User Centred Development of a Data Visualisation Dashboard for a Neonatal Intensive Care Unit

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Neonatal Intensive Care Units (NICUs) provide critical care and life support for babies born prematurely or who have experienced complications during birth. NICUs are staffed by multi-disciplinary teams, including nurses, pharmacists, doctors, and specialists, who work in high-pressure environments where the accurate and efficient interpretation of patient data is vital for saving lives. Despite technological advancements, NICUs often rely on paper-based tools for recording and evaluating patient data, which can lead to errors and inefficiencies. In this paper, we present a user-centred design process undertaken to develop an interactive dashboard for NICUs. Our process involved field observations, semi-structured interviews, iterative co-design sessions, and thematic analysis. Our study highlights the roles and interactions of key stakeholders, proposes design guidelines for an interactive NICU dashboard, and introduces a design concept inspired by existing paper charts.

CCS Concepts: • **Human-centered computing → Empirical studies in visualization**.

Additional Key Words and Phrases: NICU Decision Support, Data Visualisation, Dashboard, User-Centred Design

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1 INTRODUCTION

Neonatal Intensive Care Units (NICUs) play a vital role in delivering critical care and life-support to neonates who are premature, severely ill or have experienced challenging birth conditions. These units are staffed with multidisciplinary teams including nurses, pharmacists, doctors, and specialists, who collaborate closely to ensure the well-being of the infant by utilising a series of specialised equipment to monitor and provide efficient care. The environment is complex and time-sensitive, where rapid and precise comprehension of patient data is crucial for effective treatment and survival

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[38]. Thus, effective communication within the team is important to potentially decrease the mortality rate of infants and to make the care of infants more cost-effective [34].

The current reliance on manual tools like whiteboards, sticky notes, and paper charts for conveying patient information and data within NICUs poses significant challenges. Studies have highlighted that while these traditional tools serve as a shared overview of patients, they lack mobility and connectivity to current hospital computer systems [10, 25, 32]. Consequently, staff in NICU face difficulties in accessing and integrating data effectively, especially in the high-stress and uncertain environment [1, 22]. Employing manual procedures places an unnecessary cognitive burden on staff members as they endeavour to locate and interpret data while navigating critical, life-saving decisions [3, 18]. This situation underscores the need for solutions such as data visualisation and aggregation tools designed specifically to address the collaborative nature of NICU work, facilitating seamless communication and information exchange among staff members on duty and across shifts [6, 14, 17].

Previous studies have highlighted the need for tailored data visualisation tools in NICUs, focusing on improving the quality of care, clinician satisfaction, and overall efficiency [6, 7, 14, 17, 40]. While these tools enhance communication among NICU teams and contribute to safer workflows, challenges related to visual clarity and cognitive load during decision-making remain prevalent [8]. This underscores the critical need for effective visualisation of patient data to facilitate rapid information assimilation. Moreover, a review of Intensive Care Unit (ICU) visualisation dashboards in 2018 [14] highlighted a lack of studies on effectively implemented solutions in the environments.

To develop an effective dashboard, a multi-faceted methodological approach was employed. Study 1 involved observational ethnography and semi-structured interviews with NICU staff, which provided in-depth insights into the current workflow and highlighted key inefficiencies associated with manual data entry and paper charts. This foundational research identified critical issues and guided the subsequent design process. Study 2 then incorporated a co-design approach, where clinicians actively participated in iteratively refining interface prototypes, ensuring that the dashboard design met their operational needs and enhanced usability. Following this, user testing and thematic analysis evaluated the prototypes' effectiveness, focusing on their impact on workflow efficiency and data accessibility. This comprehensive approach aimed to address the identified challenges and develop a user-centred solution that seamlessly integrates into NICU practices, ultimately improving patient care and decision-making.

Building on these findings, this study adopts a user-centred approach to design a system specifically aimed at enhancing the presentation of data for diverse NICU staff, including nurses, doctors, and specialists. This design is intended to improve decision support and facilitate better communication among team members. To the best of our knowledge, this study represents the first effort to develop a dedicated data visualisation dashboard within an NICU setting. The objectives guiding this study are as follows:

- To understand current practices, including existing systems, data, and interfaces in an NICU.
- To identify the needs of different stakeholders through thematic analysis.
- To prototype a new dashboard interface using a user-centred design process.

2 BACKGROUND

NICU is a cornerstone of specialised care, addressing the unique requirements of newborns necessitating intensive medical intervention. In recent years, the integration of digital technology, particularly the development of dashboards, has emerged as a transformative force in managing patient data and clinical workflows within critical care settings [12]. Despite extensive research exploring the efficacy and utility of ICU dashboards in enhancing patient outcomes and

streamlining clinical processes, a discernible gap persists in addressing the specific needs and challenges unique to NICU environments. This section offers an overview of existing research on ICU dashboard design, explores the specific needs and challenges inherent in NICU settings, focus on the intricacies of the NICU environment and workflow, and outlines the fundamental principles and considerations essential for developing a user-centred dashboard tailored to the distinctive requirements of neonatal care. This section seeks to establish a foundational framework for the development of effective NICU dashboards aimed at improving patient care outcomes and optimising clinical workflows within these critical care environments.

2.1 Overview of Existing ICU Dashboard

The Intensive Care Unit (ICU) is a complex high-demand environments that require effective monitoring and management of a large volume of patient data and clinical workflows. More than 1200 data are collected for each patient per day, complicating care and information loaded in the ICU. With the advent of digital technology, the integration of ICU dashboards has revolutionised the way medical personnel handle the vast volumes of patient data and manage complex care protocols [12].

In the study from Davidson et al. [5], they have identified several key requirements essential for the efficacy of ICU dashboards. Firstly, these dashboards must exhibit flexibility, enabling swift updates to their functionality to align with evolving clinical protocols. Moreover, they should be easily accessible via mobile devices, ensuring that medical staff can utilise the dashboard while directly attending to patients. Another vital aspect is customisation, which allows the dashboard to be adapted to suit the diverse roles and preferences of individual users within the ICU. Real-time data visualisation capabilities are also important, aiding staff in promptly understanding patient trajectories and making informed decisions. Existing research on ICU dashboards underscores their pivotal role as data management tools within intensive care settings, presenting key findings that emphasise their utility and impact. Dashboards serve as essential instruments for organising and presenting patient data, offering metrics and graphs that inform comprehensive understanding of patient status and care quality [21]. Notably, integration of dashboards into ICU workflows has demonstrated several benefits, including improved clinical satisfaction among healthcare providers and support for better decision-making through enhanced accessibility and visualisation of patient data [16]. These findings collectively underscore the potential of ICU dashboards to positively impact patient outcomes and streamline clinical processes within the intensive care environment.

While dashboards serve as valuable tools for organising and presenting patient data, challenges such as data integration issues, user resistance, and potential workflow disruptions have been identified [5, 35]. Consequently, it is essential for healthcare organisations to prioritise the adoption of flexible and user-friendly dashboard solutions tailored to the specific needs of ICU environments. Future studies should also focus on user centred approaches to enhance the usability of ICU dashboards [5, 23, 35].

2.2 NICU Environment and Workflow Challenges

The NICU environment presents unique challenges due to its complex care pathways and the extensive manual data entry required by nurses, which contribute to human errors, lack of real-time data access, and difficulties integrating data from various devices and systems [30]. The reliance on manual tools like whiteboards and paper charts further exacerbates these issues, hindering effective data access and integration [10, 25, 32]. Studies have highlighted the benefits of data visualisation tools in enhancing communication, efficiency, and clinician satisfaction in NICU settings, yet challenges remain in achieving visual clarity and reducing cognitive load during decision-making processes [6, 8, 14, 17].

Furthermore, the fragmented nature of data sources complicates the creation of a cohesive patient overview, delaying decision-making and suboptimal care delivery [9, 10].

In response to these challenges, user-centred dashboards are emerging as a viable solution to streamline NICU workflows and improve data accessibility by automating data integration from various medical devices and systems, providing a comprehensive overview that enhances decision-making [30, 31]. Insights from ICU studies further support the development of decision support tools tailored to the dynamic, collaborative nature of NICU environments, highlighting the potential of visualisations in improving patient outcomes [13, 27, 32]. Despite advancements in EHR technology, significant limitations persist, necessitating ongoing innovation to address the specific challenges within NICUs and maximise the benefits of visual data representation [19, 25].

2.3 Designing a User Centred Dashboard for NICU

A user-centred dashboard can streamline the management of complex care pathways by providing real-time access to critical patient parameters, facilitating prompt intervention, and optimising patient outcomes [36]. This allows healthcare providers to quickly assess the patient's condition and make informed decisions regarding specialised monitoring and interventions.

The reliance on manual tools within NICUs hinders effective data access and integration. A dashboard designed for NICU settings can have the potential to automate data integration from various devices and systems, offering a consolidated view of patient data and improving decision-making efficiency [29, 36]. This minimises human errors, ensures real-time data access, and facilitates the integration of data from multiple sources, thereby improving the accuracy and efficiency of data entry.

To ensure a seamless communication and collaboration among multidisciplinary care teams in NICU environment, a dashboard can facilitate communication by providing a shared platform for accessing and exchanging patient information, fostering collaboration, and supporting informed decision-making [36]. With that, it helps to address disparities driven by interpersonal bias and institutional barriers, ultimately improving care outcomes for all patients [24]. The development of a NICU dashboard requires a human-centred design process, involving engagement with NICU staff to understand their tasks, goals, and pain points [4, 28]. The design process involves iterative prototyping and testing, incorporating feedback from end-users to refine the dashboard's features and functionality [4]. Continuous iteration ensures that the dashboard remains intuitive and tailored to the evolving needs of NICU staff.

The integration of feedback from NICU staff is essential throughout the design process [14]. By actively engaging end-users and incorporating their feedback, we can address usability issues, improve functionality, and enhance user satisfaction. This collaborative approach fosters ownership among NICU staff and ensures that the dashboard effectively supports their clinical practice [14]. Collaboration with healthcare professionals, including neonatal nurses, neonatologists, and paediatricians, is essential throughout the dashboard development process. Input from staff ensures that the dashboard aligns with existing workflows and enhances clinical practice within the NICU environment [14, 20].

Im summary, literature underscores the necessity of recognising the distinct challenges within NICU environments compared to general ICUs. These include the specialised care required for highly vulnerable newborns, unique workflows, and diverse user roles. In response to these challenges, a human-centred design approach emerges as imperative for the development of effective NICU dashboards [11]. Engaging NICU staff in the design process allows for a deeper understanding of their tasks, preferences, and workflow intricacies.

3 STUDY I: UNDERSTANDING NICU OPERATION

Understanding the complex operating procedures, needs of different stakeholders and the limitation of existing systems in the NICU is key to develop a new design. To gain a comprehensive understanding of these factors, we employed a dual approach consisting of observational ethnography and follow-up interviews. The observational studies allowed us to directly observe and document the NICU workflow and identify key inefficiencies associated with manual data entry and paper charts. Follow-up interviews provided additional context and clarification, ensuring that our findings accurately reflected the challenges faced by NICU staff and informed the design process. This approach was undertaken following ethical processes at the NICU.

3.1 NICU Observation

To accurately understand the NICU environment and its processes, an observational ethnography was conducted at a local hospital's NICU [39]. The aim was to learn how clinicians use data to aid their decision-making and identify opportunities for improvement through user context analysis [15].

3.1.1 Participants. The study involved 10 NICU staff members, including doctors, nurses, and support staff.

3.1.2 Procedure. The study involved two days of observation, field memos, notes, sketches, and informal conversations with NICU staff, totaling 16 hours. On Day 1, the focus was on morning ward rounds, observing clinicians' interactions with patients and data during decision-making processes, particularly the recording of vital signs on paper charts. On Day 2, attention was given to the handover process, concentrating on how information is transferred between shifts and identifying inefficiencies and potential errors in using paper charts.

3.2 Interview with Stakeholders

To follow up with the observation study, an hour-long semi-structured interview with the supervising doctor and nurse educator provided further insights and clarified observations. Questions were asked around medical jargon, confirming the processes of the ward rounds and handover processes in detail and the processes of the NICU paper charts. The interview confirmed the processes of ward rounds and handovers, highlighting inefficiencies in the use of paper charts and the need for improved data storage and visualisation tools.

3.3 Findings

The observational and interview data were analysed by thoroughly reviewing notes and transcripts, which revealed inefficiencies in manual data entry and communication processes. By examining documented practices and identifying patterns in data handling and information transfer, the analysis highlighted critical gaps in accuracy, data integration, and visualisation. This process involved synthesising observations from the NICU environment and feedback from staff to understand the impact of these issues on overall patient care and decision-making.

From this study, we learnt that the NICU intensive care charts are an essential tool to record data and analyse the development of the patient's health. A key finding from this analysis is how nurses have to manually input onto the paper charts through an *eyeball translation of the monitored data*. Hence, the data accuracy or interpolation of the average number is *highly reduced and unreliable*. Furthermore, communication between stakeholders are primarily verbal. In both nurse handovers and ward rounds, stakeholders do not refer to the paper charts as much as they should. It is important that stakeholders *transfer information accurately* to ensure that incoming stakeholders are aware of

current issues with the patient for better care. Moreover, a significant limitation of current systems is the histograms and paper chart's inability to display a longer view for analysis. Although nurses may only need hourly data to provide care for patients, *doctors need a longer time frame* to view the trending data over time to develop a management care plan for the patient.

The observations highlighted several key issues:

(1) Manual Data Entry: Nurses manually record vital signs on paper charts every hour, averaging data points rather than documenting single data points. This practice is prone to errors and inefficiencies, especially during busy periods or emergencies.
(2) Reliance on Paper Charts: Each baby has a paper chart on a whiteboard desk, collecting data on various vital signs. However, the reliance on these charts limits the accessibility and integration of data, as nurses often interact more with bedside devices than with computers. A sample paper chart is shown in Appendix A.
(3) Shift Handover Challenges: Information transfer during shift handovers is primarily verbal, leading to potential miscommunication and loss of important patient context.
(4) Ward Rounds: The ward rounds involve multiple stakeholders, including physicians, registrars, nurse practitioners, and pharmacists. The conflicting needs for short-term and long-term data analysis create challenges. Doctors prefer long-term data from histograms, while paper charts provide only short-term data.
(5) Limited Data Visualisation: Current systems, including paper charts and bedside monitors, lack effective data visualisation tools to support comprehensive patient condition analysis. This limitation hinders the ability to make informed decisions based on trends over extended periods.

A summary of the NICU Observation Study Flow Chart is shown in Figure 1. It begins with an initial discussion where the physicians consult with the room nurse and parents to identify any problems that occurred overnight and any ongoing issues. Following this, an analysis of bedside monitors and NICU intensive chart data is conducted to assess the patient's condition and determine whether there has been any improvement or deterioration. Based on this analysis, decisions are made regarding the management plan. If the patient has improved, the current management plan may be continued. If there are concerns or if the patient's condition has worsened, the plan may be altered by scheduling additional tests. The registrar's role is to document everything the physician says on PowerChart, while the nurse practitioner pulls data and graphs from Butterfly, such as the patient's growth chart, to assist the physician in evaluating the patient's progress. Lastly, the pharmacist develops medication plans for the babies based on the physician's analysis.

4 CO-DESIGNING NICU INTERFACE

To effectively address the challenges identified in this study, we initiated an iterative design process for our visualisation interface. The motivation for adopting a collaborative co-design approach stemmed from insights gathered during our observational and interview studies. These insights underscored the necessity of incorporating stakeholder perspectives from the outset to ensure the new system meets their operational needs and enhances workflow efficiency.

From our studies, we found that a future system 1) should be inspired from the existing system and current processes with an enhanced data visualisation platform, 2) should also support different views for each stakeholder, and, 3) should provide a means for clinicians to record, amend, and append data. Thus, our first design incorporated these new features and elements of the existing paper charts such as the plots of the vital signs, and tables from the fluids-in and -out. The prototypes were developed with *Figma* platform.

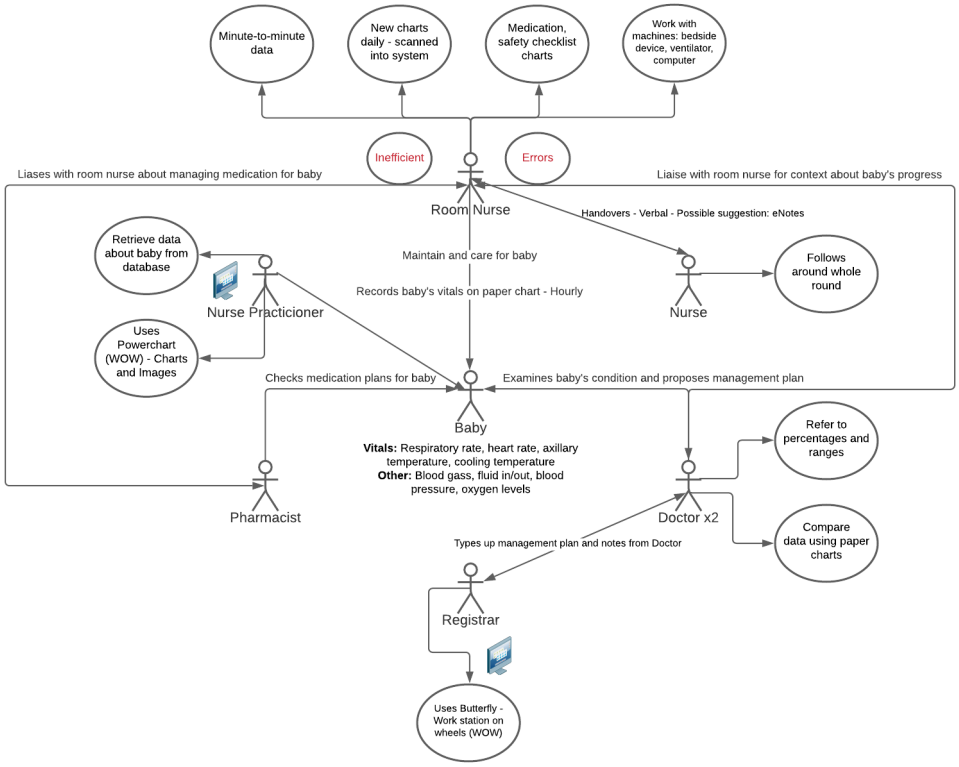


Fig. 1. NICU Observation Study Flow Chart

4.1 Participants

The co-design process involved six participants, including doctors, nurses and nurse practitioners. Their insights and feedback were crucial in shaping the interface to meet their specific needs and improve overall workflow efficiency.

4.2 Iterative Co-design Process

To ensure the new NICU interface effectively meets the operational needs of its users, a thorough co-design process was undertaken. This approach involved detailed feedback sessions with stakeholders to refine the interface iteratively based on real-world input.

In the first design revision, we developed Design 1 (Figure 2a), incorporating stakeholder suggestions for improved data visualisation and usability. This design was reviewed during consultation sessions to gather additional feedback. Based on this feedback, we created Design 2, which closely mimicked the existing NICU paper charts, offering a familiar interface for users. Stakeholders were consulted to review this design and provide further insights.

Finally, we combined the best aspects of Design 1 and Design 2 (Figure 2b) to develop Design 3 (Figure 2c). This design featured a collated graph of vital signs and individual charts for specific parameters. Final consultation sessions were held to refine Design 3 based on stakeholder feedback.

For each iteration, stakeholders were actively involved in review sessions where they tested the prototypes and provided specific feedback on usability, functionality, and integration with existing practices. This collaborative approach ensured that each design revision was closely aligned with user requirements and addressed any emerging concerns.

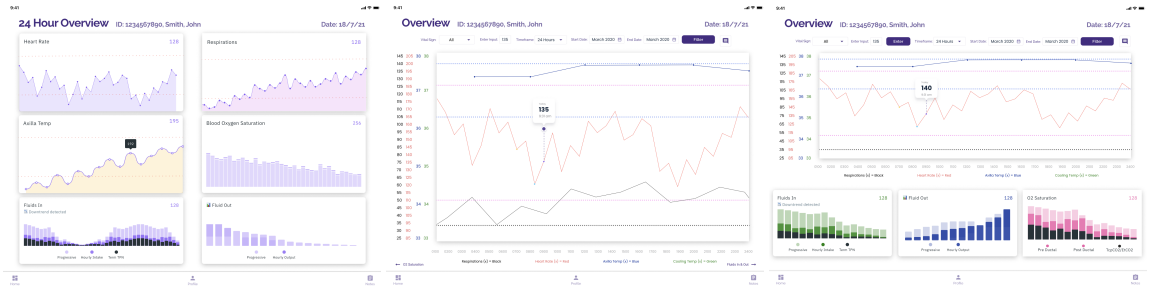
4.2.1 NICU Homepage Design. The NICU home page was structured to address the manual graphing of vital signs by incorporating six key parameters (heart rate, auxiliary temperature, respiratory rate, blood oxygen saturation, fluids in, and fluids out) into individual visualisation graphs. Participants found paper charts cluttered and hard to read, so the dashboard aims to pass data from bedside monitors directly into charts, reducing manual errors. Each graph can expand into an interactive detailed view with a timeframe toolbar, allowing clinicians to filter and display specific periods (4, 8, 24, 48, 36 hours, all time). This feature helps stakeholders view appropriate data timeframes, minimising conflicts. Nurses can analyse 24-hour trends to predict physiological instability, while doctors can review up to three days or weeks of data. Currently, NICU data is centrally stored and rarely utilised due to time constraints. A bedside dashboard would be "quite helpful." Additionally, a handover page was developed to solve miscommunication during nurse handovers by providing a shared text space for shift notes, ensuring transparent data transfer.

4.2.2 Feedback and Further Improvements. To further improve the graphical presentation, suggestions included adding "blue, yellow, and red zones" to indicate warning levels for nurses. There were concerns about documentation duplication, with nurses likely reverting to paper notes when busy, despite the handover notes prompt being a good design. Additionally, the dashboard's usability varies by demographic; younger nurses may find it easier to use, while senior staff might prefer traditional note-taking. Integration with the current nursery configuration and necessary training were also concerns. Detailed feedback from users during the co-design sessions highlighted the need for further enhancements, such as incorporating warning zones and ensuring seamless integration with existing workflows. To minimise the learning curve, the interface was designed to resemble existing paper charts and bedside monitor histograms, ensuring familiarity for all stakeholders. Overall, the NICU data visualisation dashboard aims to integrate into daily processes and address issues identified in pre-studies.

4.3 Design Iterations

As a result, this co-design session provided specific feedback needed to develop three alternative designs for health clinicians:

- Design 1: Developed to be our interpretation of what the NICU data visualisation dashboard would look like based on the observational studies, interviews, and surveys conducted. This design aimed to declutter the current NICU flow charts, especially the vital sign graphs that nurses manually draw.
- Design 2: Created to mimic and utilise the current design of the NICU paper charts, this design included a collated graph of all vital signs on the overview page.
- Design 3: Combined aspects of Design 1 and Design 2. The overview page featured the collated graph from Design 2, with the top 4 vital signs (heart rate, auxiliary temperature, respiratory rate, cooling temperature) and individual charts for fluids in and out, and saturations.



(a) Design 1 (b) Design 2 (c) Design 3

Fig. 2. Three alternative high fidelity designs, a) Design 1: Declutter vital signs into their respective charts, b) Design 2: Mimics the design of the current NICU paper charts, and, c) Design 3: Combination of Design 1 and 2.

4.4 Summary

Overall, the co-design approach ensured that the NICU dashboard aligns closely with user needs, integrates seamlessly into daily workflows, and addresses the identified challenges. By actively involving stakeholders throughout the design process, it is anticipated that usability, acceptance, and potential impact on patient care outcomes will be enhanced.

5 STUDY II: EVALUATING THE NICU DASHBOARD PROTOTYPE

The user testing session was conducted to evaluate the usability of each of the three designs created. The user study session was held on zoom due to the constraints of COVID-19. The study session started with 5 minutes of introductions and a further 5 minutes to explain the research aim and the importance of the study to NICU to help improve decision support and the representation of data for stakeholders through the design of a data visualisation dashboard using human-centred design approach.

5.1 Participants

A total of 16 NICU clinicians participated in the study, which was divided into two phases. The participants were categorised into two cohorts (as detailed in Table 1). The majority of participants were registered nurses responsible for direct patient care, with most being female and aged between 25 and 34. The first cohort comprised 10 participants who completed an initial survey, while 6 of these participants advanced to the second cohort for more detailed user testing.

5.2 Procedure

The study was conducted in two phases. The first phase involved 10 participants who completed a survey designed to gather information on their confidence with technology, their usage and perceptions of NICU paper charts, and their thoughts on handovers and ward rounds. This survey aimed to provide insights into the participants' experiences and attitudes toward existing NICU tools and processes. After the survey, participants were invited to proceed to the second phase. Of the 10 participants, 6 agreed to continue and were designated as the second cohort.

In the second phase, the 6 participants interacted with the three dashboard prototypes. They were asked to complete specific tasks, such as viewing vital signs, filtering data for nurse handovers, and creating handover notes. Participants

used the think-aloud method to verbalise their thought processes during task completion. Following the tasks, participants completed the System Usability Scale (SUS) survey for each dashboard design, providing detailed feedback on usability and design.

5.3 Data Collection

In Phase 1 of the study, data were collected via a survey completed by 10 participants. This survey aimed to assess their confidence with technology, perceptions of NICU paper charts, and views on handovers and ward rounds, providing insights into their general experiences and attitudes towards existing NICU tools.

In Phase 2, which involved user testing, participants consented to have their sessions screen-recorded for further analysis. They accessed each of the three dashboard prototypes and performed a series of controlled tasks. These tasks included viewing patient vital signs, using the filter toolbar to display data for specific timeframes (such as an 8-hour window for nurse handovers), creating handover notes, and reviewing previous nurses' notes to understand the context of the prior shift. The time taken to complete each task was recorded, and participants used the think-aloud method to articulate their thought processes and interactions with the prototypes.

Following the completion of these tasks, participants completed the System Usability Scale (SUS) questionnaire for each dashboard design. The SUS survey, which comprised 10 questions with responses ranging from Strongly Agree to Strongly Disagree, provided immediate feedback on the usability of each design.

5.4 Thematic Analysis on the Data Collected

The thematic analysis was employed to analyse and interpret the data collected from the user design study, which included qualitative data from two sources: an initial survey and user testing of dashboard prototypes. This qualitative data comprised responses from interviews and think-aloud protocols. The interviews investigated participants' confidence with technology, their perceptions of NICU paper charts, and their views on handovers and ward rounds. During user testing, participants performed controlled tasks with the prototypes while articulating their thought processes and interactions.

Thematic analysis was used to uncover underlying meanings in the survey responses, identify significant themes and patterns [2], and capture the complexities expressed by respondents in relation to the research question and relevant literature. This approach provided a systematic and structured framework for analysing the data, allowing us to gain insights into users' perspectives, preferences, and needs regarding the design of a user-centred NICU dashboard.

There are total of six stages involved: 1) familiarisation – to gain comprehensive understanding of the responses content, 2) initial coding – to identify and assign preliminary codes to words, phrases, and sentences that captured important aspects of the responses, 3) theme generation – group similar codes into potential themes that aligned with our research questions and framework, 4) reviewing themes – to refine and evaluate the generated themes based on their coherence and relevance, 5) defining and naming themes – label each theme concisely with its essence and scope, and 6) writing up – integrate the identified themes and provide supporting evidence from the responses.

The analysis was conducted manually with Microsoft Excel to facilitate the coding and organisation of data, allowing for efficient retrieval and analysis of relevant responses within each theme. There were no external thematic analysis frameworks involved in this analysis because the dataset collected is relatively small, using a complex framework might have been unnecessary. Besides, we are adopting an inductive approach where we aim to discover themes directly from the data rather than applying predefined frameworks which could have inadvertently introduced bias and restricted the discovery of unique themes specific to our study.

Table 1. Demographic data of participants

Characteristics	First Cohort (Survey)	Second Cohort (User Testing Session)	Total
Participants	10	6	16
Gender			
Female	9	5	14
Male	1	1	2
Age Group			
18-24	0	0	0
25-34	5	4	9
35-44	1	1	2
45-54	3	0	3
55+	1	1	2
Role in Hospital			
Nurse Educator	1	2	3
Clinical Nurse Specialist	3	2	5
Registered Nurse	5	2	7
Management	1	0	1
Years of Experience			
Less than 2	0	0	0
2-5 Years	2	0	2
5-10 years	3	3	6
11+ years	5	3	8
Confidence in using technology generally			
Very Confident	4	3	7
Somewhat Confident	5	3	9
Neutral	1	0	0
Somewhat Not Confident	0	0	0
Not Confident	0	0	0

5.5 Data Analysis

Through a comprehensive investigation, this analysis aims to clarify the complexities of NICU operations, identify obstacles hindering efficient workflow management, and propose actionable recommendations to enhance patient care outcomes in NICU settings. By focusing on the motivations driving healthcare providers, analysing the intricacies of NICU workflow, and exploring strategies for effective data utilisation in dashboard development, this study contributes the knowledge aimed at optimising neonatal healthcare delivery and improving clinical practices within NICU environments with the user-centred dashboards that facilitate seamless data access, interpretation, and informed decision-making. There are a total of five themes identified which are itemised as follows.

5.5.1 Theme 1: Inefficiencies in NICU Workflow. We identified the major content which is the NICU workflow. Within the NICU, a typical day involves a blend of work activities, spanning from emails and meetings to clinical rounds, handovers, and enduring 12-hour shifts. Communication is a multifaceted aspect, encompassing channels such as emails, meetings, rounds, and hands-on care discussions, including feeding and assessments. The main operation of NICU is patient care. Activities like baths, fluid changes, medication administration, and feeding are meticulously carried out to provide the best possible care for these infants.

The management of paper charts is a critical component of NICU workflow. Charts are subject to varying change frequencies – some are updated every 24 hours, others daily, and some at the stroke of midnight. Completed charts are located at the bedside for documentation, in the baby's files, bedside chart holders, or in designated spaces near the computer desk. Accessing information from the previous day involves referencing charts at the bedside or retrieving them from filing drawers. The filing process is a collaborative effort, with ward clerks responsible for separating and filing charts in folders or piles. Nurses are often integral to this process.

As technology advances, there is a push towards digitising patient records. Paper charts are scanned upon the discharge of a patient, but the transfer to electronic databases is not always seamless. The process can take months, and not all information from paper charts makes its way into the electronic systems. One of the participants commented on the data transfer: "*The data are sometimes transferred to database, however not all information - only the total daily fluid requirement, feeding regime/IVF source. And ventilator settings. As for PowerChart, the only data put there is progress notes/doctor's/allied health progress notes*" (P07). The NICU Clinical Database is a central hub that receives updates every shift, while PowerChart is dedicated to housing pathology results. However, the coexistence of these systems presents challenges. There are participants suggested an integration to streamline workflows and eliminate the potential for double charting. One of the participants highlighted the merging of system: "*Ideally clinical database and power chart should be merged; it is annoying to use both and double chart*" (P03).

5.5.2 Theme 2: Challenges with Paper Chart. The paper chart in NICU possesses a myriad of challenges. We found out that participants were having issues from problems of navigation and customisation to concerns about redundancy, space limitations, and oversight, healthcare professionals grapple with an array of obstacles. Out of 10 participants, four (40%) of the participants are having issues with space limitations, two (20%) reported of oversight. These problems have contributed to the complexity of NICU documentation setting. Paper charts are not just occasional tools; it has a high usage. They are integral to the daily workflow in the NICU. They are consulted hourly and sometimes even multiple times within a single hour, underscoring their central role in patient care. All the nurse participants have highlighted that they used paper charts in their work routine, one of the examples responses is: "*We use them all the time, for everything except progress noted*" (P07).

Paper charts play a crucial role in handovers, facilitating stability discussions, explaining vital changes, providing structural support, and ensuring easy retrieval of essential information. The use of paper charts ensures structured handovers, safety checks, and clear communication among healthcare professionals, contributing to the overall effectiveness of patient care. They are subject to regular changes, with updates occurring every 24 hours, often at midnight. Access to the previous day's charts is frequent, emphasising the importance of historical data in the NICU. "*The paper chart is used for handover; it shows what's happened and when on a shift. It helps to show and explain vitals, fluids, vent settings*" (P02). However, concerns about information retention linger, highlighting the need for streamlined processes. Challenges in scanning charts for electronic transfer are acknowledged, bringing attention to the need for improved dataset transfer and seamless integration with electronic databases. One of the nurse participants mentioned: "*Lack of important information with a complex patient*" (P02).

In response to these challenges, healthcare professionals suggest several improvements. These include a call for more accurate plotting, dedicated spaces for fluid documentation, provisions for detailing feeding methods, and integration of Near-Infrared Spectroscopy (NIRS) monitoring into the documentation process. Despite the digital age, the preference for paper charts remains strong in the NICU. We discovered that two (20 %) of the participants were not happy with the digitised version of paper charts. Their worries were limited computer access, concerns about

reliability, convenience, and time constraints. While the prospect of digital paper charts is contemplated for the future, concerns about access complexity and device support linger. However, the potential benefits, including ease of reading, management, documentation, and communication, are recognised. One participant emphasised that: "*It is the way of the future and just a matter of time. It will have everything that NICUs document as each unit has been surveyed*" (P01).

5.5.3 Theme 3: Handover Process. NICU handovers are one of the crucial tasks within the department; effective communication and seamless information transfer need to be prioritised to ensure the continuity of care for fragile newborns. Our analysis reveals the perspectives of participants regarding the process and several areas for improvement. NICU handovers often lack crucial details. We found out that participants' perspectives on handovers often lack standardisation, leading to incomplete information sharing. Lengthy rounds, and variable effectiveness among doctors underscore the necessity for streamlined processes and consistent practices. This will lead to consequences as critical information may be overlooked or misunderstood, potentially jeopardising patient care. "*Lack of important information with a complex patient. Accuracy of information handed over. Incomplete information*" (P01).

There are also challenges in communication breakdowns and inefficiencies in time management. Poor listening skills, inefficient cheat sheet utilisation, extended ward rounds, and inadequate communication during rounds hinder effective information exchange. One of the participants clarified that, "*Handover is still not done effectively. Information is lost constantly. Ward rounds are extremely long. Sometimes there is teaching whilst doing rounds which extends the time*" (P10).

The dynamics between nurses and doctors in the NICU also pose significant challenges. There were some issues identified from the survey such as nurse shaming, inconsistent care, lack of acknowledgement, and over-reliance on statistics. This highlights a need for cultural shifts towards collaboration and balanced decision-making. "*Stop the nurse shaming and criticism, it leads to a culture of people not able to use their clinical judgement and a sense of mistrust by the doctors/managers*" (P03).

To address these challenges, some recommendations were identified such as standardising approaches, implementing templates, enforcing time limits, fostering trust-building, and balancing teaching and patient care are paramount. Systematic enhancements are essential to improving the efficiency and effectiveness of NICU handovers. There are some participants emphasised about the information accessibility. They suggested a comprehensive handovers process with seamless access to a baby's history, integration of online and paper-based information, and promoting the use of NICU charts. This allows the information accessibility facilitates efficient decision-making and improves patient safety.

5.5.4 Theme 4: Priority to Understand the Key Data. Understanding the key data that healthcare providers prioritise when perusing paper charts is essential. This insight not only informs the design of effective dashboards but also underscores the importance of streamlining information for efficient decision-making in the fast-paced environment of the NICU. We identified that the healthcare providers meticulously track and analyse the vital signs such as heart rate, temperature, respiratory rate, oxygen saturation (SpO2), and blood pressure; utilising sophisticated monitoring systems to detect deviations from the norm.

Of particular importance is the monitoring of oxygen saturation, a critical determinant of respiratory function and overall well-being in neonates. Specific attention is paid to SpO2 levels following ventilation changes, ensuring optimal oxygenation, and mitigating the risk of hypoxemia. Almost all participants highlighted about the oxygen saturation, "*SpO2 particularly after you make a change in ventilation and oxygenation*" (P01). The participants also reveal the importance of conducting comprehensive evaluations encompassing various aspects of neonatal health. This includes crib temperature, fraction of inspired oxygen (FiO2), growth parameters, and respiratory support requirements.

By synthesising short-term observations with long-term trends, they able to gain invaluable insights into the baby's overall well-being, facilitating informed decision-making and personalised care plans.

5.5.5 Theme 5: Improvements. The analysis has unveiled a series of actionable insights from the healthcare providers for improving various facets of clinical practice in NICU. Most of the participants have articulated a keen interest in restructuring the flow of paper charts to enhance usability. Specific suggestions include incorporating a dedicated medication box, relocating observation values for improved visibility, providing ample space for documentation, and advocating for the adoption of standardised templates. "*Digital charts should have options to remove parameters for data. Most patients don't need every single column on the paper chart. Simplifying this to only what's needed would aid visual interpretation of baby's condition*" (P03).

To optimise the ward rounds, participants proposed measures include capping the time allocated for rounds, meticulously planning, and standardising the rounds, and streamlining the overall flow to minimise redundancies and maximise productivity. They also underscore the importance of integrating databases to eliminate redundancy and streamline processes. There are also some recommendations on handover process that include implementation of the ISBAR approach for standardised handovers, ensuring the consistent use of templates, and establishing time limits during ward rounds to optimise information exchange.

5.6 Summary

The thematic analysis of healthcare providers' perspectives in the NICU reveals critical insights for the development of a user-centred dashboard. Firstly, understanding the multifaceted NICU workflow, encompassing clinical rounds, handovers, and patient care activities, is essential. While there's a growing push for digitisation, challenges persist with paper chart documentation, including navigation and space limitations, maintaining the strong preference for paper charts. Moreover, issues with the handover process, such as lack of standardisation and communication breakdowns, underscore the need for cultural shifts towards collaboration. Healthcare providers prioritise tracking vital signs and conducting comprehensive evaluations, emphasising the importance of key data points. Recommendations for improvement, including restructuring paper chart flow and standardising processes, are crucial for enhancing efficiency and streamlining workflows in the NICU. These findings highlight the necessity of addressing documentation challenges, improving communication, and integrating key data into a user-friendly dashboard fit for healthcare providers' needs.

Hence, in our case of developing the dashboard, we emerged with several key considerations. Firstly, it's crucial to incorporate key data points such as vital signs and comprehensive health evaluations that healthcare providers prioritise. This ensures that the dashboard provides relevant and essential information for decision-making. Additionally, streamlining the NICU workflow through the dashboard design is essential. This involves integrating with existing systems to facilitate seamless data access and interpretation, thus optimising efficiency in patient care. Addressing challenges with paper chart documentation is another critical aspect. By offering customise options, ample space for documentation, and simplified data visualisation, the dashboard can alleviate documentation burdens and improve overall workflow. Standardising handover processes, such as implementing the ISBAR approach, is necessary to ensure effective communication and information transfer between healthcare providers.

Finally, enhancing usability is important, this involves standardising processes, and incorporating user feedback to optimise the dashboard's design according to the specific needs of NICU healthcare providers.By considering these factors, the dashboard can effectively support NICU operations, improve workflow efficiency, and ultimately enhance patient care outcomes.

6 USABILITY OF THE DASHBOARD PROTOTYPE

In the user testing session, three designs have been evaluated about its usability by six participants. It was found that the first design tasks took relatively longer to complete. This was foreseen as participants were unfamiliar with the functionalities and where all the data was placed. Participants used the first task to familiarise themselves with the dashboard and analysed the layout of the data to gain an understanding of the context behind the design of the dashboard. Hence, the time to complete the tasks for the subsequent two designs assigned was reduced, respectively. By the last design to test, participants had a sense of familiarity with how the dashboard may work in a real-life setting. For all tasks completed, all participants eventually ended at the desired destination. After reviewing the user's paths to complete the tasks, some participants selected the cardiovascular box within the medical requests and targets section to see if there was further information there. As cardiovascular includes the heart organ, the user's thought process led them to view this section. A possible link can be inserted to allow NICU clinicians to view the target and the detailed heart rate for further diagnosis.

Furthermore, when asked to view the baby's details, some participants referred to the ID text at the top of the dashboard. Participant's thought that more information about the baby's details would appear by clicking on the text. Hence, to improve this situation and provide more access to the baby's details, an open prompt could be included to allow users to view the main parameters from the baby's details such as current weight, weight loss/gain, gestation and age. Furthermore, although the prototypes were designed for a tablet, participants did not utilise the swiping functionality. This may be a limitation of the user study session being conducted online, as participants cannot provide touch manipulation on a computer.

6.0.1 System Usability Scale (SUS). The results of the SUS from the user study session aims to determine the usability performance of the three dashboard designs in the aspects of effectiveness, efficiency, and overall ease of use.

As seen in Table 2, it is clear that Design 1 had the best SUS score with an average of 89.17, which translates to an excellent adjective rating. The design that had the lowest SUS score was Design 3, with an average score of 78.33. Design 1 is the prototype that users find has the best usability performance and effectiveness and should be highly considered when designing the next version of the high-fidelity prototype.

Table 2. Summary of SUS scores for NICU dashboard designs

	Design 1	Design 2	Design 3
Min	75.00	62.50	65.00
Max	97.50	97.50	87.50
Average	89.17 (SD=9.17)	82.92 (SD=13.59)	78.33 (SD=10.08)
Adjective Rating	Excellent	Excellent	Good

6.1 Feedback on Designs

6.1.1 Design 1. Participants responded positively to Design 1 (Figure 2a), particularly appreciating the visual aspect of the graphs representing vital signs. They liked the clarity and ease of reading the dot-point graphs and found it helpful to see all vital signs separately with trends presented on the main screen. Some concerns were raised about the style of graph for auxiliary temperature and the predominance of purple colour, which could pose issues for colour-blind users. Suggestions for improvement included incorporating contrasting colours, making the "between the flags" parameters

more prominent, and including histograms to analyze trends and proportion of time spent within acceptable ranges. Participants also expressed interest in functionality to collate parameters for easier analysis and suggested including prompts for medical targets and basic patient information on all screens.

6.1.2 Design 2. Participants found Design 2 (Figure 2b) to be similar to their current system, appreciating its ease of use and clean visual display. However, some participants felt that it presented an overload of information and resembled the current NICU paper charts too closely. Suggestions for improvement included matching colours with warning zones, simplifying the layout, and incorporating a mean blood pressure graph for more comprehensive data representation.

6.1.3 Design 3. Participants liked Design 3 (Figure 2c) for its variety of data and ability to change time frames, finding the colours catchy and easy to distinguish. They appreciated the option to select desired vital signs and the inclusion of "beyond the flags" warning zones. Some participants found the layout slightly harder on the eyes compared to other designs and suggested removing the y-axis from the graph for continuous display. Suggestions for improvement included adding a 24-hour view of fluid balance and simplifying the interface for easier navigation.

6.2 Summary

Based on the user study session results, the chosen design voted by participants as their most ideal prototype design was Design 1 (66%), and Design 3 (44%) coming in shortly after. Participants who chose Design 1 appreciated its layout, with all parameters individualised and separated on the screen, and the option to view detailed pages for each parameter to narrow down trends. They found the larger graphs easier to read, allowing them to see all parameters in a specific timeframe. Design 1 also reduces the need for nurses to toggle through multiple pages, as all essential vital sign parameters are displayed on the home screen. One of the main reasons for preferring Design 1 was its ease of use, providing clear trends and being easy to understand, which benefits staff who struggle with technology, such as senior nurses. Participants who favoured Design 3 liked the ability to collate graphs onto one view, allowing NICU clinicians to easily analyse how each parameter interacts with others. This is useful, for example, if a baby suddenly gets hot, as nurses can quickly check for correlations with other parameters.

Overall, participants did not favour Design 2 due to its usability issues. Navigating to the blood oxygen saturation page and fluids in and out required clicking arrows, which is not ideal for senior nurses who are less familiar with computers, making it time-consuming to find these functionalities. A suggested improvement was to make the font bolder and more prominent for better accessibility. Although not tested, participants liked the comments section functionality, which allows users to mark specific points in time and provide further information about data points.

6.2.1 General Feedback and Improvements. Participants suggested several improvements for all designs. They recommended including options for users to preset selections based on different parameters, making the drop-down toggle more prominent for easier functionality access, adding all parameters to the vital sign drop-down for easier access, and researching the impact of colour choices on colour-blind users. These suggestions address issues from the thematic analysis related to errors and inefficiencies in manual data documentation on paper charts and the limited data visualisation tools hindering comprehensive analysis and decision-making.

Additionally, participants recommended providing more links to pages to make other vital signs, such as blood oxygen saturation and fluids in and out, more accessible. They also suggested changing the term "profile" to "patient details" to avoid confusion, as some participants thought "profile" referred to the user's details rather than the baby's. They proposed that the patient details page should include more essential parameters, such as the baby's weight gain or

loss and a handover checklist for nurses' assessments. This aligns with the thematic analysis finding of the need for standardised communication during shift handovers and systems supporting long-term data analysis.

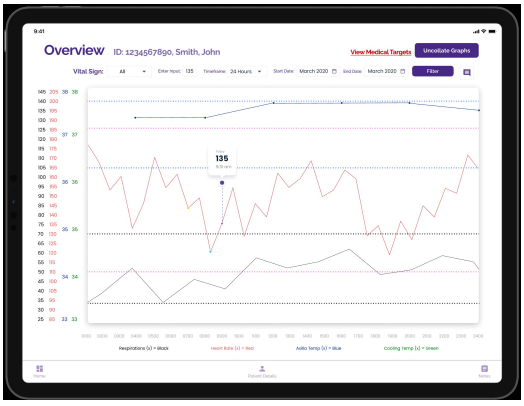
Overall, participants acknowledged that these designs require nurses to learn and adapt, which is a common practice with new technologies. Implementing training sessions will help nurses understand and effectively use the system in their daily operations, ultimately improving their practices and decision support when caring for patients. Participants' recognition that the designs are "better than paper" reflects their awareness of the need for improved visual clarity and reduced cognitive load, as highlighted in the thematic analysis.

6.3 Proposed Design

(a) Main Page incorporating Design 1

(b) Quick View of Patient Details

(c) Collate Vital Signs Functionality



(d) Medical Targets Functionality

Fig. 3. Proposed High Fidelity Design

The proposed Figma high-fidelity prototype design, showcased in Figure 3, incorporates feedback from the user study sessions, merging elements from Design 1 as depicted in Figure 3a. Building upon this foundation, we enhanced the prototype to provide NICU clinicians with improved access to patient details and medical targets. For instance, Figure 3b illustrates how the ID is now clickable, revealing essential patient data such as weight and gestation levels.

Additionally, the prototype enables clinicians to collate the four main vital signs into a single graph, similar to Design 2 as shown in Figure 3c. This feature facilitates the analysis of vital sign correlations, offering insights into patient distress indicators.

Moreover, we included a clickable "Medical Targets" text in the design, as depicted in Figure 3d, to aid in care planning and practice guidance. This enhancement allows NICU clinicians to compare patient progress against predefined care management plan goals set during handovers, fostering improved communication and transparency among stakeholders. Furthermore, adjustments to the colour scheme were made to ensure better visual distinction between vital signs, drawing from the scheme used in traditional paper charts to promote familiarity among NICU nurses. Additionally, we emphasised the 'beyond the flags' warning lines to clarify safety zones, addressing concerns raised about visual clarity and safety precautions.

In summary, these enhancements in the proposed dashboard design are aligned with key findings from the thematic analysis of healthcare providers' perspectives in the NICU. By prioritising accessibility, data clarity, and usability, the prototype aims to streamline workflow, alleviate documentation burdens, and support clinical decision-making processes. Ultimately, these improvements seek to enhance patient care outcomes by meeting the specific needs and challenges of NICU healthcare providers.

7 DISCUSSION

Findings from these studies have suggested that the NICU dashboard has the potential to out-perform the use of paper charts in retrieving and analysing patient data. The proposed high-fidelity prototype design for the NICU dashboard addresses several key issues identified through thematic analysis and user study sessions. By incorporating feedback from healthcare providers and iteratively refining the design, the prototype aims to improve workflow efficiency, data accessibility, and decision-making processes in the NICU setting. Based on the results of the methodologies performed for this study, it is clear that all participants within the user study session agreed that the NICU dashboard designs could significantly impact the current NICU clinical practice. The benefits of the proposed dashboard design can be seen through the development of enhanced data visualisation graphs to display data, improving analysis support for NICU clinicians, and reducing the time and effort to understand and retrieve data [33]. The NICU dashboard also has the capability to empower changes in the processes of how paper charts are stored and transform clinical roles within the environment. As the dashboard is an electronic platform, there is no need for the ward clerk to collect paper charts and store them in the communications room. Thus, clinicians will not need to search through paperwork to find previous days data points for analysis.

When comparing the usability of the dashboard to the paper charts, participants have mentioned that the dashboard would enable clinicians to easily investigate data points from the whole history since a patient has entered the NICU. This effectively reduces the cognitive strain for clinicians and improves the way they diagnose the patient. As time spent on unnecessary and tedious processes is removed with the dashboard, NICU clinicians are able to effectively utilise their time to care for patients and significantly enhance the support for clinicians to make vital decisions to improve the progress of patients. Further to the direct visualisation, our discussion indicated that the dashboard should allow clinicians to view and display data trends, filter data based on times, events, etc. This functionality provides stakeholders with an agile functionality to filter data to a critical time, supporting the clinicians' cognitive ability to efficiently analyse data, compared to clinicians searching through much-unorganised handwriting on the paper charts, which have resulted in cognitive strain.

Hence, to further improve the decision support for clinicians and patient care, participants have suggested providing a mechanism for NICU clinicians to have the ability to customise the interface to fit their needs. Having options for clinicians to collate vital signs will enable them to narrow down the correlation between parameters further and enhance diagnosis, especially in critical situations where the patient is deteriorating. Overall, findings from the studies found that all participants are keen to see the development of the NICU dashboard unfold. Additionally, the iterative design process, informed by user feedback and thematic analysis findings, underscores the importance of stakeholder engagement in system development. By actively involving healthcare providers in the design process, the final prototype aligns closely with their needs and preferences, ultimately enhancing user acceptance and adoption potential.

All in all, the proposed dashboard design has the potential to significantly impact NICU workflow and patient care outcomes. By providing healthcare providers with intuitive tools for data documentation, analysis, and decision-making, the dashboard aims to improve efficiency, reduce errors, and enhance the quality of care delivered to neonatal patients. Moreover, the emphasis on user-centred design and iterative feedback loops ensures that the dashboard is tailored to the needs and challenges faced by NICU healthcare providers, maximising its potential impact on clinical practice.

7.1 Limitations

7.1.1 System Limitations. A major limitation we see in developing a dashboard for the NICU is the challenges it will face in actual deployment of the system. There are numerous regulations and policies that the system needs to be adhered to before deployment and have to secure approvals. In the scope of this project, we did not consider these regulations since our focus was on gathering requirements and designing the interface. However, it is important to consider these before transitioning from high-fidelity prototypes to a real implementation.

Furthermore, from the clinicians point of view, our study participants expressed their concerns in terms of the scalability and technical aspects of the NICU dashboard as potential challenges which may be faced if it is going to be implemented within the NICU environment [7]. Some nurses have expressed that in a critical scenario where they are in need of finding data from a technological interface, the process of logging into the system every time to find the desired data point is highly time-consuming and tedious. That is where some participants find the paper chart more valuable than a dashboard interface because there are no technical issues that may occur and because all the data points needed can be seen on one large sheet of paper without the need to log in. In the best scenario, the dashboard would be able to be always available, so NICU clinicians are able to navigate the system without access barriers. However, the data security and privacy concerns of such an operation needs to be further evaluated.

Additionally, the problem space survey of the NICU environment and the observational studies identified a broader range of problems. Although this study focused on the processes within the NICU setting, it lacked the behavioural connection that underlies these processes, especially processes that require collaboration between different stakeholders and how that can be utilised within the dashboard. The survey study highlighted the severe problem of miscommunication between nurses and doctors. Participants discussed the vital need for clear communication, especially during the ward rounds, so all stakeholders are clear of the management plan and the critical progress of the baby [37]. Thus, the dashboard needs to provide a collaborative process or functionality for NICU clinicians to effectively communicate their needs and facilitate more significant interaction and access to workflow information. Ultimately, this study lacked to address these issues, which need to be highly considered in future studies.

Also, as a result of time constraints and ethical constrains, the implementation of the real system could not be completed. This includes obtaining data from current interfaces and devices. In order for the proposed design to be fully implemented, there needs to be considerations to how data will be extracted from these devices. As there are

many systems that the local NICU utilises, it would be difficult to integrate these systems together. This is imperative to test whether the proposed NICU Dashboard could be an effective interface to help clinicians with decision-making. Many software design applications and structures that need to be considered when developing the real system and we considered this is outside the scope of current study.

7.1.2 Study Limitations. As a result of the pandemic, the observation studies were only limited to only two days of morning shifts. Two days of observations are too minimal to grasp the whole NICU environment, especially with the lack of night shift observations. Night shifts have fewer staff members monitoring patients, and could result in different scenarios. This is important to determine the effectiveness of the dashboard in situations where there is a limited skill mix of staff. Thus, more days within NICU would allow us to gain a better understanding of the interactions between NICU clinicians.

Besides that, as nurses cannot leave the bedside for very long, we could not conduct extended interviews or group interviews with nurses. Also, the NICU setting is tranquil not to disturb the babies, which prevented us from conducting think-allowed observation to understand the mental model of the participants. The user study session acquired a relatively small sample size of 6 participants and utilised a limited range of clinical scenarios [26]. The sample of the participants mainly consisted of registered nurses and clinical nurse specialists. Thus, there could be more disparity in the roles of NICU clinicians, with participants such as doctors and consultants being included in the mix.

Another major limitation to our study was that parents were not considered. Parents are a major stakeholder within NICU, and are highly interested in the progress of their baby during this critical time. Due to the COVID-19 restrictions, parents experienced a difficulty in visiting their baby in the intensive care unit. With limited contact to parents, we were not able to grasp information on how they would like to be involved in the design process. This can definitely be a huge focus for researchers in future studies. An application for parents to understand the underlying issues of their baby and current management plans are possible considerations for a future study.

8 CONCLUSION

This paper outlines the development of a user-centred data visualisation dashboard for the NICU at a local hospital, aiming to overcome challenges associated with traditional paper-based methods. Through iterative user-centred design, a high-fidelity prototype was created to enhance workflow efficiency, data accessibility, and decision-making processes. Key features included data sorting filters, adjustable time frames for vital signs, and a collation function for parameter viewing flexibility. User feedback highlighted the dashboard's potential to streamline NICU operations, particularly during handovers and ward rounds. The study underscores the importance of stakeholder engagement in system development, ensuring alignment with healthcare providers' needs and preferences and fostering enhanced usability and adoption potential.

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A NICU PAPER CHART

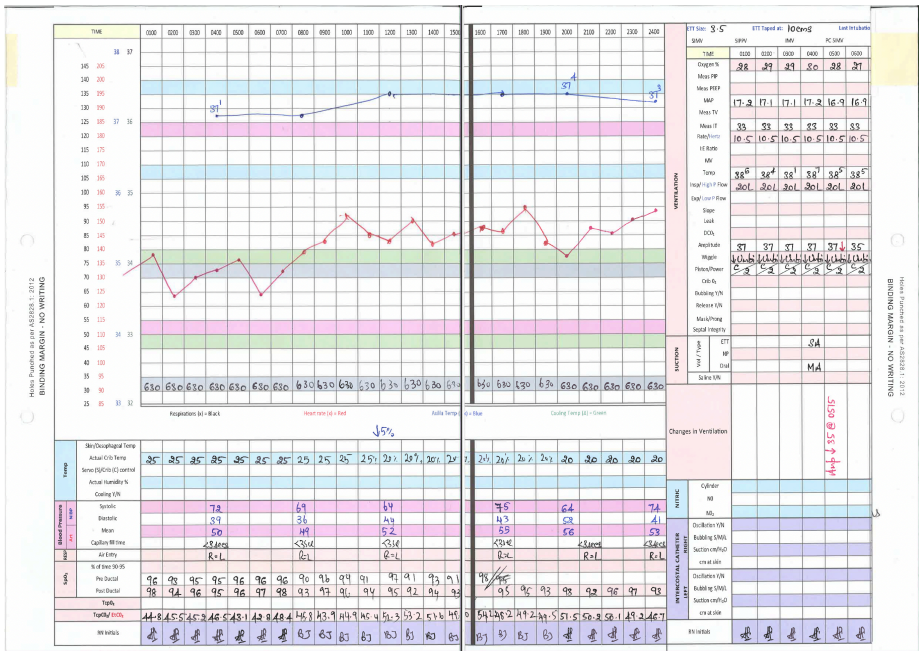

Fig. 4. A sample NICU Paper Chart with mock data.