of the instruments and modify them.

External validity is the extent to which the conclusion drawn from the study can be generalized to other context (Leedy and Ormrod 2015, p. 105). In this study, all data will be collected from the life setting to ensure the external validity. For example, the researcher will conduct the interviews and prototype testing where the participants work, so that the conclusion can be applied to real-life situations. However, because of the time limit and the confidentiality issues with the hospitals, it might not be practical to recruit a representative sample or to duplicate the study in multiple hospitals in Norway. In this case. This limitation will be acknowledged when drawing a conclusion.

5.1.2 Reliability

Reliability is the consistency with which a measurement generates consistent result from a stable entity (Leedy and Ormrod 2015, p. 116). To enhance reliability, the main study will be conducted by only one researcher and the measurements will be consistent for the same sample. Guidelines for observation, interviews, workshops and testing will be created beforehand to ensure that different sessions can be conducted consistent and the results between sessions can be comparable.

5.2 Limitation

5.2.1 Limitation of the Sample

Due to the difficulty to contact hospitals or resuscitation units and for recruiting participants, there are two main limitations to the sample. Most of the participants in the survey were mainly HCPs from St. Olavs Hospital in Trondheim and SUS and medical students from NTNU. Participants in the individual interview, co-creation workshop and testing workshop were mainly recruited from SUS. St. Olavs Hospital and SUS are hospitals that can treat infants with GA less than 28 weeks. Only a few participants were from hospitals that can treat infants with GA more than 28 weeks. Therefore, the sample may not be representative of HCPs in other hospitals in Norway. However, theses are the hospitals where most high-risk deliveries happen and therefore have more values to focus on.

Besides, the overall sample is small. There were only 11 participants in the individual interview, and only 2 in the co-creation workshop and testing workshop respectively. And the participants in the interview haven't included all the main roles in the resuscitation, which has limited the researcher's understanding of midwife, NICU nurse and nurse assistant. However, other participants have worked closely together with these roles and have provided some information to fill the gap.

If this could be done differently, the researcher would spend more time on finding more hospitals or resuscitation units that are willing to collaborate, to reach a more representative sample. The researcher would also think about various ways of attracting midwife, NICU nurse and nurse assistant in SUS, such as increasing the incentives for participation, distributing some leaflets in the ward, or even giving small presentation during their lunch break.

5.2.2 Not able to Conduct Observation

At the beginning of the project, the researcher planned to observe the neonatal resuscitation in the clinical setting and to receive a basic training from a HCP. However, since this involved the patient's consent, and would require the approval

from Regional Komiteer for Medisinsk og Helsefaglig for Forskningsetikk (REK), which can takes around two months before the researcher can start to collect data, let alone the difficulty to recruit willing patients. Therefore, the researcher changed the original plan to observe simulation training in universities or hospitals. However, due to the corona virus restriction, simulation training have been cancelled in many schools and in SUS, therefore it's impossible to conduct observation. The lack of observation made it more difficult and takes more time for the researcher, who has very little background knowledge on neonatal resuscitation, to understand the context and how different roles collaborate with each other in neonatal resuscitation, and to build empathy with them. Although the researcher managed to collect this information from literature review, survey, interview and workshops, it's worth noting that what the interviewee have reported might differ substantially from reality due to the memory loss, desirability bias or confirmation bias, or they simply don't realize that they are not doing as what they thought. Contradictory among different participants' answers have been found. Theses are the reasons why it's so important and necessary to conduct the observation along side with other methods.

If this could be done differently, the researcher would contact the hospitals much earlier, and see how to adapt the researcher plan for observation. To the researcher's knowledge, SUS have been recording the clinical events for their own research projects. It might be possible to apply for access to those videos if the researcher have applied and received approval from REK.

5.2.3 Limited time on Prototype and User Testing

The original plan was to spend at least one month on developing prototype, and have several rounds of usability testing and prototype iterations, until satisfied results have achieved. However, since the project is related to medical area, though not a medical research project, it took more time than a normal project, around two months, to get the final approval from Norsk Senter for Forskningsdata (NSD). Apart from applying for NSD, the researcher have also applied for the project evaluation from REK, which had been required by NSD. After that, it took another three weeks before the researcher got the permission to enter SUS as an hospitant (in Norwegian) and to conduct research. Because of these unforeseeable obstacles, large amount of the time have been spent on getting approval from different parties, therefore time that could have been spent on the rest of the project have been sacrificed, especially for the prototype and testing.

It can be argued that the researcher should have spent more time on the prototype and testing instead of on the user research. However, neonatal resuscitation is a domain that requires large amount of professional knowledge. Although the researcher has spend lots of time on reading literature review to get familiar with the domain, the knowledge from the papers can't replace the values of spending

some actual visits to the resuscitation room, and to talk with the participants. This ground work has considerably contributed to the researcher's understanding of how HCPs perform neonatal resuscitation in reality, and what difficulties and expectations they have. Lack of this proper ground work might lead to a misunderstanding of the problems and developing a poor quality solution, and then more time have to be spent on correcting the understanding and prototype.

If it could be done differently, the researcher would apply for the approval from REK and NSD much earlier, so that more time could be spent on developing the final solutions and the testing.

Chapter 6

Conclusion

This research aims to understand how healthcare professionals(healthcare professionals (HCPs)) in Norway provide neonatal resuscitation, what are the barriers and enablers for providing a high quality resuscitation, and finally using this information to develop an effective solution to support the healthcare professionals through the process and improve their performance.

A human center design approach with both quantitative and qualitative methods have been applied in this research, including literature review, survey, individual interview and field study. Field study and individual interview have been used to empathize with the users and to cultivate a deeper understanding of the HCPs and healthcare system. Multiple data analysis methods(e.g. persona, journey map) have been used to define the problems, and the most prominent problems are the difficulty to give sufficient ventilation and have good communication in the team. With this finding, the researcher has invited two HCPs to a co-creation workshop to discuss about possible solutions. With these inputs, the researcher further developed the ideas into storyboard and prototype and tested them with two HCPs separately in testing workshops. The researcher has received generally positive feedback that this solution could help document the event, increase their understanding on what has happened during resuscitation and improve their performance with the help of timely prompts and the debrief report.

6.1 Contributions

The current research has several contributions:

- It provides an in-depth understanding of the current practice of neonatal resuscitation in Norway and the related health ecosystem;

- It provides a better understanding of the barriers and enablers to a high quality resuscitation, and what expectations and requirements the HCPs have for the solution;
- It suggests a tool, when implemented together with Monivent Neo 100 and NeoBeat, which can improve the understanding of the situation for the healthcare professionals during a neonatal resuscitation, and have the potential to improve their performance and adherence to the Norwegian newborn resuscitation guideline.

6.2 Future Work

Due to the limited time, the researcher has finished only the key interfaces for the prototype in the current study. Therefore, the next step would be to finish the rest of the interfaces, including the history, setting and brief sections and the interactive components. Refinement to the storyboard would also be made based on the feedback from the testing workshop. The researcher should also consult the possibility of implementing the tablet in the delivery ward or other ways of collecting the correct time of birth and cord clamp. The prototype together with the storyboard would be tested in a usability testing workshop with a bigger sample including midwife, NICU nurse, nurse assistant, pediatrician and anesthesia personnel, to gather feedback from different perspectives. After the usability testing, the prototype should be improved based on the feedback and be tested in a resuscitation simulation training together with a respiratory function monitor (RFM) and NeoBeat. The purpose of this testing would be to to testify several hypotheses, whether this solution can increase their situation awareness, whether it can reduce their errors during ventilation, whether it can improve their adherence to the NRR guideline, and whether it can reduce the workload.

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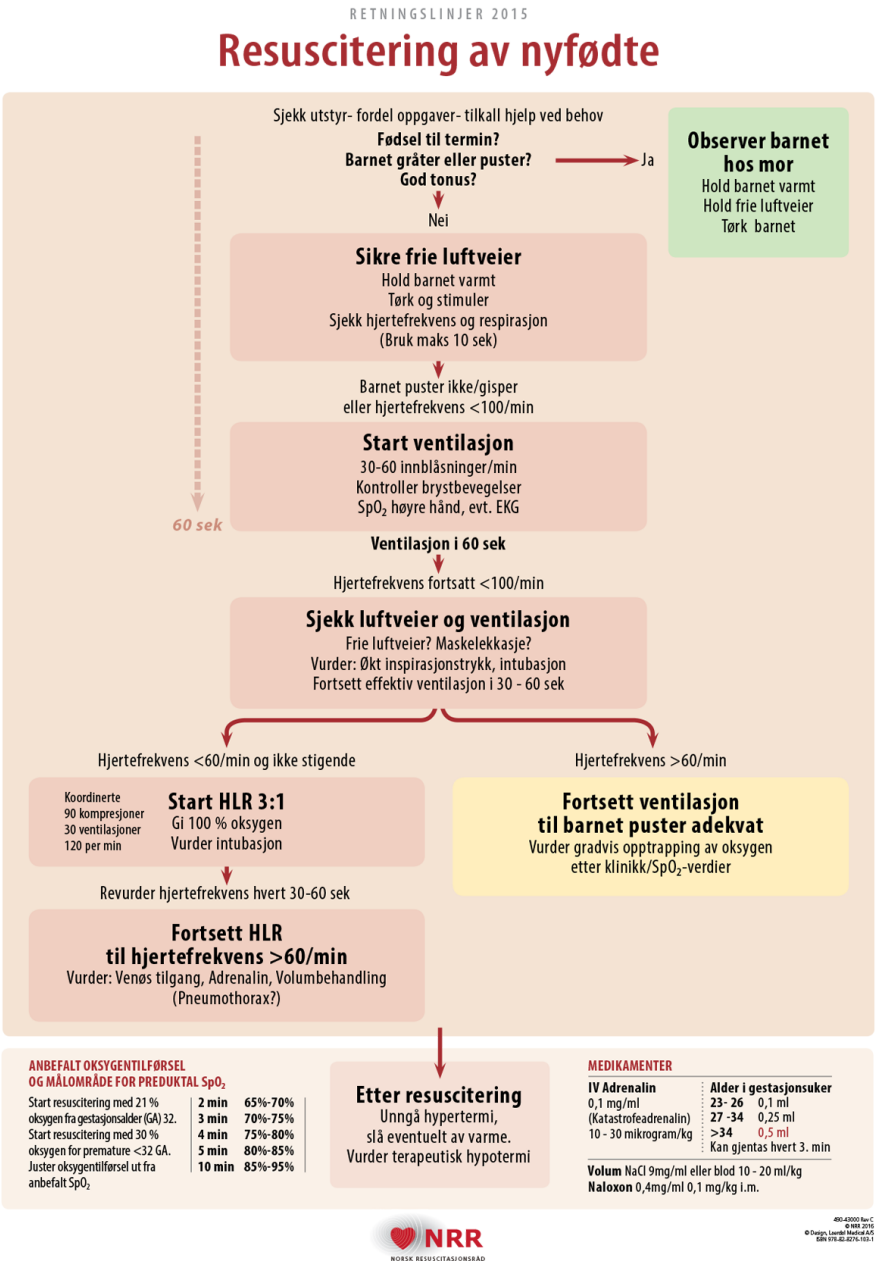
Appendix A

Appendix

A.1 Norwegian 2015 Newborn Resuscitation Guideline



A.2 Survey Questions

Studie om Forbedring av Nyfødt Resuscitering

Side 1

Hei, jeg er en masterstudent fra NTNU. For tiden skriver jeg en masteroppgave om ***forbedring av nyfødt resuscitering***.

Er du **lege eller sykepleier** som har fått **simuleringstrening i nyfødt resuscitering** og helst med **klinisk erfaring**? Hvis ja, kan du hjelpe meg med å fylle ut undersøkelsen. Du kan også få sjansen til å vinne et **500 kroners gavekort!**

Undersøkelsen inkluderer spørsmål om klinisk erfaring og simuleringstrening om nyfødt resuscitering, og vil koste deg rundt **5 minutter.**

Personopplysningene blir anonymisert rett etter innsamling, og alle resultatene vil bli slettet ved prosjektets slutt, senest 31. desember 2021. Du kan trekke deg når som helst under undersøkelsen. Gå til denne lenken for fullversjonen av informasjonsbrevet.

Hvis du har spørsmål, kan du sende meg en e-post (jiaxinl@stud.ntnu.no). Og hvis du kjenner noen andre som kan være interessert, ikke nøl med å videresende undersøkelsen. Takk for din tid og ha en fin dag!

Dette spørreskjemaet er oversatt fra engelsk til norsk av Jon Sverre Langaker.

Jeg har mottatt og forstått informasjon om prosjektet «Hvordan forbedre klinisk resuscitering av nyfødt», og har fått anledning til å stille spørsmål. Jeg samtykker til å delta i denne undersøkelsen. *

- ◯ Ja
- ◯ Nei

Jeg samtykker til at mine opplysninger (f.eks. E-postadresse) behandles frem til prosjektet er avsluttet, senest 31. desember 2021. *

ⓘ Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Jeg har mottatt og forstått informasjon om prosjektet «Hvordan forbedre klinisk resuscitering av nyfødt», og har fått anledning til å stille spørsmål. Jeg samtykker til å delta i denne undersøkelsen.»

- ◯ Ja
- ◯ Nei

Sideskift

Side 2

Er du *

- ◯ Jordmor
- ◯ Neonatolog

- ○ Barnelege (LIS)
- ○ Barnesykepleier
- ○ NICU sykepleier
- ○ Anestesilege
- ○ Anestesisykepleier
- ○ Fødselslege
- ○ Annet

Hvis du valgte annet, vennligst spesifiser *

ⓘ Dette elementet vises kun dersom alternativet «Annet» er valgt i spørsmålet «Er du»

Hvor mange års relevant arbeidserfaring har du? *

- ○ 0-3 år
- ○ 4-7 år
- ○ 7-12 år
- ○ mer enn 12 år

Hvor gammel er du? *

ⓘ Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Jeg samtykker til at mine opplysninger (f.eks. E-postadresse) behandles frem til prosjektet er avsluttet, senest 31. desember 2021.»

- ○ 18-30
- ○ 31-40
- ○ 41-50
- ○ 51-60
- ○ 61-70
- ○ mer enn 70
- ○ ønsker ikke å oppgi

Har du deltatt i nyfødt resuscitering? *

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Jeg samtykker til at mine opplysninger (f.eks. E-postadresse) behandles frem til prosjektet er avsluttet, senest 31. desember 2021.»

- ○ Ja
- ○ Nei

Hvor ofte utfører du nyfødt resuscitering? *

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du deltatt i nyfødt resuscitering?»

- ○ mindre enn en gang per måned
- ○ 1-5 ganger per måned
- ○ 6-10 ganger per måned
- ○ mer enn 10 ganger per måned

Hvor ofte gjennomføres BRIEF før resuscitering av en nyfødt baby (not the one before labour)? *

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du deltatt i nyfødt resuscitering?»

fra 1 (aldri) til 5 (alltid)

1 2 3 4 5

Verdi

Hvor ofte gjennomføres DEBRIEF etter resuscitering av en nyfødt baby? *

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du deltatt i nyfødt resuscitering?»

fra 1 (aldri) til 5 (alltid)

1 2 3 4 5

Verdi

Hvilke data samler du inn under nyfødt resuscitering? *

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du deltatt i nyfødt resuscitering?»

- [ ] Vurdering av hjertefrekvens
- [ ] Temperatur
- [ ] Apgar score
- [ ] SpO2 monitorering
- [ ] Intubation
- [ ] Chest compression
- [ ] Tidspunkt for avnavling
- [ ] PPV
- [ ] CPAP
- [ ] Umbilical blood gas
- [ ] Væskestøt
- [ ] Adrenalin iv
- [ ] Transfer to NICU
- [ ] Annet

Hvis du valgte annet, vennligst spesifiser *

Dette elementet vises kun dersom alternativet «Annet» er valgt i spørsmålet «Hvilke data samler du inn under nyfødt resuscitering?»

Har du brukt NeoBeat for å evaluere barnets hjertefrekvens? *

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du deltatt i nyfødt resuscitering?»

- ( ) Ja
- ( ) Nei

Hor nyttig synes du NeoBeat er under resuscitering? *

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du brukt NeoBeat for å evaluere barnets hjertefrekvens?»

fra 1 (unyttig) til 5(nyttig)

1 2 3 4 5

Verdi

Opplever du noen av følgende vanskeligheter når du gir nyfødt resuscitering? *

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du deltatt i nyfødt resuscitering?»

- [ ] Kommunikasjonsproblemer i teamet
- [ ] Vanskeligheter med å vurdere om barnet puster tilstrekkelig
- [ ] Vanskeligheter med å vurdere om barnet responderer på behandlingen jeg gir
- [ ] Vanskeligheter med å finne utstyr
- [ ] Mangel på medisinsk personell
- [ ] Stressfølelse
- [ ] Annet
- [ ] Jeg har ingen vanskeligheter

Hvis du valgte annet, vennligst spesifiser *

Dette elementet vises kun dersom alternativet «Annet» er valgt i spørsmålet «Opplever du noen av følgende vanskeligheter når du gir nyfødt resuscitering?»

Opplever du utfordringer rundt brief og debrief? *

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du deltatt i nyfødt resuscitering?»

- [ ] Har ikke tid for brief eller debrief
- [ ] Vanskelig å samle alle for debrief
- [ ] Vanskelig å huske hva som skjedde under resuscitering
- [ ] Annet
- [ ] Jeg har ingen vanskeligheter

Hvis du valgte annet, vennligst spesifiser *

Dette elementet vises kun dersom alternativet «Annet» er valgt i spørsmålet «Opplever du utfordringer rundt brief og debrief?»

Har du gjennomført simuleringstrening på nyfødt resuscitering? *

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Jeg samtykker til at mine opplysninger (f.eks. E-postadresse) behandles frem til prosjektet er avsluttet, senest 31. desember 2021.»

- ( ) Ja
- ( ) Nei

Hvor ofte har du simuleringstrening på nyfødt resuscitering? *

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du gjennomført simuleringstrening på nyfødt resuscitering?»

- ( ) Mer enn en gang per uke
- ( ) En gang per uke
- ( ) 2-3 ganger per måned
- ( ) En gang per måned
- ( ) Mindre enn en gang per måned

Hvor godt liker du simuleringstrening på nyfødt resuscitering? *

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du gjennomført simuleringstrening på nyfødt resuscitering?»

fra 1(misliker) til 5 (liker)

1 2 3 4 5

Verdi

Hvor ofte gjennomføres debrief etter simuleringstreningen på nyfødt resuscitering? *

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du gjennomført simuleringstrening på nyfødt resuscitering?»

fra 1(aldri) to 5 (alltid)

1 2 3 4 5

Verdi

Hvor ofte får du tilbakemelding på hvor godt du presterte i simuleringstreningen under de-briefen? *

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du gjennomført simuleringstrening på nyfødt resuscitering?»

fra 1(aldri) to 5 (alltid)

1 2 3 4 5

Verdi

Opplever du noen problemer under simuleringstrening om nyfødt resuscitering? *

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du gjennomført simuleringstrening på nyfødt resuscitering?»

- [ ] Ikke realistisk, for forskjellig fra den kliniske hendelsen
- [ ] Trener ikke hyppig nok
- [ ] Kommunikasjonsproblemer i teamet
- [ ] Vanskeligheter med å vurdere om dukken puster tilstrekkelig
- [ ] Vanskeligheter med å vurdere om dukken responderer på behandlingen jeg gir
- [ ] Vanskeligheter med å finne utstyr

- [ ] Stressfølelse
- [ ] Annet
- [ ] Jeg har ingen vanskeligheter

Hvis du valgte annet, vennligst spesifiser *

Dette elementet vises kun dersom alternativet «Annet» er valgt i spørsmålet «Opplever du noen problemer under simuleringstrening om nyfødt resuscitering?»

Har du noen forslag til hvordan man kan forbedre nyfødt resuscitering?

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du deltatt i nyfødt resuscitering?»

Har du noen forslag til hvordan man kan forbedre simuleringstrening på nyfødt resuscitering?

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Har du gjennomført simuleringstrening på nyfødt resuscitering?»

Vil du bli med i trekningen av et gavekort? Hvis ja, vennligst fyll inn e-postadressen din her

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Jeg samtykker til at mine opplysninger (f.eks. E-postadresse) behandles frem til prosjektet er avsluttet, senest 31. desember 2021.»

Hvis du vil delta i et intervju, vennligst fyll inn e-postadressen din her. Du har sjansen til å vinne 800kr gavekort!

Dette elementet vises kun dersom alternativet «Ja» er valgt i spørsmålet «Jeg

samtykker til at mine opplysninger (f.eks. E-postadresse) behandles frem til prosjektet er avsluttet, senest 31. desember 2021.»

Takk for at du tok deg tid til å svare. Hvis du har spørsmål, kan du sende meg en e-post (jiaxinl@stud.ntnu.no).

Se nylige endringer i Nettskj

A.3 Checklist used in Neonatal Resuscitation

A.3.1 Checklist used in Gjøvik Hospital

best
www.bestnet.no

NYFØDT TEAM

Mors navn: _____

Mors fødselsnr.: _____

Tvilling/Trilling nr.: _____

VIKTIG INFO OM FØDSEL

Født dato: _____ Klokken: _____

Kjønn: Jente ❑ Gutt ❑ Vekt: _____ GA: _____

Vannavgang kl.: _____ Meconium ❑

Vaginalt ❑ Vacuum ❑ Tang ❑ Sectio ❑

Intub.: ❑ CPAP / Neo-Puff Tp.: _____

Annet: _____

APGAR SCORE

	1 min.	5 min.	10 min.		
Hjertefrekvens					
Respirasjon					
Muskeltonus					
Reaksjon					
Hudfarge					
Sum					

ALARM

Dato: _____ Klokken: _____

INTUBERT

Dato: _____ Klokken: _____

Tubestr.: _____

HJERTEKOMPRESJON

Start kl.: _____ Stopp kl.: _____

PERSONELL

	Tilstede kl.
Jordmor 1:	
Jordmor 2:	
Barnelege:	
LIS barn:	
Barnespl. 1:	
Barnespl. 2:	
Anestesilege:	
Anestesispl:	
Gynekolog:	
Loggfører:	

SJEKKLISTE

❑ Frie luftveier ❑ Padding under skuldre

❑ Suging i munn / svelg (kun ved obstruksjon)

❑ Ventileres ❑ Romluft ❑ O_2 %: _____

❑ Maske / bag ❑ Neo-Puff ❑ CPAP

❑ Intuberes

❑ Rtg. thorax best.

❑ Venflon kl. _____

❑ Navlevenekateter kl. _____

❑ I.O. kanyle kl. _____ ❑ Hø. ❑ Ve.

❑ Væskebehandling

❑ Blodprøver / blodgass / blodsukker

❑ Apgar

❑ Temperatur ❑ Rect. ❑ Skin

❑ Temperaturregulerende tiltak

❑ Varme slått av kl. _____

Tid i minutt:	1	2	3	4	5	6	7	8	9	10	15	20	25	30	35	40	45	50	55	60
Tp: ◉ P: ♥/BT: ⌛																				
42 260																				
41 240																				
40 220																				
39 200																				
38 180																				
37 160																				
36 140																				
35 120																				
34 100																				
33 80																				
32 60																				
31 40																				
30 20																				
Merknad:																				
O_2 l/min.																				
FiO_2 %																				
SpO_2																				
Resp. frekvens																				
Inndragninger																				
Maske / bag																				
Neo-Puff																				
CPAP																				
Hudfarge																				
Kapillærfylning																				
Overvarme																				

MEDIKAMENTER

	Styrke	Adm.form	Dose	Kl.	Dose	Kl.	Dose	Kl.	Dose	Kl.
Adrenalin	0,1 mg/ml	i.v.								
NaCl.	9 mg/ml	i.v.								
Nalokson	0,4 mg/ml	i.v./tube/i.m.								
Glukose	100 mg/ml	i.v.								
Blodtrans./SAGM	10-20 ml/kg	i.v.								

Funn, tiltak og behandling:

Merknad:

BLODPRØVER / BLODGASS

Klokken:								
Art. / Ven.	A	V	A	V	A	V	A	V
Kap. / Navlestr.	K	N	K	N	K	N	K	N
pH								
PaO_2								
$PaCO_2$								
Laktat								
BE								
Na								
K								
Blodsukker								
Hb								
Leucoc.								
Tromboc.								

Videre behandling, undersøkelser og forordninger:

PAS. OVERFØRING

Dato: _____ kl. _____

❑ Mor ❑ Nyfødt int. ❑ Annet: _____

Ansv. lege videre:

Calling:

Sign. ansvarlig lege:

HUSK

- Gjør deg kjent med asfyksirommet og utstyret
- Tenk fremover og planlegg i fellesskap
- Be om hjelp i tide
- Utøv lederskap - følg teamleder
- Fordel arbeidsoppgavene og bruk tilgjengelige ressurser
- Kommuniser effektivt og bruk all informasjon
- Unngå å fokusere på bare én ting - bevar overblikket
- Dobbeltsjekk medikamentdoser, sideangivelser, koblinger o.l.
- Bruk sjekklister og prosedyrer
- Ta jevnlige oppsummeringer og dokumentér funn
- Bevar årvåkenhet - barnet kan raskt bli dårligere
- Husk at manglende kontroll av luftvei og ventilasjon dreper raskt og oftest

ABCDE -

Undersøk pas. raskt og systematisk i prioritert rekkefølge!

Airways - luftveier
Breathing - respirasjon
Circulation - sirkulasjon
Disability - bevissthet, nevrologi
Expose/environment - oversikt og omgivelser

Iverksett tiltak dersom du finner utilfredsstillende forhold under ett av punktene.
A må rettes opp før du går videre til **B** etc.

APGAR SCORE etter 1 minutt - 5 minutt - 10 minutt

	0 poeng	1 poeng	2 poeng
Hjertefrekvens (slag pr. min.)	0	Under 100	Over 100
Respirasjon	Ingen	Gisping	Regelmessig
Muskeltonus	Slapp	Noe fleksjon	Normal
Reaksjon på stimuli	Ingen	Ansiktsgrimaser	Skrik
Hudfarge	Blek eller blå	Blå på hender og føtter	Hele kroppen rosa

REFERANSE GUIDE

PREMATURE/GA	Blodvolum 80-90 ml/kg	HR per min.	Mean BT mmHg	RF per min.	TV 4-5 ml/kg	Tubestr.
26 uker = 750 g	65	130-175	Over 25-30	40-70	3 - 3,75	2,5
28 uker = 1000 g	100	130-175	Over 25-30	40-70	4 - 5	3,0
30 uker = 1500 g	150	130-175	Over 25-30	40-70	6 - 7,5	3,0
32 uker = 1800 g	170	130-170	Over 30-35	40-70	7,2 - 9	3,0
34 uker = 2200 g	200	130-170	Over 30-35	40-70	8,8 - 11	3,0
FULLBÅRNE						
2500 g	220	110-160	Over 35-40	40-60	10 - 12,5	3,0
3000 g	270	110-160	Over 35-40	40-60	12 - 15	3,5
3500 g	315	110-160	Over 35-40	40-60	14 - 17,5	3,5
4000 g	360	110-160	Over 35-40	40-60	16 - 20	3,5

Det er vanlig å angi minimum mean BT som like mye i mmHg som barnet er GA i uker.
Obs at BT ikke er en optimal markør på sirkulasjon hos nyfødte, må vurderes i en totalsammenheng.

Respirasjonsfrekvens hos friske fullbårne kan være opptil 65 per min. de første to levetimer.

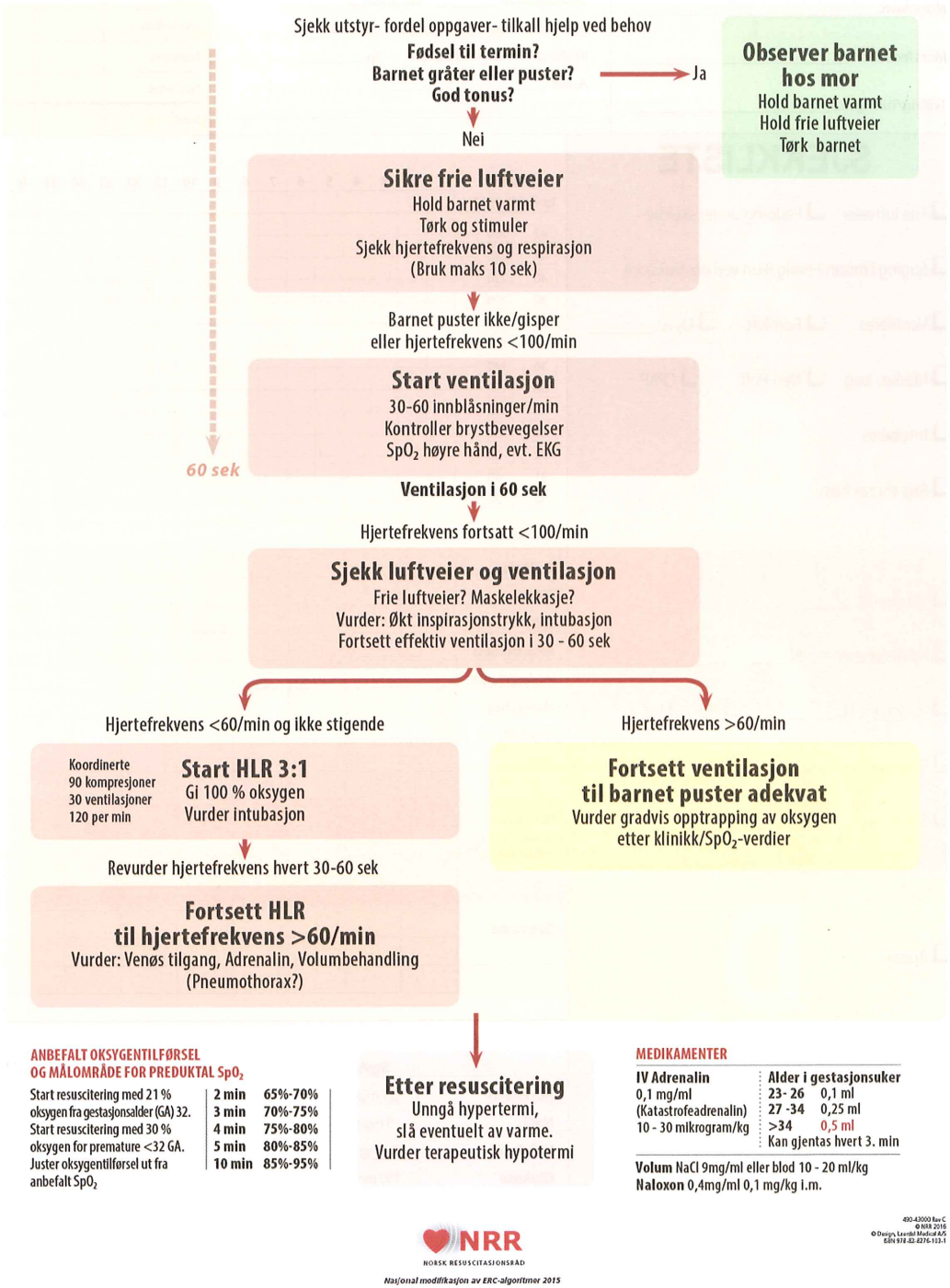
MEDIKAMENTER	Styrke	Adm. form	Dose fullbårne	Dose premature	Merknad
Adrenalin	0,1 mg/ml	i.v.	0,5 ml	Lavere, se NRR plakat	Kan gjentas hvert 3. min.
NaCl.	9 mg/ml	i.v.	10-20 ml/kg		Gis over 5-10 min.
					Ved mulig hypovolemi
					Kan gjentas
Nalokson	0,4 mg/ml	i.v./tube/i.m.	0,25 ml/kg		Hvis mor har fått morfinprep. de siste 4 t. før fødsel
Glukose	100 mg/ml	i.v.	Behandlingsmål: Blodsukker mellom 2,6 og 4,5 mmol/l		

Blodtransfusjon/SAGM 10-20 ml/kg

OBS! Alle verdier er veiledende, dette gjelder også doseringer.

RETNINGSLINJER 2015

Resuscitering av nyfødte



NRR
NORSK RESUSCITASJONSRÅD

Nasjonal modifikasjon av ERC-algoritmer 2015

A.3.2 A registration form has been used in SUS for baby who is transferred to NICU

Overflyttingsskjema nyfødt, - fra fødeavdelingen til nyfødtintensiv 3D

Mors navn og fødselsdato (klisterlapp):

Termin ultralyd TUL: _____

Sykdommer hos mor: _____

Medikamentell behandling - mor: _____

Celeston gitt: ____ Nei ____ Ja Dato: ____ Klokkeslett: _____

Vannavgang dato: ____ Klokkeslett: ____ Utseende: _____

Symptomer på amnionitt: _____

Tatt blod til forlik: ____ Ja ____ Nei

Kvinnen/paret samtykker til at barnet får testet morsmelk: ____ Ja ____ Nei

Barnets fødselsdato: _____ **Klokkeslett:** _____

vekt:_____ lengde: _____ hode: _____

Førløsningsmetode: ____ Spontan hodefødsel ____ Vaginal seteforløsning
____ Vakumekstraksjon VE ____ Tangforløsning ____ Vanskelig skulderforløsning
____ Akutt sectio ____ Elektiv sectio ____ Generell narkose

Indikasjon for inngrep: _____ Smertelindring: ____ epidural/spinal ____ Morfin

APGAR SCORE:

	1 minutt	5 minutter	10 minutter
Hjertefrekvens			
Respirasjon			
Muskeltonus			
Reaksjon			
Hudfarge			
Total antall poeng			

ASTRUP: Arteriell pH:_____ BE: _____ Venøs pH: _____ BE: _____

Konakion 1mg im. gitt: ____ Ja ____ Nei **Barnets temp/kl.sl:** _____ bl.s/kl.sl: _____

Håndmelket: _____Ja _____Nei **Fått mat:** ___ Nei ___ Ja Kl.sl. ____ Ammet____
Tillegg: ____ ml Testet morsmelk: ____ ml Morsmelk(Hånsmelket): _____ml

A.4 Individual Interview Guide for Medical Staff

Individual Interview Guide - Medical Staff

Target User Group

Clinicians who has clinical experience on neonatal resuscitation and received newborn resuscitation training, including: 1. Six users from midwife (jordmor), midwife nurse (barnepleier); 2. Six users from paediatrician, paediatrician nurse; 3. Six users from obstetrician; 4. Three users from anesthetist

Research Goal

- Understand how they perform newborn resuscitation, what steps and equipment they used, how often?
- How do they feel during resuscitation? Is there any difficulty or problems?
- Do they brief and debrief? How do they do it? How often? What do they think of it? Is there any difficulty or problems?
- What kind of training do they have? How often? What do they think of it? (like and dislike)
- Do they evaluate their performance and if yes, how and how often?
- How do they improve their performance?

How to reach them:

I will try to contact the person in charge in the hospitals, and ask him/her to recruit participants for me. I will contact St.Olavs Hospital in Trondheim and Stavanger University Hospital first.

Interview Questions

The questions and the structure will be adapted according to the participants' roles and their answers.

Approximate time: 1 hour

- **Introduction (5mins)**
    - Jiaxin Li (master student of interaction design at NTNU)
    - Master thesis: how to improve clinician's performance on newborn resuscitation
    - Ethical considerations:

Sign consent form, audio and video will be recorded, information will be anonymized after collected, they don't need to answer questions if they don't want to, and they can withdraw whenever they want.

- **Open questions (5mins)**

1. How long have you been working in this role or field?
2. What do you do when you work? What does a typical day at work look like to you?

- **Resuscitation Clinical Event (15-20mins)**

1. How many births do you give in one day or week?
2. How many times do you need to give resuscitation in one day or week?
3. How do you know if a baby needs resuscitation?
4. How many people are involved in the resuscitation? What kind of roles do they have?
5. Can you tell me how do you give new born baby resuscitation? What guidelines do you follow? what equipment do you use?
6. How can you tell whether the newborn needs suction or ventilation? How do you know how long he/she needs?
7. Do you have any difficulties when you give resuscitation? (how do you know whether the mask is leaking or not?)

communication problems within the team, difficulty to assess the baby's condition correctly, difficulty to find the equipment, in short of medical staff, feeling stress…

   - YES: what solutions do you think can solve the difficulties? / what do you think can make resuscitation easier?

8. What do you think about the resuscitation experience? (is it stressful?)
   - if stressful: do you have any suggestions to make it less stressful?
9. Can you tell me the last time you gave resuscitation support?
10. Can you tell me another example which you remember most when you gave resuscitation?
11. Why is it so memorable?

- **Debrief (10mins)**

1. Do you have brief before resuscitation?
    - YES: how often? how do you do it?
2. What do you think about the brief? (what's the benefits?)
3. Do you have any difficulties when doing brief?
    - YES: what do you think can make it easier?
4. Do you debrief after resuscitation?
    - Yes: How often?
5. How do you do the debrief? Do you have a facilitator? Do you use any report in the debrief?
6. Do you receive feedback on how well you performed and what you can improve?
7. Do you know how they evaluate your performance?
8. What do you usually do to improve your performance?
9. What do you think of debrief? What do you like/dislike about it?
10. Are there any challenges or difficulties during debriefing?
11. what would make it easier?

- **Training (10mins)** (drop this if there's not enough time)

1. How often do you receive training on newborn resuscitation? How long?
2. What do you do in the training? (brief and debrief?)
3. What do you think about the training? Something you like or dislike? Why?
4. What's the difference between training and the clinical event?
5. Are there any challenges or difficulties during training?
6. What do you think can improve the training or solve the difficulties?

Draw an empathy map and journey map together (10-15 mins)

Provide template and some emoji stickers.

- **Ending (5mins)**

1. Considering everything we have talked about today, what's one thing that's most important to you?
2. Is there anything we haven't talk about today but you would like me to know?

A.5 Mural board, before workshop

BRAINSTORM - GROUP - PRIORITIZE

Use this when you have defined the problem you're trying to solve and you're ready to start exploring solutions.

1 Problem statement

What problem are you trying to solve? Frame your problem as a How Might We statement.
This will be the focus of your brainstorm.

⏱ **5 minutes**

Problem statement 1

[The HCPs who participate in a newborn resuscitation]
needs to
[provide sufficient ventilation to the baby]
because
[they want to save the baby's life].

it's difficult to know if they have gotten air into the lungs, because it's not easy to see chest movement
, or listen to the lungs, or discover mask leakage, requires multiple people,
ECG and SpO2 monitor takes time to get stable and reliable number.

How Might We [make it easier for the HCPs who participate in a newborn resuscitation to know if they manage to give sufficient ventilation] ?

2 Brainstorm

Write down any ideas that come to mind that address your problem statement.
Remember, the key rules of brainstorming are:

Defer judgment | Go for quantity | Build on the ideas of others | Stay on topic | Encourage wild ideas

PRO TIP: Select a sticky note and click the pencil icon in the menu to sketch.

⏱ **5 x 2 minutes**

Try to write your name on a sticky note.

Problem statement 2

[The HCPs who participate in a newborn resuscitation]
needs to
[have better communication in the team]
because
[they want to have a better understanding of the situation, and contribute to helping]

poeple don't say what they want to do, what they are doing or what have been done, so it's difficult to understand the situation and what's going on. and when the team leader is focusing on the ventilation, it's difficult for them to assign tasks to the team.

How Might We [provide an overview of the situation and help the HCPs find their tasks] ?

2 Brainstorm

Write down any ideas that come to mind that address your problem statement.
Remember, the key rules of brainstorming are:

Defer judgment | Go for volume | Build on the ideas of others | Stay on topic | Encourage wild ideas | Go for quantity

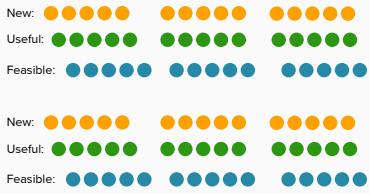
PRO TIP: Select a sticky note and click the pencil icon in the menu to sketch.

⏱ **5 x 2 minutes**

4 Vote

Each one has 5 votes.

⏱ **5 minutes**



A.6 Workshop Plan

Workshop Plan

Target User Group

Clinicians who have clinical experience on neonatal resuscitation and received newborn resuscitation training, including: 1. midwife (jordmor), midwife nurse (barnepleier); 2. Neonatologist, paediatrician, NICU nurse; 3. obstetrician; 4. anesthetist, anesthesia nurse

6-8 users for one group, and there are representatives from each user group.

Goal

- Develop some possible solutions
- Select the most promising ones for further development

Approximate time: 1 hours

Material:
An excel sheet for participants to register available time slots. journey map, POV & HMW, post-it, the rules for brainstorming and so on.

Activities:

1. **Introduction** (10 min)
- Introduce myself
- Introduce the background of the project
- Introduce the workshop's goal and plan
- Sign consent form (send out before the workshop and ask them to send back after workshop) and start to record

2. **Ice breaking (5 min)**
   Ask them to introduce themselves

3. **Task analysis or journey map (10 min)**

Present the four journey maps to the participants to see if there's any disagreement.

4. **Brainstorming** (30-40min)
- Present POV 1 and HMW 1 (5min)
- Introduce brainstorming methods and rules
- Each brainstorming session lasts for 4-5 mins, after each session the participants and I share ideas to each other.
- and then have second session of brainstorming. Crazy 4's can be introduced in the brainstorming session if needed.
- Combine the similar ideas into more complex solutions.
- Repeat the same steps for POV 2 and HMW 2.

5. **Dot Voting** (10mins)

- Introduce dot voting method and rules
- Set up criteria for voting,s it can be NUF(new, useful and feasible)
- Everyone has 5 votes, and the time is around 5 minutes
- Select 3-5 ideas with the most votes and everyone share the reasons what they like about them

6. **End** (5mins)

- Thank you everyone for attending the workshop
- Ask if they have any questions
- Stop recording

A.7 Testing Workshop Plan

Testing Plan

User: 1 pediatrician, 1 anethesiologist
Ideally the participants should be the same as workshop session 1, so that they can have the similar understanding of the projects.

Goals:

- What do they like or dislike about the solutions?
- Are the solutions feasible?
- Could the solutions be useful?
- Do the solutions have the potential to make it easier to assess the baby and improve the ventilation?
- Could the solution help them understand what has happened in the event?
- Could the solutions improve their communication?
- Will the solutions cause any problems?
- Is there anything they would like to change about the solutions?
- Would they like to use the solutions?

Approximate time: 0.5 hours

Material:
storyboard, prototype.

Activities:

1. **Introduction** (5 mins)

- Introduce myself
- Introduce the background and some key findings of the project
- Introduce the workshop's goal and plan
- Sign consent form and start to record

2. **Discussion of storyboard** (0.5 - 1 h)

- Present the storyboard, and then let them have control of exploring it, ask them what they see on each scene, explain if they have questions or misunderstand something.(10 min)

Storyboard link:
https://www.figma.com/proto/b0WgL2wVrbGxEemEXDMXYj/Master-thesis?page-id=1%3A2&node-id=489%3A3044&viewport=87%2C-103%2C0.05088265985250473&scaling=min-zoom

Storyboard briefing

Hi, I have prepared this series of illustrations showing how a respiratory monitor and a decision support tool function in a resuscitation scenario. In this situation, you as the pediatrician will be informed that a baby probably has difficulty

breathing after being delivered. So you and a NICU nurse will go to the resuscitation room.

This scenario is based on my understanding of current procedures and some ideas of how new technology will change them, please let me know if something doesn't seem plausible or if you have any other comment.

3. **Discussion of prototype** (10min)

- Present the prototype. explain if they have questions or misunderstand something. (10 min)
- Ask feedback on different versions of the **overview, observe page, and debrief page.**

4. **Ask them questions**. (15 min)
    - Does this match your current work flow?
        - If not, where doesn't? What do you think of these differences?
        - Do you think they will have positive effects on the current work-flow? What positive effects?
        - Do you think they will have negative effects on the current work-flow?
    - What do you like about this solution?
        - Why
    - What do you dislike about it?
        - Why
    - Do the solutions have the potential to make it easier for you to assess the baby and improve the ventilation?
        - If YES: why
        - If NO: why
    - Could the solution help you understand what has happened in the event?
        - If YES: why
        - If NO: why
    - Could the solutions improve your communication?
        - If YES: why
        - If NO: why
    - Can you think of any problems that this solution could occur? What problems?
    - Is there anything you would like to change about the solutions?
    - Are the solutions feasible?
        - If NO: why

- Would you like to use this solutions?

- Can this iPad be used for other things? Who will be mainly using this ipad?

5. **End** (3-5 mins)

- Thank you everyone for attending the workshop
- Ask if they have any questions
- Collect all the materials and equipment and leave

A.8 Information Letter for Survey

Are you interested in taking part in the research project *"How to Improve Clinical Delivery of Newborn Resuscitation and Respiratory Support at Birth"*?

This is an inquiry about participation in a research project where the main purpose is to **discover the problems when giving new born resuscitation and find out possible solutions**. In this letter we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project
This master thesis project aims to understand how clinicians provide neonatal resuscitation in Norway, to discover the difficulties or barriers when they perform resuscitation, and to develop a possible solution to support the process and improve their performance.

Who is responsible for the research project?
Researcher (student): Jiaxin Li
jiaxinl@stud.ntnu.no
Tel 46237197

Supervisor: Giovanni Pignoni
giovanni.pignoni@ntnu.no
Tel 46904106
Norwegian University of Science and Technology (NTNU) Institute for design

Co supervisor: Michelle Site
michelle.site@laerdal.com
Tel 94010140
Laerdal Medical in Stavanger

Why are you being asked to participate?
You have been selected as a midwife, midwife nurse, paediatrician, paediatrician nurse, obstetrician, or anesthetist of the St.Olavs Hospital in Trondheim, who has clinical experience on neonatal resuscitation and has received relevant training.

What does participation involve for you?
If you chose to take part in the project, this will involve that you fill in an online survey. It will take approx. 5-10 minutes. The survey includes questions about clinical experience and simulation training on neonatal resuscitation. Your answers will be recorded electronically.

Participation is voluntary
Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data

We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).
You will not be identified in any reports on this study. Your personal data will be anonymised after collecting and be stored in strict confidentiality. It is voluntary to participate, and you can at any time withdraw your consent without stating the reason. Please contact jiaxinl@stud.ntnu.no to ask for the removal of your personal data before 31.12.2021.

What will happen to your personal data at the end of the research project?
The received original data will be stored on an encrypted external hard drive and deleted after the completion of the final report for the master thesis project connected to this research, at the latest 31st December 2021. After the project ends, the consent form with your signature and anonymised data will be stored safely at NTNU and be deleted after 31st December 2023. Only the researcher and supervisor will have access to the data.

Your rights
So long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?
We will process your personal data based on your consent.

Based on an agreement with NTNU, NSD – The Norwegian Centre for Research Data AS has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?
If you have questions about the project, or want to exercise your rights, contact:

- Norwegian University of Science and Technology (NTNU) Institute for design via **Giovanni Pignoni**.
- Our Data Protection Officer at NTNU: **Thomas Helgesen,** by email: (thomas.helgesen@ntnu.no) or by telephone: +47 93079038.
- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

Yours sincerely,

Jiaxin Li	Giovanni Pignoni
(Researcher)	(Supervisor)

Consent form

I have received and understood information about the project "*How to Improve Clinical Delivery of Newborn Resuscitation and Respiratory Support at Birth"* and have been given the opportunity to ask questions. I give consent:

- ☐ to participate in an online survey
- ☐ to participate in a nonparticipant observation
- ☐ to participate in a participant observation
- ☐ to participate in individual interview
- ☐ to participate in group interview
- ☐ to participate in workshop
- ☐ to participate in testing
- ☐ for my personal data to be processed in Norway

I give consent for my personal data to be processed until the end date of the project, approx. 31st December 2021.

(Signed by participant, date)

A.9 Empathy maps

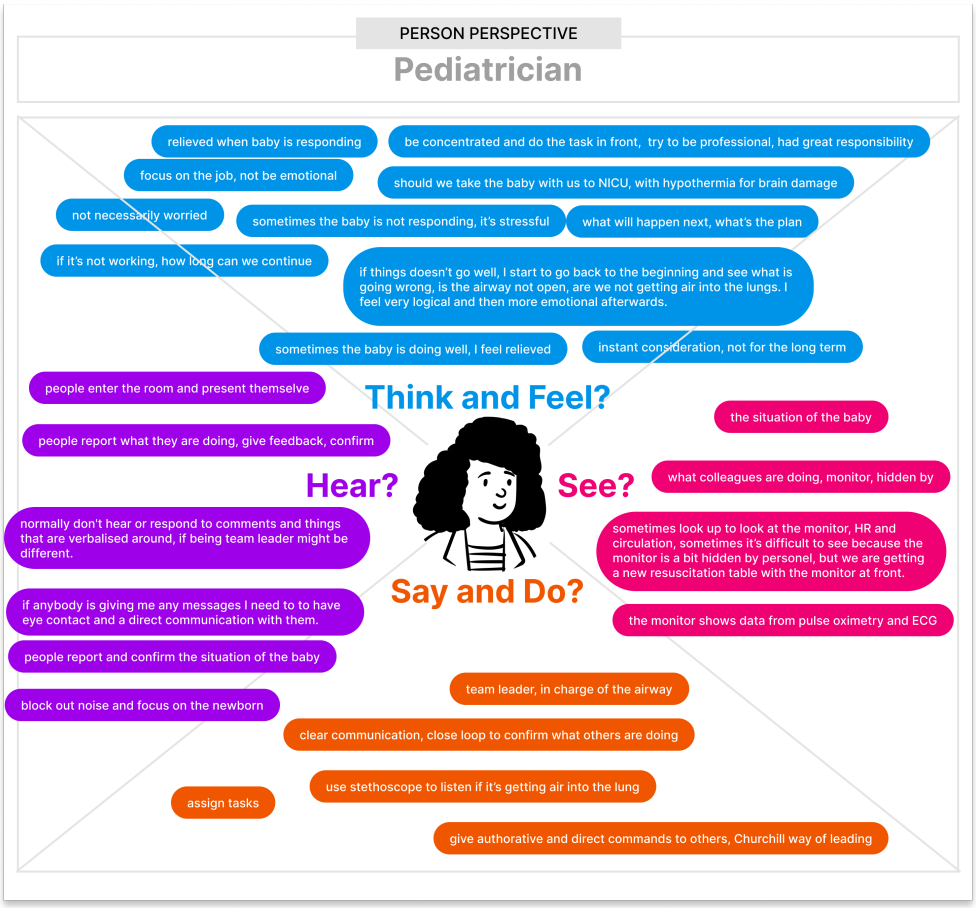


Figure A.1: Empathy map for pediatrician

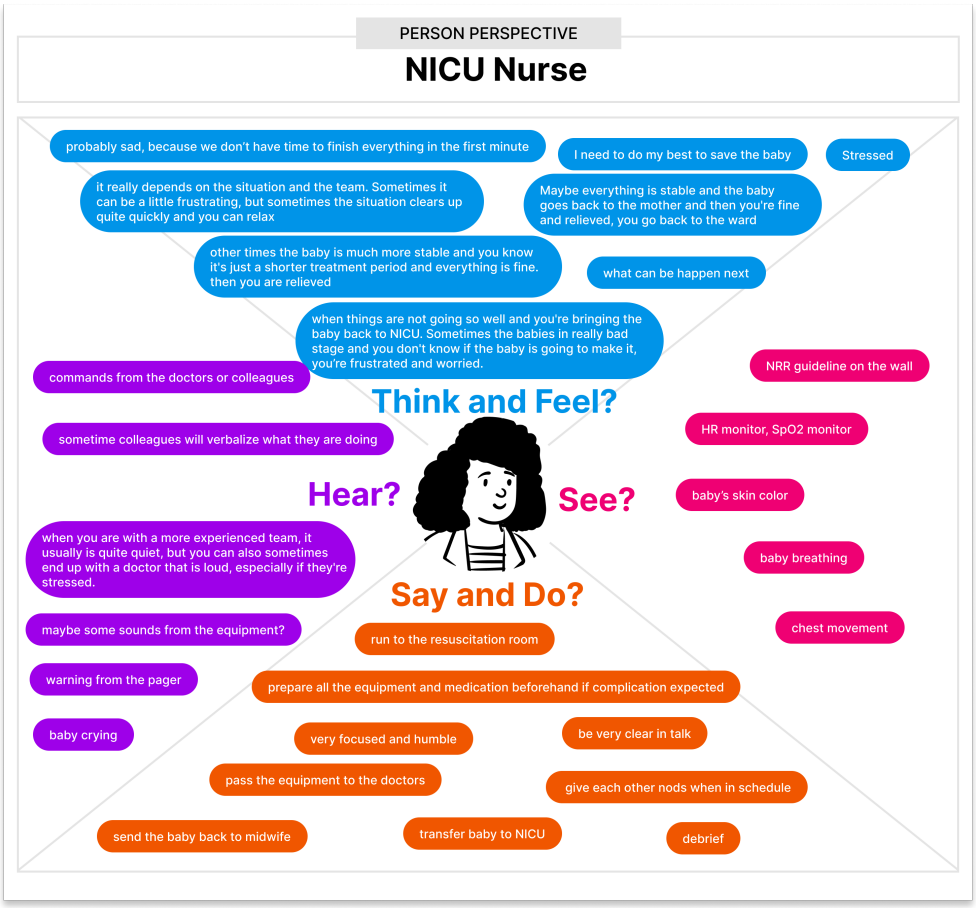


Figure A.2: Empathy map for NICU nurse

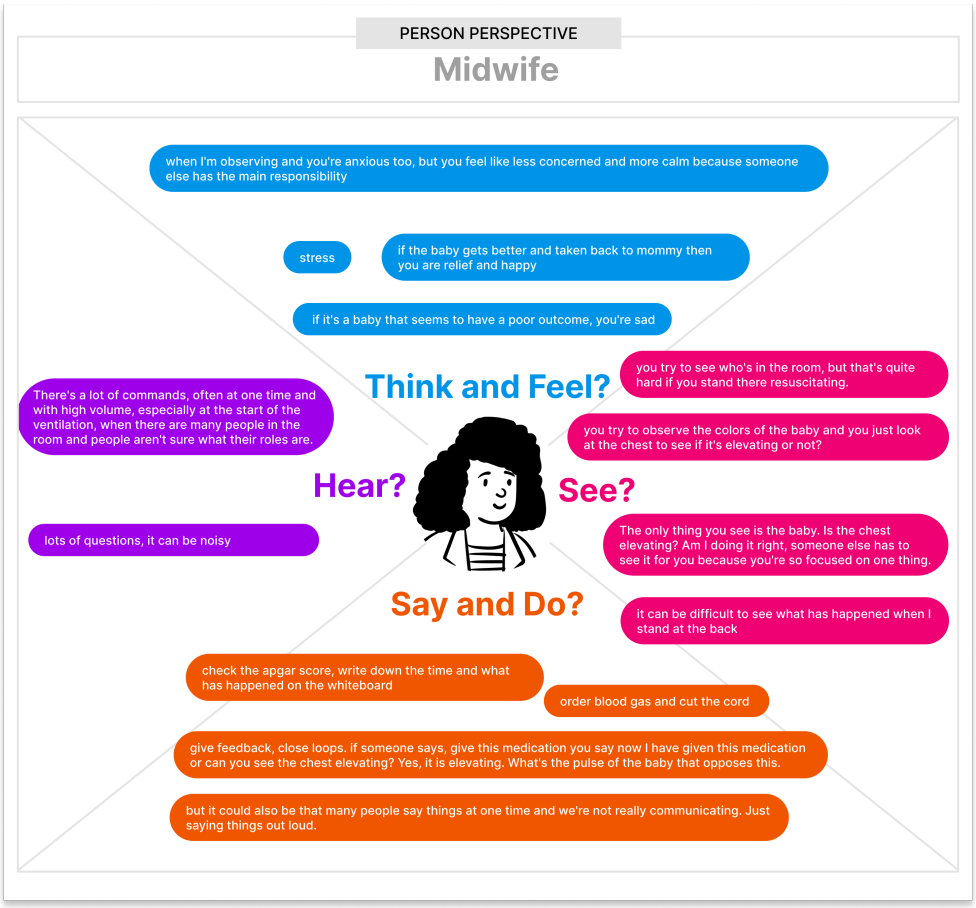


Figure A.3: Empathy map for midwife

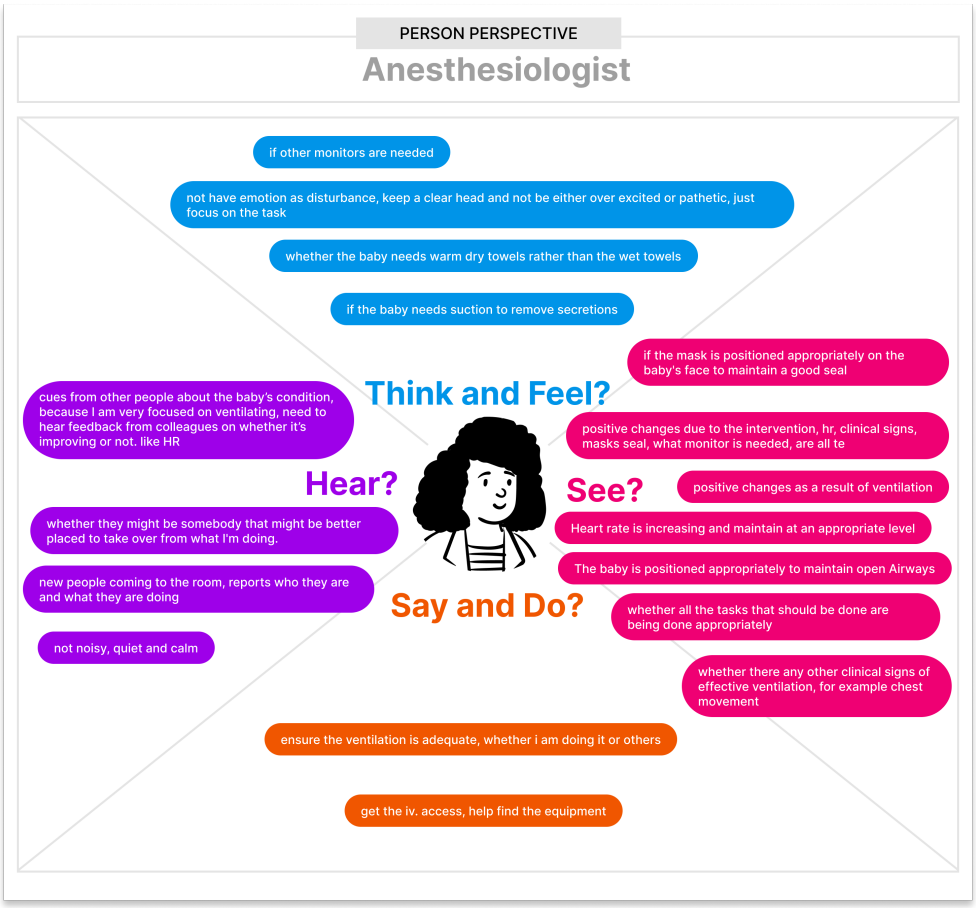


Figure A.4: Empathy map for anesthesiologist

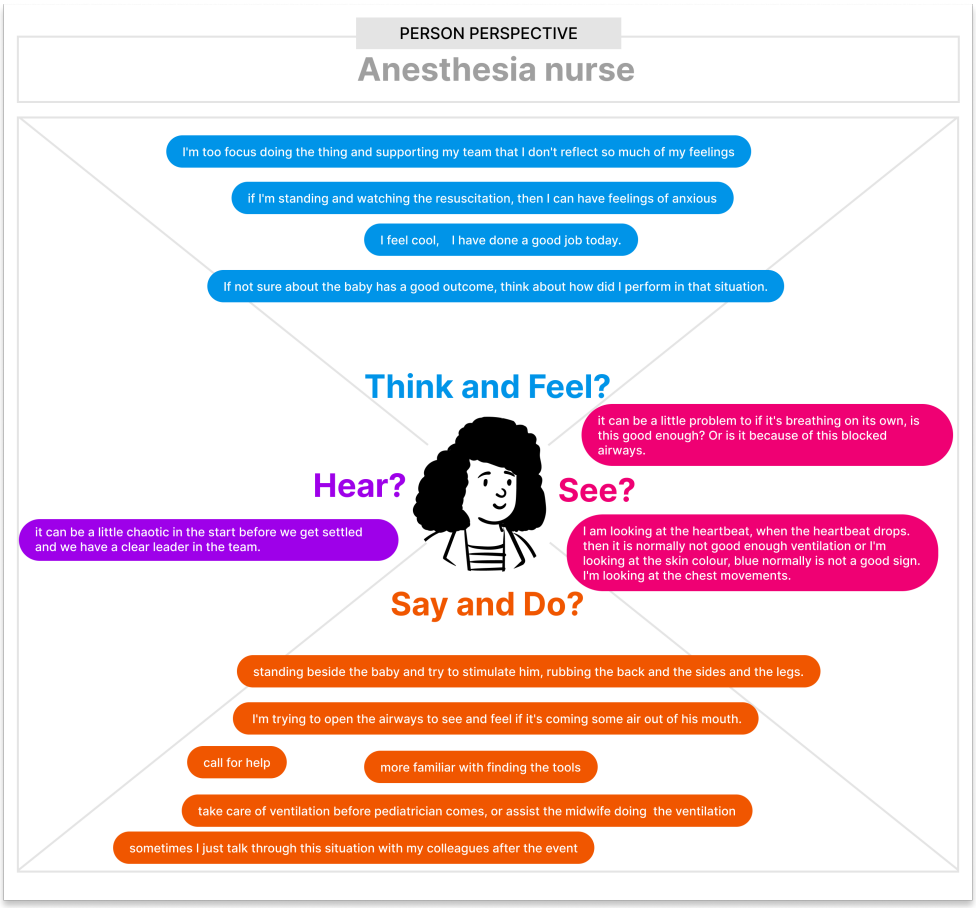
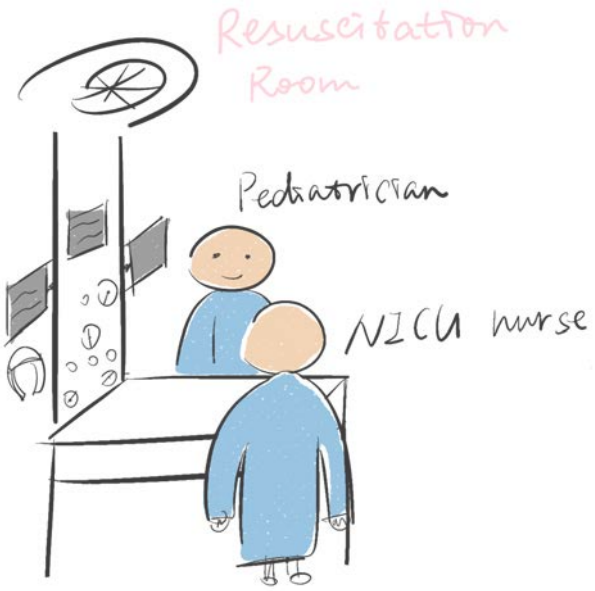


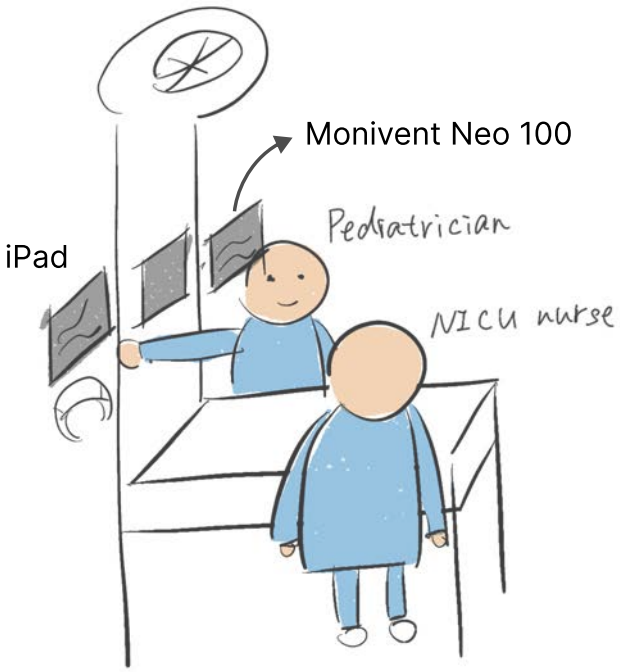
Figure A.5: Empathy map for anesthesia nurse

A.10 Storyboard

Storyboard



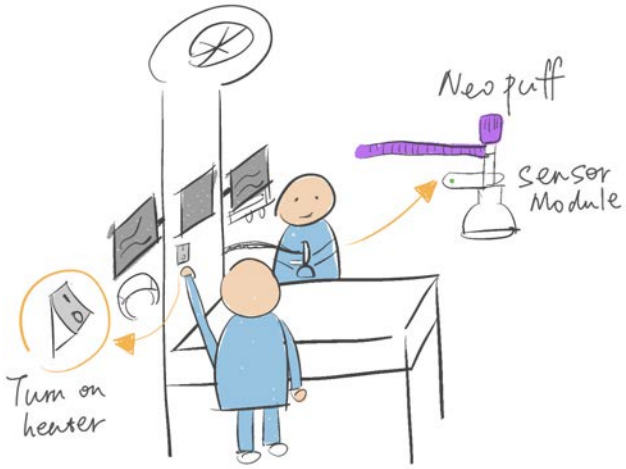
One pediatrician and one NICU nurse were informed that the baby was premature and might need help after birth, so they come to the resuscitation room and wait there.

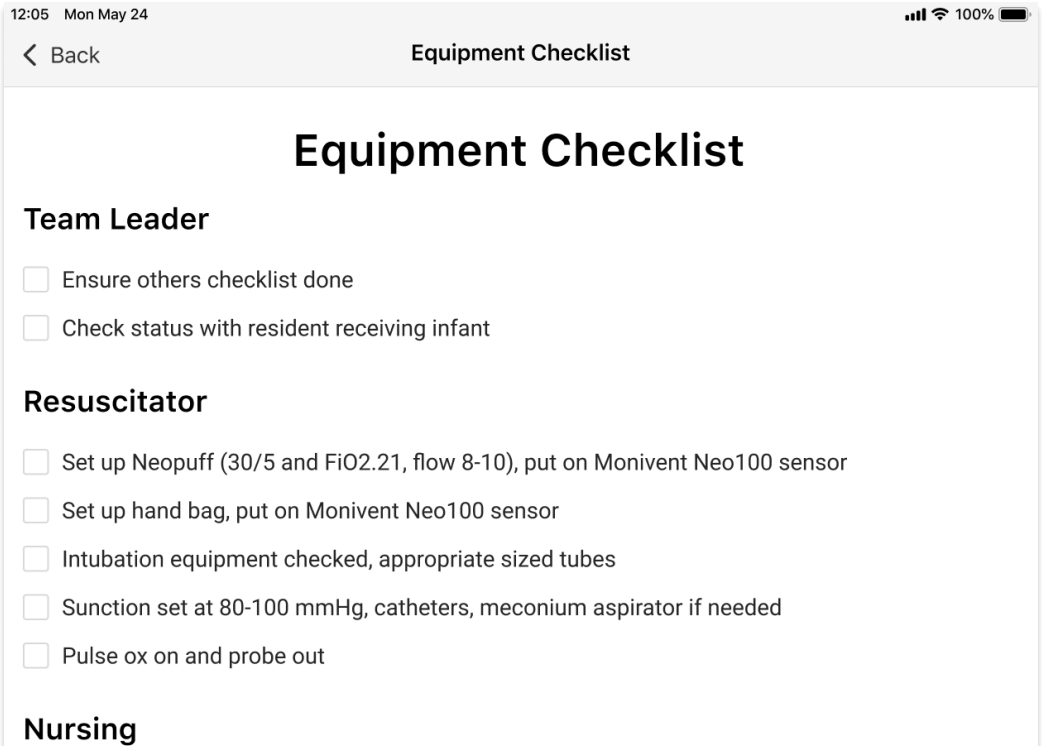


The pediatrician picks up the tablet from the stander.

They use the iPad to brief, the pedidatrician assigns roles, discuss plan and expectation(closed loop communication techiniques).

They use the check list to check the equipment, set the right setting, attach Monivent Neo100 sensor module to the Neopuff





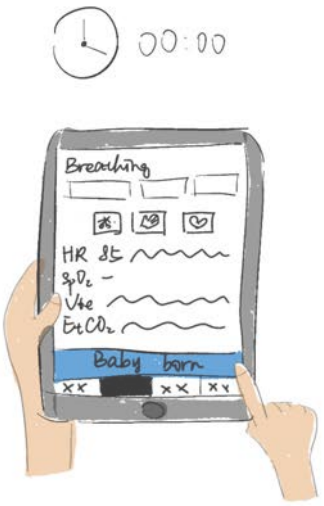
- [ ] If crash C/section (call for help), ensure line is set up, Epi drawn up.
- [ ] Radiant warmer on MANUAL at 100%, probe and cover available, hat
- [ ] Stethescope
- [ ] Plastic wrap for < 28 weeks, chemical mattress for < 25 weeks
- [ ] NeoBeat or ECG Leads
- [ ] Ensure Monivent Neo 100 moniter is on

Brief | Resuscitation | History | Setting

Is the checklist realistic?

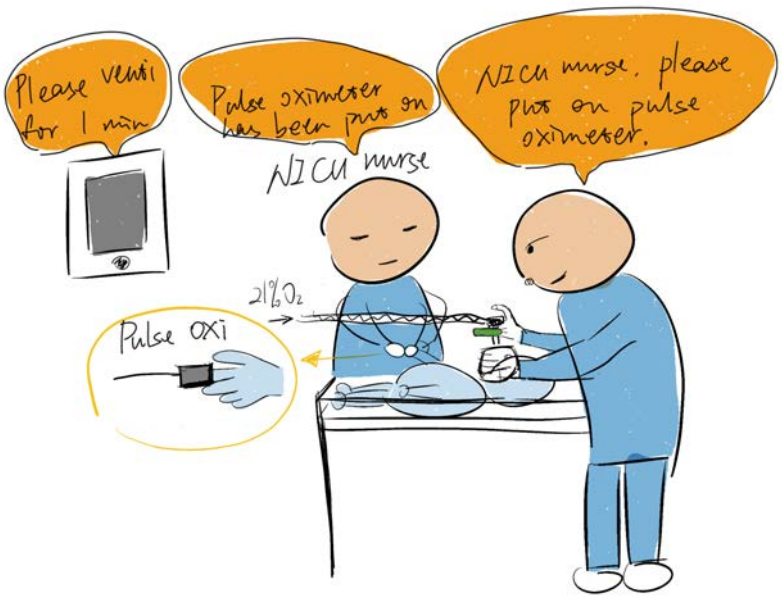
The baby is born...

The baby doesn’t breathe, midwife takes the baby out to the resuscitation room.



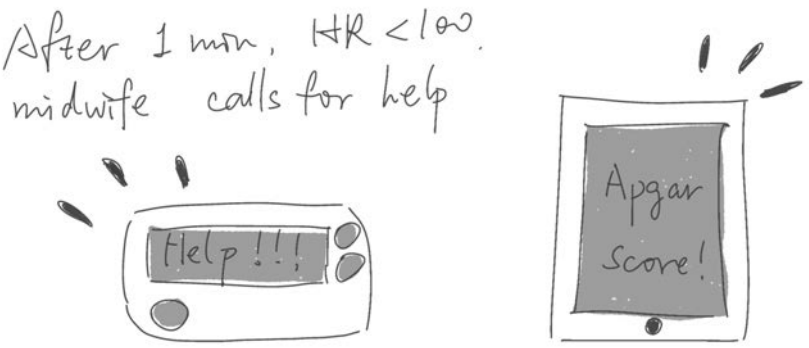
00:00, they start the clock on the panda warmer, midwife dry and stimulate baby, NICU nurse put neobeat on，pediatrician type in the weight into Monivent Neo 100 system, barnepleier take the ipad and register on the screen

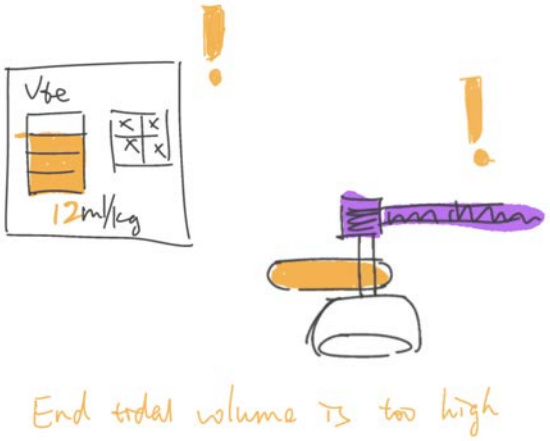
Who and when weigh the baby? Where do all these people stand?
Are the locations of these two screens right?



- Pediatrician starts to ventilate with Neopuff
- NICU nurse puts oxygen oximeter on
- midwife orders blood gas test

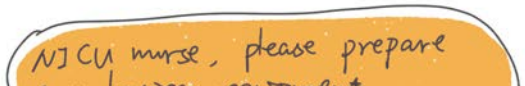
01:00, after ventilating for one min, the baby is not improving, so they call for help by pager. And the iPad reminds them to type in apgar score.





Monivent Neo 100 screen and the sensor module gives warning that Vte is too high, so the pediatrician tries to correct her ventilation techniques.

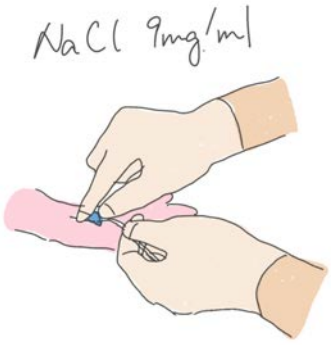
02:00, iPad gives warning again that SpO2 is lower than the recommended level, so they increase the O2 level.



After 2-3 min, a more experienced pediatrician comes and takes over the team leader, she looks at the ipad to see what has happened.
An anesthesiologist comes as well. The more experienced pediatrician asks NICU nurse to prepare for intubation, and anesthesiologist to prepare for iv. fluids.

what does barnepleier and midwife do now?
why does a baby need fluids here? preterm?

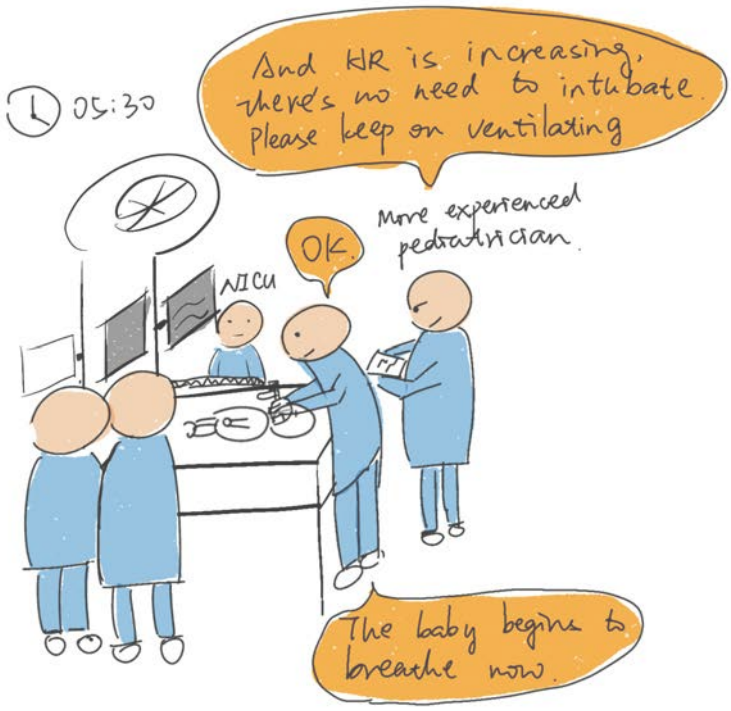
Anesthesiologist gives fluids of NaCl 9mg/ml to the baby, pediatrician register this on ipad

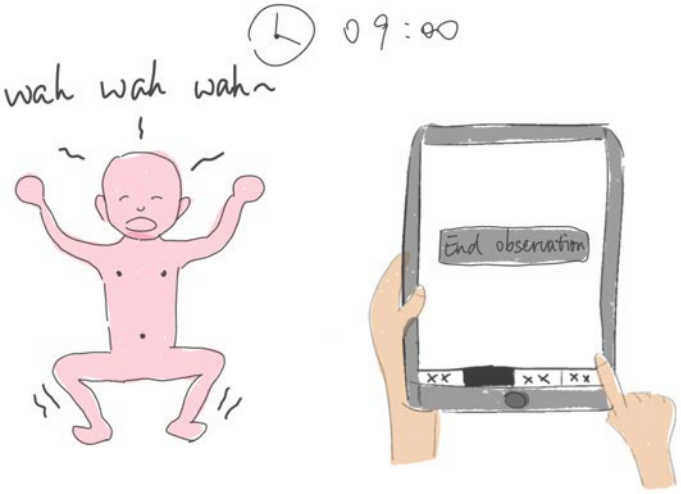


how much fluids should be given, based on the weight?

05:00, iPad reminds pediatrician to register Apgar score.

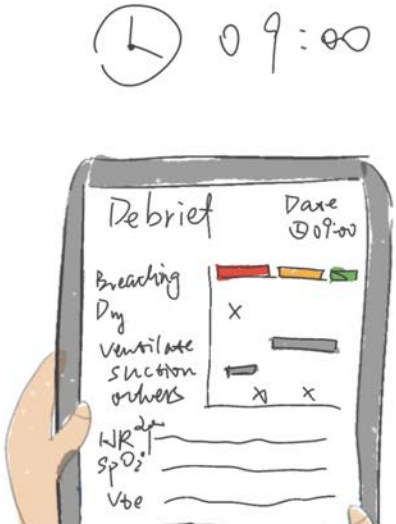
The HR is increasing, and the baby begins to breathe now, so there's no need to intubate. They ventilate for another 3 mins.

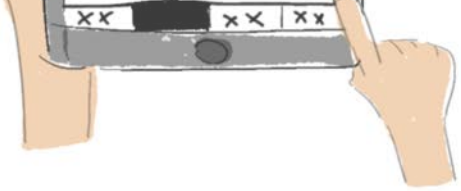




09:00, baby starts to cry, pediatrician ends the observation on iPad.

The whole team has debrief for 10min. They look at the data report from iPad, and discussion about improvements.



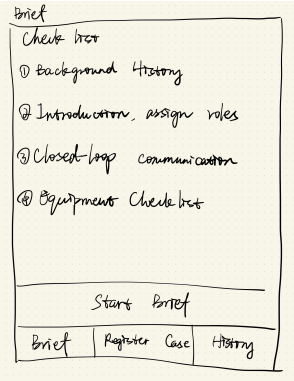


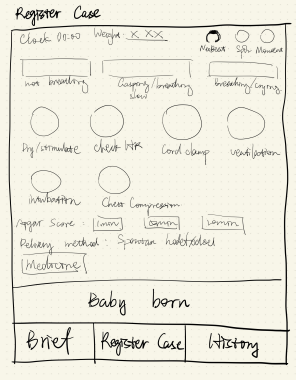
Should the baby be sent to mother immediately or can it wait for 10 mins?
what about the 10min apgar score, food registration?
Can the iPad be taken out of resuscitation room?

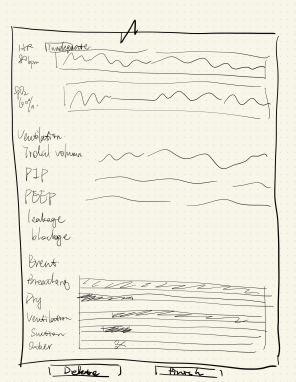
The midwife bring the baby back to the father and mother.

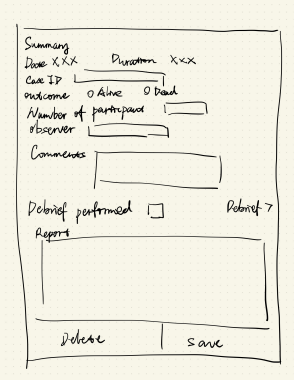
The End

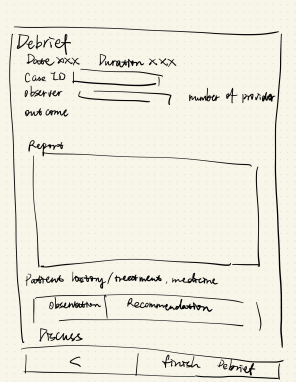
A.11 Wireframe











A.12 Prototype

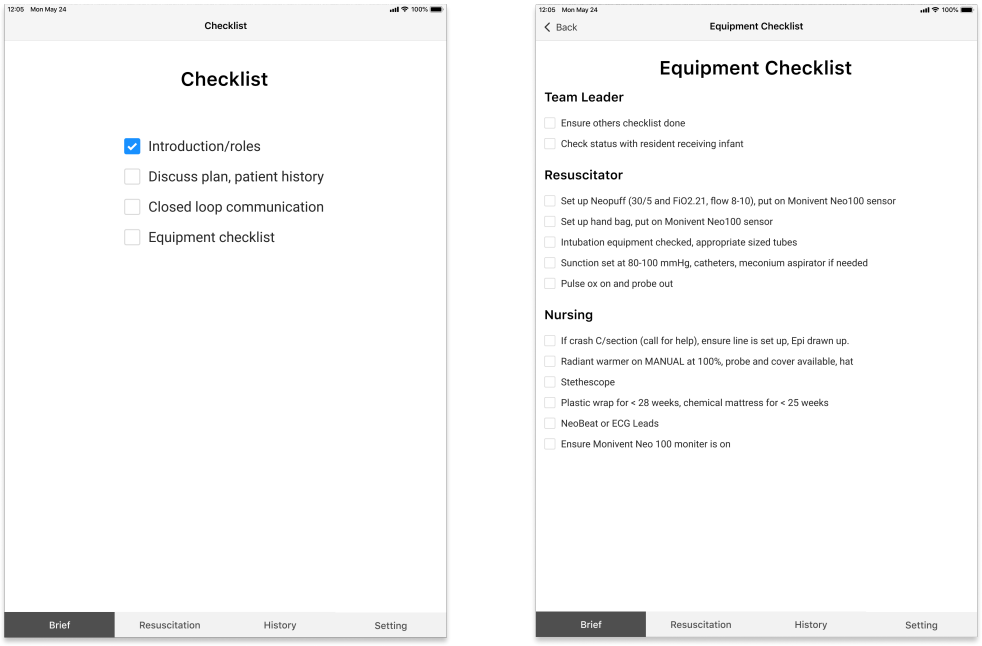
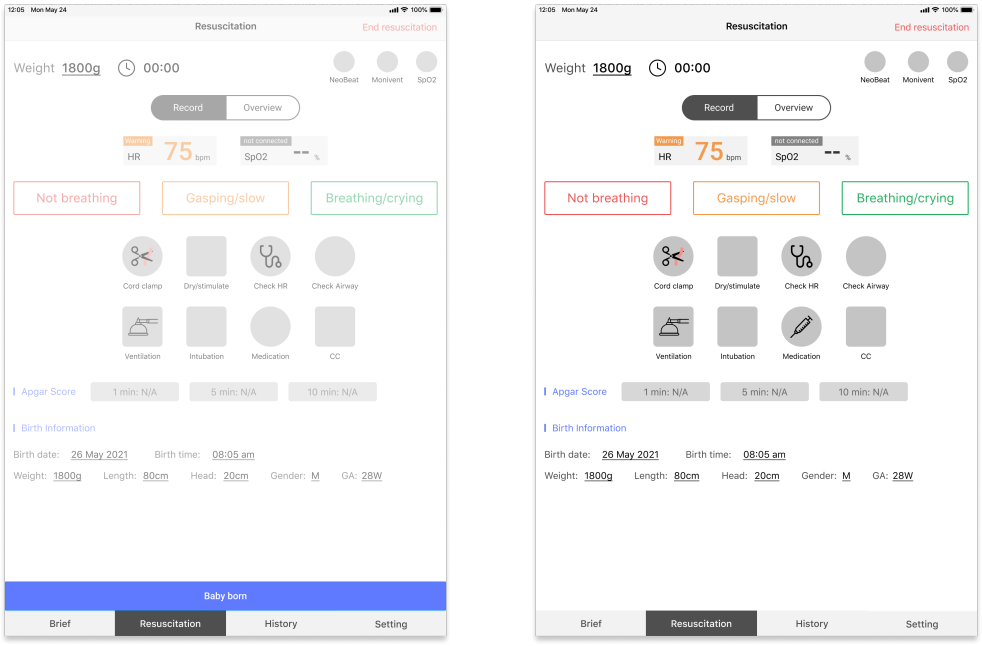


Figure A.8: Brief pages



(a) Record resuscitation(a) inactive

(b) Record resuscitation(a) active

Figure A.9

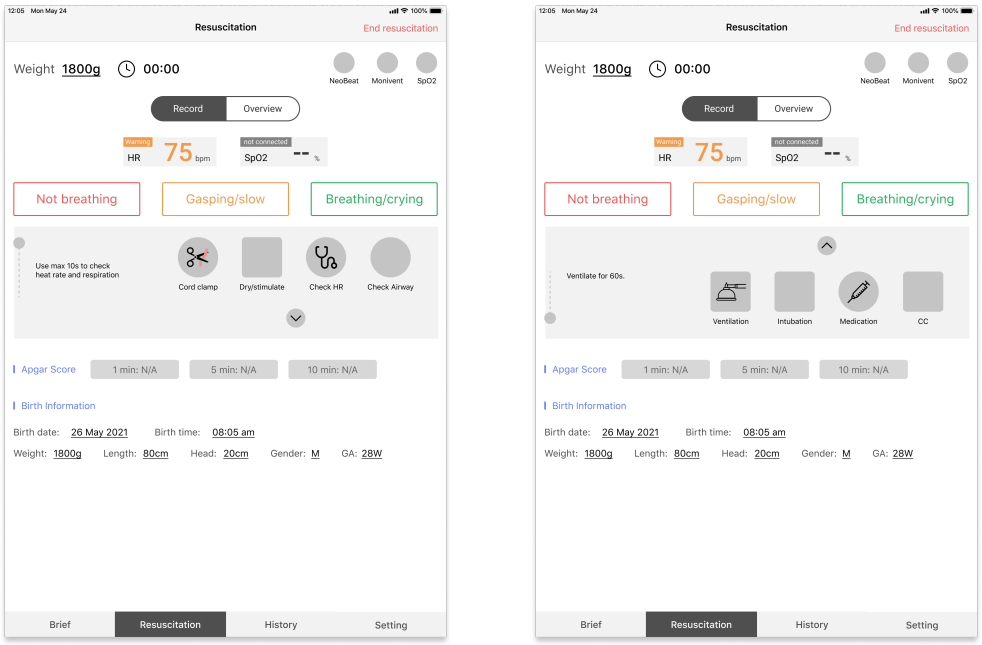


Figure A.10: Record resuscitation(b)

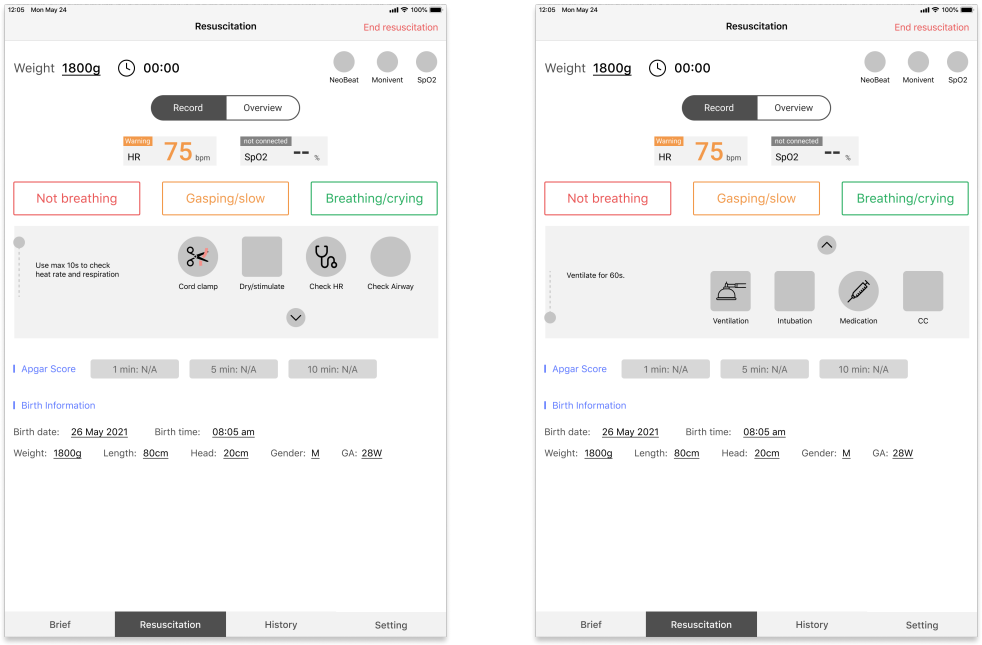
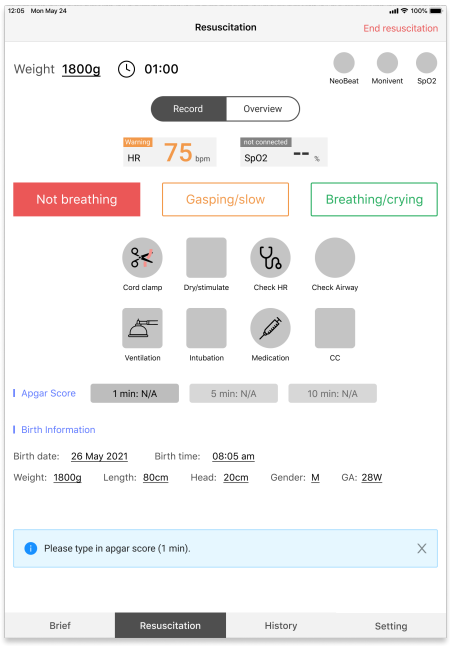
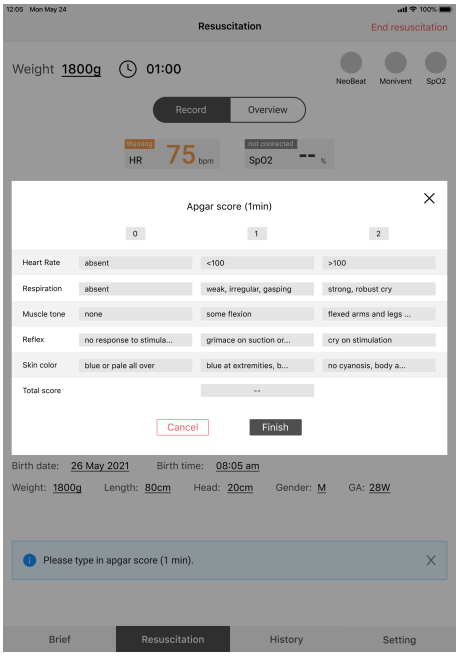


Figure A.11: Record resuscitation(b)



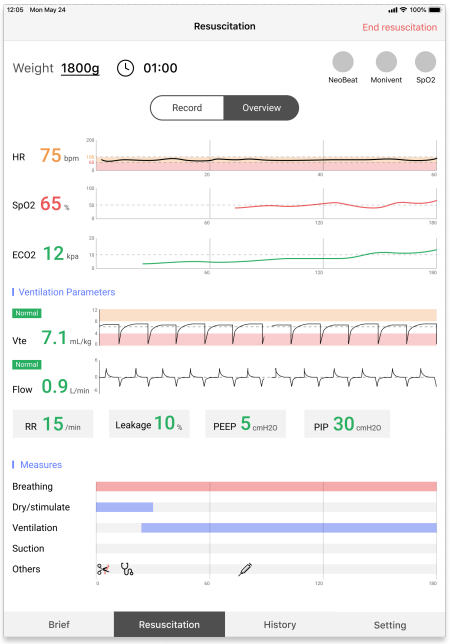
(a) Record resuscitation 1min



(b) Record resuscitation apgar score

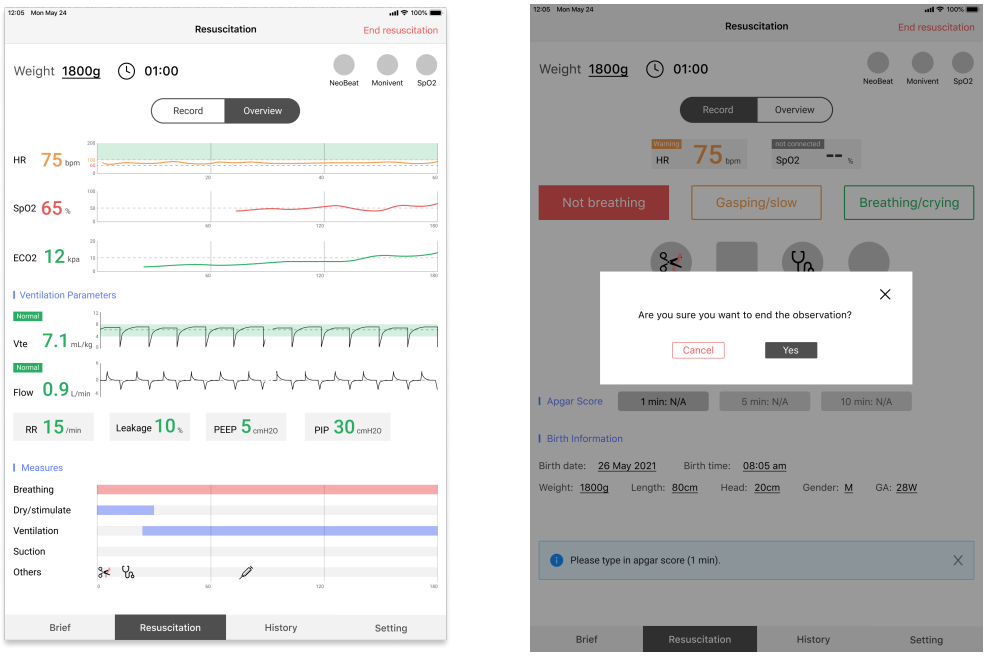
Figure A.12

(a) Overview page(a)



(b) Overview page(b)

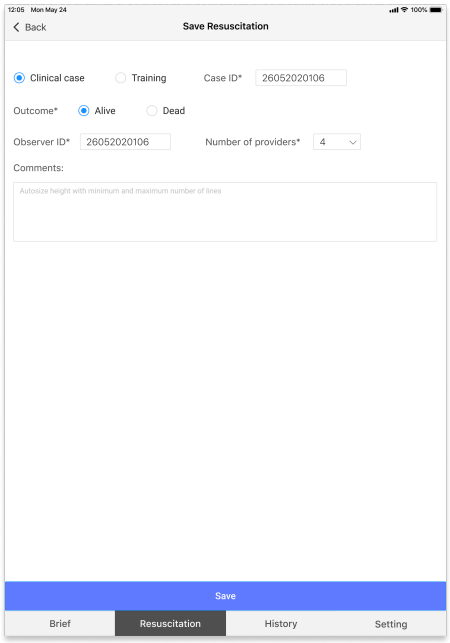
Figure A.13



(a) Overview page(c)

(b) End resuscitation page

Figure A.14



(a) Save resuscitation page

(b) Debrief page

Figure A.15

A.13 Research Project plan

TASK	TASK	PROGRESS	START	END
1	**User Research**			
1.1	contact hospitals	100%	1/4/21	2/28/21
1.2	apply NSD, REC	100%	12/12/20	2/12/21
1.3	survey	100%	12/12/20	3/26/21
1.4	interview with doctors, midwives	100%	12/12/20	12/23/20
1.5	transcribe, coding and analysis	100%	12/24/20	12/27/20
1.6	persona, empathy map, journey map	100%	12/28/20	12/31/20
2	**Problem Definition and Ideation**			
2.1	POV and HMV	100%	4/28/21	5/2/21
2.2	brainstorming and voting workshop	100%	5/3/21	5/10/21
2.3	competitive analysis	100%	5/1/21	5/20/21
2.4	Ideation sheet	100%	5/18/21	5/18/21
3	**Prototyping and Testing**			
3.1	Mind mapping	100%	5/18/21	5/19/21
3.2	Storyboard	100%	5/20/21	5/26/21
3.3	Wireframe and prototype	100%	5/19/21	5/26/21
3.4	Testing workshop	100%	5/26/21	5/28/21
3.5	analyse data	100%	5/26/21	5/30/21
4	**Writing Thesis**			
4.1	first draft	100%	5/1/21	6/4/21
4.2	final version	100%	6/5/21	6/8/21

A.14 The project assessment from REK

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK midt	Ramunas Kazakauskas		19.01.2021	215464
			Deres referanse:	

Jiaxin Li

215464 Hvordan forbedre klinisk levering av nyfødt gjenoppliving og respiratorisk støtte ved fødselen

Forskningsansvarlig: Norges teknisk-naturvitenskapelige universitet

Søker: Jiaxin Li

Søkers beskrivelse av formål:

Dette masteroppgaveprosjektet tar sikte på å forstå hvordan klinikere gir nyfødt gjenoppliving i Norge, hva er vanskeligheter eller barrierer når de utfører gjenoppliving, og å utvikle en mulig løsning for å støtte prosessen og forbedre ytelsen. Menneskesentrerte designmetoder vil bli brukt for å samle inn og analysere data i denne studien. Observasjon, kartlegging, intervjumetoder vil bli brukt til å samle inn data om hvordan klinikere gir nyfødt gjenoppliving i Norge. Empatikart, affinitetsdiagram, persona, reisekart, "synspunkt", "hvordan kan vi" vil bli brukt til å analysere dataene. Hjernestorming, prikkstemming og konkurranseanalyse vil bli brukt til å generere løsninger. Prototyping og testing vil bli brukt for å vitne om løsningene. Prosjektet har potensial til å lage løsninger for å forbedre klinikernes nyfødteytelse.

REKs vurdering

Du sendte en søknad om framleggingsvurdering til oss. Dette skjemaet skal brukes når søker er i tvil om et prosjekt må godkjennes av REK. Henvendelsen har blitt vurdert av komiteens sekretariat. Vurderingen er kun å betrakte som veiledende.

Vi har vurdert skjemaet, samt nyeste versjon forskningsprotokoll for studien (mottatt den 18.01.2021).

Vi vurderer at studien ikke er framleggingspliktig for REK. Prosjektet framstår som annen type forskning enn medisinsk eller helsefaglig forskning. Vi begrunner vår vurdering med at formålet i prosjektet er å undersøke helsetjeneste, det vil si hvordan helsepersonell opplever diverse sider ved nyfødt gjenoppliving og respiratorisk støtte. Du har ikke planlagt å bruke helsedata i studien og observasjon av helsepersonell vil være i en simulert situasjon. Intervjuene stiller heller ingen spørsmål om helse. Hele studien er også samtykkebasert som gjør at det ikke er krav om dispensasjon for taushetsplikt.

rosjektet er annen typen forskning (det vil si ikke medisinsk eller helsefaglig forskning). Prosjektet er følgelig ikke omfattet av helseforskningslovens saklige virkeområde, jf. helseforskningslovens §§ 2 og 4. Prosjektet kan derfor gjennomføres og publiseres uten godkjenning fra REK.

Vurderingen er gjort på grunnlag av de innsendte dokumenter. Dersom du gjør endringer i prosjektet, kan dette ha betydning for vår vurdering. Du må da sende inn ny søknad/framleggingsvurdering.

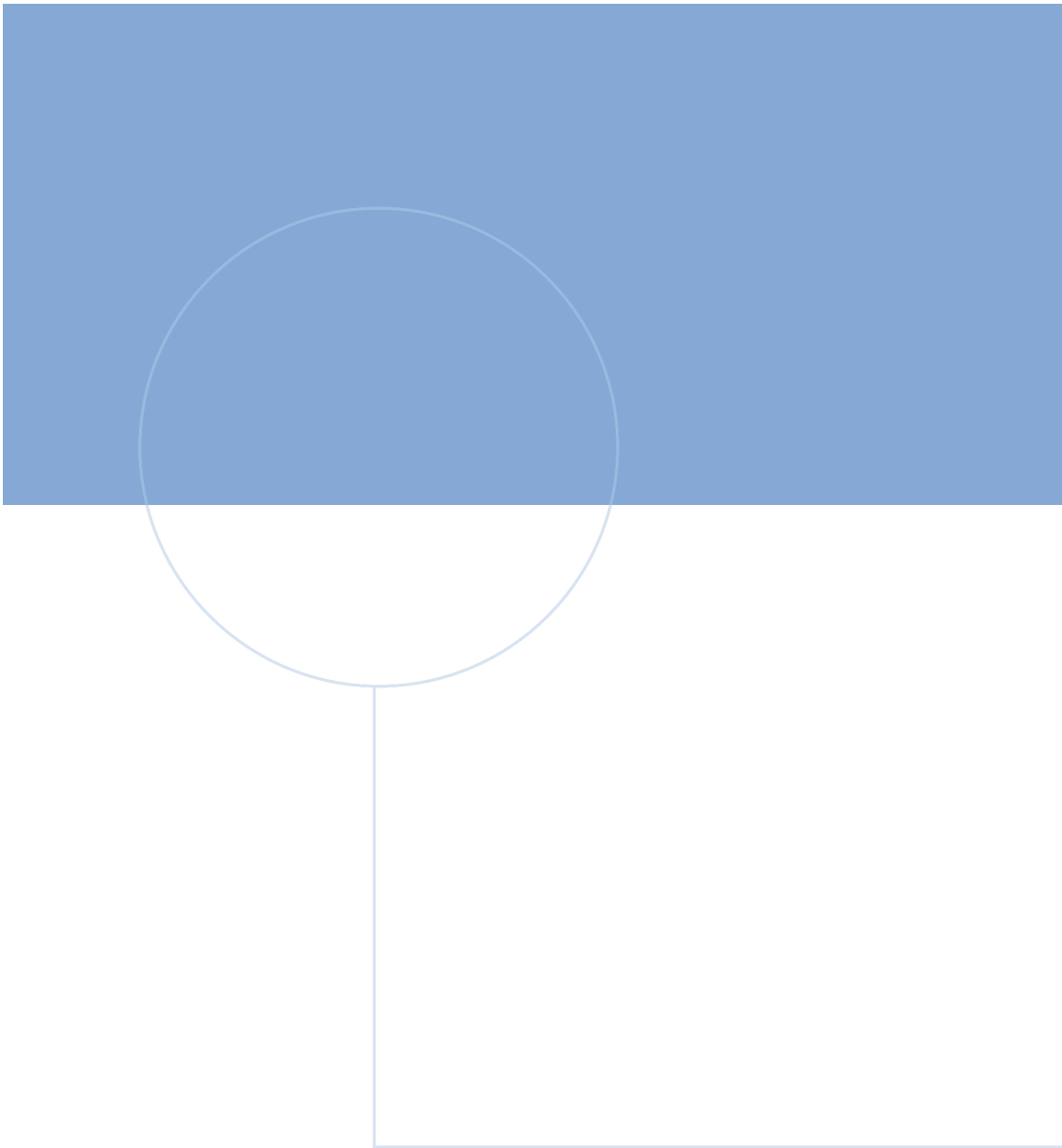
Vedtak

Ikke fremleggspliktig

Med vennlig hilsen

Hilde Eikemo
Sekretariatsleder

Ramunas Kazakauskas
Rådgiver



NTNU

Norwegian University of
Science and Technology