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Implementation of a National Electronic Health Record in the specialised setting of Neonatal Intensive Care Units

Thesis presented by

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Glossary of Terms

µmols/L	micromoles per Litre
AACTT	Actor, Action, Context, Target, Time Framework
AAP	American Academy of Pediatrics
AI	Artificial Intelligence
ANP	Advanced Nurse Practitioner
APGAR	Appearance, Pulse, Grimace, Activity and Respiration
BAPM	British Association of Perinatal Medicine
CAB	Change Advisory Board
CAG	Clinical Advisory Group
CFIR	Consolidated Framework for Implementation Science
CHIR	Canadian Institute of Health Research
CREC	Clinical Research Ethics Committee
CUMH	Cork University Maternity Hospital
CWIUH	Coombe Women and Infants University Hospital
D & I	Dissemination and Implementation
eHealth	Electronic Health
HER	Electronic Health Record
EHDS	European Health Data Space
EOS	Early Onset Sepsis
EU	European Union
GDPR	General Data Protection Regulations
GP	General Practitioner
GRO	General Register Office
HIQA	Health Information and Quality Authority
HMD	Hyaline Membrane Disease
HSE	Health Service Executive
ICT	Information & Communication Technology
IGG	Information Governance Group
IMEWS	Irish Maternity Early Warning Score
IMO	Irish Medical Organisation
iPARIHS	Integrated, Promoting, Action on Research Implementation in Health Sciences
ISO	International Organisation for Standardisation
LIGG	Local Information Governance Group
LIS	Laboratory Integration System
Mg/dL	Milligrams per Decilitre

Mls	Millilitres
mls/kg/day	Millilitres per kilogram per day
MN-CMS	Maternal & Newborn - Clinical Management System
NCC-WCH	National Collaborating Centre for Women and Children's Health
NCHD	Non-Consultant Hospital Doctor
ND	Nutritional Dashboard
NEC	Necrotising Enterocolitis
NHS	National Health Service (of the United Kingdom)
NICE	National Institute of Clinical Excellence
NICU	Neonatal Intensive Care Unit
NMBI	Nursing and Midwifery Board of Ireland
NMH	National Maternity Hospital
NN-SCI	Neonatal Standardised Concentrated Infusion
Non-PROD	Other domains than the live production
NPEC	National Perinatal Epidemiology Centre
NPM	Normalised Process Model
NPT	National Project Team
NPT	Normalisation Process Theory
PAEHR	Patient accessible Electronic Health Records
PAS	Patient Administration System
PROD	Production (Live domain)
PROMPT	Practical Obstetric Multi-Professional Training
RCOG	Royal College of Obstetrics and Gynaecology
RDS	Respiratory Distress Syndrome
RE-AIM	Reach, Effectiveness, Adoption, Implementation and Maintenance
ROP	Retinopathy of Prematurity
SCI	Standardised Concentrated Infusion
TI	Test Issue
TMFs	Theories, Models and Frameworks
UCC	University College Cork
UHK	University Hospital Kerry
UK	United Kingdom
UMHL	University Maternity Hospital Limerick
UOM	Unit of Measure
US	United States
VON	Vermont Oxford Network
WHO	World Health Organisation

Declaration

I declare that the work I am submitting is my own and has not been submitted for any other degree in University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism and intellectual property.

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Abstract

Background

Electronic Health Records (EHRs) are being introduced worldwide and are necessary to update modern healthcare. The introduction of EHRs however is complex and is dependent on a myriad of factors. One key factor in successful EHR implementations is workflows and workflow compliance. Through acceptable workflow designs, clinicians can document appropriate clinical information at source which can be used for clinical decision making and contribute to patient care improvements. In the Republic of Ireland, a national EHR is being introduced for women and their babies- the Maternal and Newborn - Clinical Management System (MN-CMS) EHR provides the research environment for this thesis.

Aims and Objectives

This thesis aims to (1) To assess the role workflows play in the successful implementation of an EHR (2) Explore the potential aspects of Implementation Science - using the Normalisation Process Theory (NPT) for evaluation of a successful implementation of an EHR and (3) Can EHR user interfaces be improved with clinician engagement to better facilitate input and management of healthcare data?

Methods

Primarily quantitative methods, with some qualitative methods, were used for the research contained in this thesis. From exploration of implementation science literature, the Normalisation Process Theory was identified as being useful in complex and technological changes and the various implementation strategies and

outcomes are explored. A retrospective document review was undertaken of the MN-CMS Phase One Closure Report to identify the key lessons learned. A retrospective document review was also undertaken to analyse the MN-CMS workflows. The process of workflow design was outlined and evaluated using the AACTT Framework (Actor, Action, Context, Time, Target). Healthcare clinicians (nurses n=76; doctors n=29) workflow compliance was quantifiably measured using background system audit logs and system reports to gain a comprehensive analysis of the workflow compliance. Data were analysed using means and standard deviations. Pre – Post mean differences, and their 95% confidence intervals were calculated and their statistical significant was assessed based on p-values derived from paired t-tests (nurses) and independent t-tests (doctors). The final study of this thesis was improving data quality of newborn feeding in the EHR. Firstly, an expert multidisciplinary group (n=38) were used to design the changes to feeding data entry and review components. Then a quantitative pre-post design was used to assess feeding documentation from newborns electronic records (n= 322). Descriptive statistics and Pearson's Chi-Square were used to assess pre-post differences and statistical significance. A focus group (n=5) was conducted post implementation and data were analysed using reflexive thematic analysis.

Results

This thesis has focused on the Normalisation Process Theory as providing a useful framework for complex changes such as EHR implementation. The use of the AACTT framework is specifically useful in guiding workflow developments. This research has identified key lessons learned and recommendations for a large scale EHR implementation in terms of the planning, implementation and optimisation

phases. The key role workflows play in EHR implementation was identified through a retrospective assessment of patient focused workflows from the MN-CMS with modifications and a new workflow successfully implemented using the AACTT framework. Quantifiably measuring workflow compliance identified that the introduction of a new patient summary page demonstrated some very positive changes and adoption of the EHR. Finally, following a collaborative approach to redesigning newborn feeding within an EHR, data completeness significantly improved.

Conclusion

This thesis has explored the benefits of the Normalisation Process Theory and the AACTT Framework in implementing EHRs and the key role of workflow development and evaluation. Appropriately designed workflows can underpin the EHR and encourage appropriate and accurate data entry. This thesis has also identified that the EHR system design can be improved with clinician user engagement to improve data input in the EHR.

Chapter 1

Introduction

Chapter 1- Introduction

1.1 Introduction

Electronic Health Records (EHRs) are being introduced worldwide across Europe, North America, Australasia, and the Middle East[1] and they are essential to attempt to modernise healthcare[2]. The benefits of EHR utilisation include enhancing the availability of patient data for health care providers and promoting health equity[3]. According to the International Organization for Standardization (ISO) an EHR is 'a repository of information regarding the health status of a subject of care, in computer processable form'[4]. Healthcare can generate huge volumes of data daily[5] and the delivery of safe and effective healthcare can depend on the availability of accurate and up-to-date data in a legible, reliable and timely manner[5,6]. The introduction of EHRs in the healthcare setting has been described as complex[7] particularly in the hospital setting compared to private industry, due to the nature of the organisational setting that involves caring and curing, data security, confidentiality and data accuracy[8]. Many complex steps have been identified in the implementation of an EHR from procurement, design, building, testing, training through to adoption and optimisation[9]. A hospital wide EHR implementation needs to consider a number of organizational, human, and technological factors as well as organizational structure, culture, technical infrastructure, financial resources, and coordination[8,9].

The World Health Organisation (WHO) define eHealth as the use of Information and Communication Technologies (ICT) for health and eHealth is recognised as one of the most rapidly growing areas in health today, transforming

the delivery of health services and systems across the world[10]. The European Union (EU) recognises that eHealth can benefit patients, health professionals and also health organisations and public authorities, facilitate socio-economic inclusion and equity and provide greater transparency through access to services and information[11]. At a national level, Ireland's digital health strategy published in 2013[6] states that eHealth is a critical enabler of best-practice health systems and care delivery[6]. eHealth is essential to improve efficiency, effectiveness and quality and safety of patient services[6]. The availability of timely and accurate information is key to the provider-patient relationship to result in improved outcomes[6]. eHealth involves the integration of all information and knowledge sources in the delivery of healthcare via technology-based systems[6] such as patient based registration systems and EHRs. The national Sláintecare Implementation Strategy and Action Plan (2021-2023) report, highlights the need for state funded investment in digital health solutions and EHRs, as key enablers for the health service reform and aiming to achieve a single tier health service for all[12]. Although health budget allocations have increased for digital health, there is a need for further investment to facilitate integrated EHRs as recommended under Sláintecare[12].

The development of the first national EHR in Ireland was one of the key recommendations from the Lourdes Inquiry in 2006, an inquiry into peripartum hysterectomies at Our Lady of Lourdes Hospital in Drogheda[13]. The recommendations in Judge Harding Clark's report included, among others, that an electronic system of data storage be implemented and that relevant staff receive training and education on computer skills and systems[13]. It was from here that the Maternal and Newborn - Clinical Management System (MN-CMS) was developed,

a single national record and repository of clinical data for women and their babies in the maternity services in Ireland.

1.2 Healthcare Data

The availability of standardised and structured data has the potential to greatly enhance patient care and patient outcomes[14]. EHRs, such as MN-CMS, can facilitate this data capture to provide up to date clinical information available at the patient's bedside for clinical decisions of care. Clinical healthcare data are at the core of all good work in the health services[14] contributing to health research for new treatments and care for patients[14]. Healthcare data can be used to inform audit and improve practices and with appropriate analytics has the potential to improve quality, safety and the cost effectiveness of care across the health service[14]. Healthcare data has the potential to contribute to dashboards and artificial intelligence (AI). AI based algorithms can often perform better than humans for characterisation and prognosis of disease in patients based on imaging and biomarkers from their EHR[15]. The advancement of the data science and AI field has been rapid in recent years due to a number of factors namely, a larger data collection of data libraries, increased computer processing speeds and a larger talent pool of AI engineers[15]. This could potentially provide a paradigm shift for healthcare and society[15].

1.3 Electronic Health Record Implementation

At an international level, no other country has achieved a fully interoperable national EHR within the community or acute care settings[9,16,17].

Although there have been many successful implementations of an EHR within a single hospital setting, health systems and health trusts within countries such the United States, United Kingdom, Denmark, Serbia, and Sweden from which we can draw immense knowledge, the key success of an implementation is multi-faceted. Most countries depend on a shared data platform of healthcare information, such as in Singapore where multiple clinical systems contribute to one national platform of standardised data[18].The process and framework of the implementation of an EHR in the hospital setting is varied and complex and is equally described as such in the literature[7]. Maguire and colleagues highlight the need for flexibility in the digital change transformation and treating the digital change more like a clinical change rather than an ICT Project has a positive effective on a successful large-scale implementation[7]. Fennelly and colleagues review EHR implementation under organisational factors, human factors and technological factors[9]. This systematic review by Fennelly et al, identified key organisational, human and technological factors for a successful EHR implementation. Each health system or hospital can vary based on size, structure and type of healthcare delivery however there are numerous identified factors which are relevant throughout the implementation process[9]. Organisational factors such as governance, leadership, culture, end-user involvement, training, support, resourcing and workflows are all essential in EHR implementation[9,19,20]. Many human factors have been identified in a successful implementation such as the skills and characteristics of those individuals involved, their perceived benefits and incentives and their perceived changes to the health ecosystem such as concerns regarding data privacy[9,19,20]. Additionally, many technological factors have been identified in an EHR success such as the EHR

usability, interoperability with other health care organisations, infrastructure (including the hardware, software and connectivity points), regulation standards and policies, adaptability of the software and comprehensive testing are all critical elements in a successful EHR implementation[9,20]. The optimal usability of an EHR in the clinical setting can support clinicians in achieving their goals in a safe and effective manner[21,22]. End-user clinician involvement in the EHR design is a critical step to success for the entire organisation to promote efficiency, productivity and satisfaction through appropriate workflow development at the outset of design [9,20,23]. In order to facilitate adoption of the EHR to the end-user workflows within the healthcare organisation, the actual software product needs to be flexible[7,24]. Fixed solutions should not be enforced on health care professionals[7,24]. For a successful adoption, flexibility and customisation are essential in meeting the needs of the end users in order to achieve the work practices of the organisation and at the same time being compliant with their workflows.

1.3.1 Importance of Workflows

Despite a myriad of factors involved in a successful EHR implementation as discussed above, this thesis focuses on the importance of workflows in this process. A key element to successful implementation identified in the literature is workflows and workflow development[9,25,26]. A workflow is a series of steps enacted to perform a certain clinical activity[26]. The concept of workflows is often undervalued in the implementation process but creating and adapting both the technology and work practices in workflow development, is a key factor is the implementation of the EHR[8]. More information is needed around the structure and

work processes involved in helping end users realise the benefits of a health information system[17].

The critical importance of workflows is alluded to in many reviews where the success of the EHR implementation is associated with the compatibility of the EHR system and the end-user workflow[19,23,24]. Large scale EHR implementations fail on workflows at the front line rather than because of failed technology[25] and an understanding, standardising and testing of workflows is recommended for a successful implementation[25]. In particular patient driven workflows need to be part of the system design rather than being process or task driven[9]. Workflows should fit the organisation and the end-users, be optimised as much as possible and that any disruption to end users should be kept to a minimum[9]. The end-users of hospital based EHRs are healthcare professionals. Healthcare professionals provide evidence-based medicine and care to patients[27]. In high acuity environments, they examine, diagnose, treat and prevent illness and injury[27]. EHR based workflows need to complement their work processes and tasks, and not hinder clinical care provision. There is a variety of literature published on the failure of workflows at the frontline which led to a failure of the EHR implementation as a whole in some organisations. Emergency Departments, for example, are identified as an area having an erratic workflow due to emergency presentations with intermittent computer interactions and a variety of medications timings[28]. Poor workflow development can also contribute to workflow fragmentation while attempting to complete a clinical task which increases end-user dissatisfaction with the EHR due to the task switching required[26]. An example of a fragmented workflow is a user logging off one

computer to log onto another to enable printing of laboratory specimen labels or discharge summaries or repeatedly logging into a computer due to short time-outs[26]. Patient orientated workflows include a number of clinicians interacting to provide patient care and the needs of the patient binds and choreographs the essential elements of the workflow[29]. These elements and actions need to be mapped out in a chronological manner with the specific clinicians to provide a process map of which steps are followed in which order to complete the clinical task in providing patient care and documenting that care in the EHR. The importance of workflows is highlighted as being the very foundation of EHR build and design[9]. Some literature highlights the adaption of workflows post go live in an attempt to facilitate adoption and enhance end user satisfaction[30,31]. Understanding workflow processes and designing workflows has therefore been highlighted as a key focus for this thesis.

1.3.2 Normalisation Process Theory and EHR Implementation

While acknowledging the variety of factors involved in an EHR Implementation such as those mentioned previously around human, organisational and technological factors, this thesis also focuses on the importance of a scientific framework around the implementation process itself. The scientific field of implementation science provides many theories, models and frameworks for various healthcare implementation projects. From hundreds of various frameworks identified in the literature, the Normalisation Process Theory (NPT), was identified from the literature for complex and technological changes (such as EHR implementation) which focus on organisational and behavioural changes [32–

[34]. The NPT was developed using sociology tools to understand and explain social processes through which new practices are enacted in the health care setting[35]. The NPT is particularly appropriate for EHR implementation as it has been described as a theory of *action* and has a starting point of looking at what people do and how they do it[35] and additionally addressing what is changing and for whom it is changing[36]. This is similar to EHR-based patient orientated workflows, where the process map is developed from the task/action each healthcare professional needs to undertake in order to complete the workflow. This thesis therefore focuses on the NPT as an appropriate framework for EHR implementation.

1.4 Research Environment

The implementation of the EHR in the Maternity Services in Ireland was a seminal moment in the digital maturity of the country. The MN-CMS pathfinder project is the design and implementation of an EHR for all women and babies in the maternity and gynecology services in the Republic of Ireland[37]. It is for this reason, the MN-CMS provided an optimum research environment for this thesis. The MN-CMS is a significant development in healthcare, the first electronic national system in maternity and newborn care anywhere in the world. The introduction of the MN-CMS is a necessary step in modernizing health care and aligns with the strategic goals of the Department of Health and the eHealth Ireland digital roadmap[6]. At an international level, this national EHR implementation is the first of its kind as no other country has achieved a fully interoperable national EHR within the community or acute care settings[9,16,17]. The MN-CMS includes all the relevant processes required including order communication, medications,

anesthesia, and theatre as well as all clinical documentation for maternity, newborn, and gynecology (See Figure 1.1). Laboratory orders are a closed loop of order communication from initial order placement to laboratory resulting and clinical endorsement and review of results. Medications are fully electronically prescribed with assisted decision support and electronic recording of administration. The MN-CMS has the potential to design the most cost-effective models of care and establish a national epidemiological database[38] which will inform national clinical care, audit, research and business intelligence.

With a national birth rate of 57,540 in 2022 [39], MN-CMS currently supports 40% of the births in Ireland, in 4 maternity hospitals/units, with a plan to implement to all 19 maternity units in the country [37]. The maternity units in Ireland vary in size, the smallest unit has about 1,000 deliveries per year and the largest unit has over 8,000- 9,500 deliveries[40,41]. The MN-CMS project is planned to roll out on a phased basis to all 19 maternity units in the country. Each phase of the project will include a specified number of maternity units/hospitals. *Phase One* of the MN-CMS project included 4 maternity units implementing the EHR.

Figure 1. 1: Connected elements of the MN-CMS project including Maternity, NICU, Medications and reporting.

The four hospitals included in Phase One were Cork University Maternity Hospital, University Hospital Kerry, The Rotunda Hospital and The National Maternity Hospital. The different phases of the implementation project will be discussed in Chapter 3.

Following completion of the phase one of the implementation project in 2018, the MN-CMS is currently live and in use in 4 Maternity hospitals/units. These 4 maternity hospitals encompass 40% of births in Ireland. Cork University Maternity Hospital (CUMH) is a tertiary hospital with approximately 7,000 births per year[42], and the only tri-located maternity hospital in the country. A tri-located maternity hospital has both specialist paediatrics and adult services on campus. The CUMH went live with the EHR in December 2016. University Hospital Kerry

(UHK) is a smaller maternity unit within a general hospital with approximately 1,200 births per year[42] went live in March 2017. Two further tertiary stand-alone maternity hospitals went live with the MN-CMS – the Rotunda Hospital with approximately 8,000 births per year[41] introduced the EHR in November 2017 and the National Maternity Hospital (NMH) with approximately 7,000 births per year[43] adopted the EHR in January 2018.

The MN-CMS will continue to be implemented to all maternity units in the country on a phased basis. Phase two of the project began in 2024 with the inclusion of The Coombe Women and Infants University Hospital (CWIUH), the fourth and final tertiary hospital, and University Maternity Hospital Limerick (UMHL). The completion of phase two will encompass approximately 60% of births on the MN-CMS EHR. The MN-CMS EHR provides a large repository of clinical information and generates multiple national reports. Access to these clinical data is controlled by a number of systems both nationally and locally. At a national level, access to clinical data and user reports is governed by the MN-CMS Information Governance Group (IGG). At CUMH and UHK, both hospitals in the Ireland South Women and Infant Directorate are governed by the Clinical Research Ethics Committee (CREC) and Social Research Ethics Committee (SREC) at University College Cork (UCC) and locally through the Local Information Governance Group (LIGG) for Ireland South Women and Infants Directorate. The Rotunda and NMH Hospitals are each governed by their own research ethics boards, the Rotunda Hospital Ethics Committee, and the National Maternity Hospital Research Ethics Committee. Access to all clinical data and user activity used in this thesis was

approved both nationally by MN-CMS IGG and locally by each LIGG/ethics committee for the relevant hospitals/groups.

1.4.1 Neonatal Intensive Care Unit

The Neonatal Intensive Care Unit (NICU) is a specialised area caring for preterm and sick newborns. In the field of medicine, neonatology is in fact a relatively new medical speciality, which has evolved rapidly over the last 50-60 years[44,45]. However, as far back at 1923, Dr J.W. Ballantyne predicted that

> *"The specialist in neonatal diseases and the nurse intensively trained and expert in the management of delicate newborns will be commonplace ere long"*[45].

It was in the 1920's in Coney Island, New York, that Dr Martin Couney displayed premature babies in incubators, charging viewers for entry and in turn saving many lives of preterm babies with adequate thermoregulation[45]. From here neonatology faced many challenging years of managing oxygenation, ventilation, and nutrition for preterm babies. World renowned musician, Stevie Wonder, was born six weeks premature in 1950, and lost his sight due to Retinopathy of Prematurity (ROP) most likely due to too much oxygen in the newborn period[46]. However, it was in 1963, when United States (US) President John F. Kennedy's son, Patrick, died following his preterm birth, that the specialist field of neonatology gained momentum. Born at approximately 34weeks gestation and weighting 2.1kgs it has been reported his cause of death was Hyaline Membrane Disease (HMD)[47] now commonly called Respiratory Distress Syndrome (RDS) due to surfactant deficiency. Following this high-profile premature newborn's death, research funding increased in the US and

the field of neonatology grew[45]. Neonatal intensive care has grown rapidly and has been very effective in reducing mortality and morbidity of newborns[44] through advances in ventilation, preterm formulae, parenteral nutritional and improvements in newborn developmental care. These changes in newborn care have resulted from research, audit and practice improvements which have all began with reviewing and analysing healthcare data leading to better outcomes for newborns. Today newborn healthcare data from around the world is compiled in the Vermont Oxford Network (VON) database, which provides a neutral and independent platform, in analysing and providing benchmarking data for centres to identify local opportunities to improve newborn care[48]. Likewise, in Ireland, newborn data is compiled by the National Perinatal Epidemiology Centre (NPEC) for reports such as the Very Low Birth Weight report[49] or the Therapeutic Hypothermia Report. Through such data analyses, key recommendations have been made to improve neonatal outcomes such as the recommendation that babies born before 28 weeks gestation in Ireland, should ideally be delivered in a maternity hospital with a tertiary neonatal unit for an better chance of survival without major morbidity[49].

The British Association of Perinatal Medicine (BAPM) have been reviewing standards for neonatal care for over 30 years and recommend that neonatal intensive care should only be provided in larger neonatal units[44]. The larger units with the highest levels of activity have better outcomes and smaller units are amalgamated into a network of support from the tertiary unit[44]. A tertiary neonatal unit should be staffed by a neonatologist at all times and have adequate neonatal nursing staffing ratios according to the BAPM guidelines[44].

The NICU is a particularly appropriate area to focus research on for EHR implementation firstly due to it being an emerging technological area of medicine with complex ventilation, observation methods such as continuous vital signs, electroencephalography, therapeutic hypothermia, and close nutritional management. As newborns have a EHR from birth, they generate extensive and high-dimensional data through their continuous monitoring[50]. With an EHR from birth, a newborn will have a complete picture of their clinical state [50] throughout their NICU journey and it is therefore essential this is represented accurately for the entire health care team to access and provide optimum care. For this reason, the focus of EHR implementation through workflow development and accurate data acquisition is essential for the most vulnerable population of neonates.

1.5 Methods

This thesis explored the implementation of an EHR, and the various factors that can influence a successful implementation. The author has a key role within the national project implementation team for the MN-CMS and had the opportunity to explore the implementation process first hand. The methods used for this thesis include primarily quantitative methods with some qualitative research in chapter 6 to fully capture the implementation process and factors that can influence a successful implementation primarily around patient centred workflows. The implementation of evidence-based practices in healthcare can be problematic and theories, models and frameworks from implementation science framed the research in this thesis for workflow development and overall EHR implementation. As the MN-CMS is continuing

to roll out into phase two in 2024, it was key for this research to identify important recommendations for the EHR implementation in the MN-CMS project and for the Irish Health Care System. As the author is the Neonatal Intensive Care Unit (NICU) workstream lead for the MN-CMS, the research in this thesis primarily focuses on the NICU and the NICU workflows however the findings and recommendations are generalisable to any EHR implementation. The author used various data collection and analysis methods including document reviews, background audit log files from the EHR and activity reports generated from the system for quantitative pre post assessments. Quantitative data were analysed using SPSS 27 and 28 using descriptive statistics, crosstabulation, pre/post mean differences and their 95% Confidence Intervals were calculated. Independent t-tests and Paired t-tests and Pearson's Chi-Square was used to calculate statistical significance. Poisson regression testing was also used with Stata software. Qualitative research was conducted with expert end users of the system and a focus group. Qualitative data were analysed using reflexive thematic analysis methods based on Braun and Clarke process[51,52] using manual coding and NVivo 14 software to assist. Despite a myriad of factors influencing EHR implementation, this author focused the research on workflows, measuring workflows, and the key role workflows play in a successful EHR implementation. A successful implementation, leading to user's workflow compliance, can help realise the benefits of EHRs in healthcare, including a core national database of standardised clinical data which has immense potential in improving healthcare delivery through audit, policy development and frontline clinical care. The entry of clinical data

through EHR use can transform these data to useful clinical information which can be used to inform clinicians of a patient's condition, therefore transforming information to knowledge. This, however, can only be realised if end user workflows have aligned with the clinical process and software development to ensure data are captured in an amenable way to frontline clinicians.

1.6 Summary

In summary, this thesis will outline EHR implementation in the Maternity services in Ireland, with a particular focus on NICU, and the importance of workflows, and workflow compliance to ensure data completeness and quality. Implementation Science provides a theoretical framework for implementation and the Normalisation Process Theory will be discussed in detail. This thesis will present a number of publications in relation to MN-CMS EHR implementation, implementation science, workflows, and workflow measurement. Adherence to workflows during clinical practice and utilising EHRs can enhance data entry and the information available across all members of the multidisciplinary team providing direct patient care. Accurate and up to date information available in a timely manner, can improve patient outcomes, and contribute greatly to audit, policy development, and improvements in patient care.

1.7 Thesis Outline

At the outset of this project, the author wanted to explore the implementation of an EHR focusing on workflows, workflow development and workflow measurement.

Chapter 2 identifies the important role implementation science plays in complex healthcare changes and in particular the NPT.

Chapter 3 is a publication of a document review of the phase one closure report from MN-CMS, a single national EHR for mothers and their babies in the Republic of Ireland. This publication highlights the key lessons learned at each stage of the project.

Through implementation science, this thesis then focuses on workflows in chapter 4 and the importance of workflows in everyday practice. The process of workflow mapping is outlined, and the actual workflow design is retrospectively assessed based on an implementation science framework to assess adherence to certain criteria. A new workflow is implemented using the AACTT framework.

The author then progressed to measuring compliance to certain workflows in two research studies. Chapter 5 details the quantitative measured workflows of doctors and nurses in the NICU in one hospital following an upgrade to the patient summary page. Improvements were observed in workflow compliance for both groups leading to more standardised and structured data being observed.

In chapter 6 the author engages key end users to improve the software design of one particular and critical workflow for newborn feeding. A pre-post quantitative measurement is conducted to assess the quality of documentation in

the EHR. Qualitative research is used to gain insight, opinions and perceptions of clinician end users.

A summation of the relevance of this research to the areas of practice, policy and research is presented to focus attention of the relevance of this research to each of these key areas in healthcare and to make some recommendations for further clinical practice, healthcare policy and research.

1.8 Aims and Objectives of each chapter

CHAPTER	TITLE	AIMS & OBJECTIVES
2	Implementation Science	This chapter explores the role of implementation science in complex healthcare changes such as EHR development and in particular explores the use of the NPT for evaluating successful implementation of an EHR.
3	Introduction of a Single Electronic Health Record for Maternity Units in Ireland: Outline of the Experiences of the Project Management Team	This chapter is a retrospective document review of the implementation of the MN-CMS based on the phase one closure report and identifies the key lessons learned at each stage of the project: planning, implementation, and optimisation phases.
4	Workflows	This chapter looks at assessing the role workflows play in the successful implementation of an EHR.
5	Impact of an Upgraded Patient Summary Page: Measuring Workflow Compliance in a Neonatal Electronic Health Record	This chapter measures workflow compliance for NICU doctors and nurses following an upgraded patient summary page.
6	Improving the quality of newborn feeding documentation in an electronic health record using a mixed method approach	This chapter assesses if an EHR user interface can be improved with user engagement to better facilitate input and management of healthcare data. Data quality is measured pre and post the changes.

Chapter 2

Implementation Science

Publication:

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Abstract and Poster Presentation:

Sheehan O, Bradfield L, McNabola G, Finch K, Kehoe B, Cleary B, Murphy B, McKernan J, Greene R. (2023). **Implementing a process to print medication infusion labels in neonatal intensive care units using implementation science**.

Presented at:

The 5th Joint European Neonatal Societies Conference (jENS). Rome, Italy. September 2023.

Chapter 2 – Implementation Science

2.1 Abstract

Background

Implementation Science is the study of methods to promote the uptake of an evidence-based practice into the everyday routine practice of healthcare clinicians.

Objectives

To explore useful theories, models, and frameworks focusing on the Normalisation Process Model, along with implementation strategies and outcomes, for use in the implementation of healthcare based EHRs.

Methods

The many theories, models and frameworks of implementation science were explored and their use in health care to implement an evidence-based practice. The theories, models and frameworks were categorised based on prominent literature. Implementation strategies and outcomes were outlined.

Results

Implementation Science and its use in maternity and neonatal healthcare is identified and in particular its benefits for EHR implementation. This chapter focused on one particular theory called the Normalisation Process Theory and its use in applying EHR implementation practice to be part of everyday practice. Finally, a new EHR workflow was implemented using the AACTT Framework.

Conclusion

This chapter summarises implementation science by outlining theories, models and frameworks, implementation strategies and implementation outcomes which can be used to implement new policy and practices in the healthcare setting. In particular, the Normalisation Process Theory is outlined, and a new EHR based workflow is implemented using the AACTT framework.

2.2 Introduction

This chapter aims to introduce the concept of implementation science and its use in healthcare and in particular Electronic Health Record (EHR) implementation. Firstly, implementation science will be broadly defined and its use in healthcare will be discussed. The theories, models and frameworks will be outlined, followed by implementation strategies and implementation outcomes. The use of implementation science in maternity and neonatal care will be explored and the use of implementation science guiding EHR implementations in complex healthcare settings will be discussed. Finally, one theory will be explored in detail and applied to EHR implementation and workflow development.

2.3 Implementation Science

Implementation science is defined as the scientific study of methods to promote the systemic uptake of evidence-based practice and research findings into everyday routine practice and thereby improving the quality and effectiveness of healthcare[53]. Implementation science has emerged primarily to advance evidence-based population health with aims to address the challenges of implementing research-based findings into healthcare practice and health policy across all health care spaces [54,55]. Early implementation science was empirically driven without any real theoretical frameworks[55]. The main goals of implementation science are to bridge the gap between theory and practice. There are as many as 100 terms to describe this knowledge translation into practice[56] such as Translational research, Dissemination and Implementation (D&I) research or most commonly Implementation Science. The core elements of implementation science are the

evidence-based practice or innovation/intervention to be implemented ("the thing"), the strategy used to implement it ("the how") and the implementation outcomes which are "how well" the people or organisation do "the thing". Implementation science in itself is the study of methods, to identify barriers and facilitators across multiple contexts and develop strategies to address these barriers and facilitators [55].

2.4 Theories, Models and Frameworks

Over the past 20 years, the use of structured theories, models and frameworks have emerged, and are being recognised in implementation science in order to facilitate implementation[55]. Nilsen (2015) provides a very useful taxonomy of Theories, Models and Frameworks (TMF) based on a narrative review of selective literature including books and prominent implementation science journals. The terms, theories, models and frameworks are often used interchangeably in implementations science [55] however Nilsen (2015) has categorised the TMFs into the following:

- Process Models
- Determinant Frameworks
- Classic Theories
- Implementation Frameworks
- Evaluation Frameworks

A process model will aim to describe or guide the process of translating research into practice by specifying steps or stages in the process[55]. Examples of process models are the Canadian Institute of Health Research (CHIR) Model of Knowledge

Translation[57], the Ottawa Model[58] and the Quality Implementation Framework[59]. A determinant framework will specify types of determinants (or domains) which act as barriers and facilitators that may affect the implementation outcomes[55]. Some determinant frameworks will also describe the relationship between determinants[55]. The overall aim of the determinant framework is to understand and explain what influences the implementation outcomes either prospectively or retrospectively[55]. The most frequently referenced[60] determinant framework in the literature is the Consolidated Framework for Implementation Research (CFIR)[61]. Classic theories are those which have originated external to implementation science such as those from psychology or sociology[55]. Classic theories such as the Theory of Diffusion[62] which is useful in identifying early adopters of change. Implementation theories are theories which have been developed by implementation scientists[55]. Implementation theories provide an understanding of aspects of the implementation and allow due recognition for the organisational context[55]. The Normalisation Process Theory (NPT) is a common example of implementation theories[32]. This framework is useful as it explains the normalisation of complex interventions to promote or inhibit the complex embedding of interventions[32] and has been used to frame the implementation of an EHR[32]. Finally, evaluation frameworks specify aspects of the implementation that could be evaluated in order to determine the success of the implementation[55]. Examples of such frameworks include the Reach, Effectiveness, Adoption, Implementation and Maintenance (RE-AIM) [63,64] or indeed the framework outlined by Proctor in evaluating implementation outcomes[65]. Having outlined the taxonomy of TMFs, the aim of using an appropriate TMF(s) are to (1) describe or

guide the process of research into practice, (2) understand or explain what influences outcomes and (3) to evaluate the implementation[55].

2.5 Implementation Strategies

Implementation strategies are the "how" we implement and are just as important as "what" we implement. An implementation strategy is defined as the methods or techniques used to enhance the adoption, implementation, sustainment and scale-up of a program, practice or change[66,67]. The implementation strategy is how we seek to get the evidence-based change into practice. There may be a discrete strategy (single action of process), or multi-faceted strategies (combining multiple actions) needed to achieve the project aims. Implementation strategies can be used to address contextual barriers or enablers during different phases of implementation and is a growing field of research in implementation science[68]. For example, training alone cannot be the only strategy used to implement a new policy or change to practice[69] particularly if an organisational level of poor culture is not addressed[69]. Utilisation of strategies should align with the barriers and facilitators identified in various stages throughout the project e.g., if leadership is needed, then the strategy needs to be identifying and preparing champions or if there are gaps in knowledge then training should be the strategy. There have been some important publications on strategies by Powell and colleagues in terms of collating Expert Recommendations for Implementation Change (ERIC)[68]. This publication of ERIC strategies clearly outlines the numerous strategies that can be utilised for implementation projects and is an important piece of research to standardise the terms and definitions for

strategies used in implementation science[68,70]. The ERIC strategies are extremely useful and the compilation of each of the 73 strategies are defined to aid in the implementation process[68]. The definition and categorisation of implementation strategies is essential to use in practice and research, and their definitions should be precise enough to enable measurement and reproducibility in research[67]. The work of the ERIC strategies was further developed to cluster the strategies based on their conceptual relationships- nine clusters of implementation strategies were developed[71]. The nine clusters of implementation strategies and examples of each are listed below[71]:

1. Use of evaluative and iterative strategies

   e.g. Identify barriers and facilitators

2. Adapt and tailor to context

   e.g. Tailor strategies

3. Train and educate stakeholders

   e.g. Conduct ongoing training

4. Engage consumers

   e.g. Involve consumers and family members

5. Change infrastructure

   e.g. Change physical structures

6. Provide iterative assistance

   e.g. Clinical supervision

7. Develop stakeholder interrelationships

e.g. Identify and prepare champions

8. Support clinicians

   e.g. Develop resource sharing

9. Use financial strategies

   e.g. Access new funding

Multiple strategies could be used from different clusters to support the implementation of an evidence- based change for example identifying barriers and facilitators, changing physical structures and access new funding could all be used based on the assessment needs of the project and the site its being introduced to. Recently, there has been further analysis of the ERIC strategies and the need to describe the actions involved with each strategy[72]. The concept of behavioural change techniques associated with ERIC strategies is being analysed and a taxonomy is being developed[72] focusing on the behaviours needed to apply a strategy. The ERIC strategies are continuously evolving based on frontline staff feedback to continue to be useful in healthcare.[73] The use of implementation strategies described in the literature for specific EHR implementation is limited however some studies identify barriers and facilitators to the EHR implementation process. Barriers include cost, technical concerns, technical support, resource constraints, insufficient training, and resistance to change[74,75]. Facilitating factors include leadership, governance, end-user involvement, training, support, adequate resourcing and appropriate workflows[9]. Recommendations include assessing how to deploy these factors in the local context of EHR implementation[9] as various factors may need to be tailored or adapted based on factors influencing each hospital site such as resources available or infrastructure concerns.

2.5.1 Tailoring Implementation Strategies

Implementation strategies should be individual to each implementation project and specifically chosen to overcome an identified barrier. Selection and tailoring of strategies are a collaborative process to select and modify implementation strategies in response to implementation determinants[70]. The research describes a range of theories, models and frameworks to guide the identification of implementation determinants, and the selection of appropriate strategies and different methods can be used as part of the tailoring process e.g. concept mapping and intervention mapping [70]. Specific evidence-based implementations and EHR implementations need specific strategies applied based on the specific site or facility as there is no "one size fits all" approach. The benefits of using implementation science are the adaptability of frameworks and the ability to use more than one framework, to tailor implementation strategies and use an iterative approach to implementation.

2.6 Implementation Outcomes

Implementation outcomes are the deliberate and purposeful actions to implement changes to treatments, practices or services[65]. Implementation science outcomes have been defined by Proctor and colleagues (2011) and include acceptability, adoption, appropriateness, feasibility, penetration, cost, sustainability, fidelity, and reach. Each of these can be used to evaluate the process and outcome of implementation[65]. The image below defines each of these outcomes (Figure 2.1).

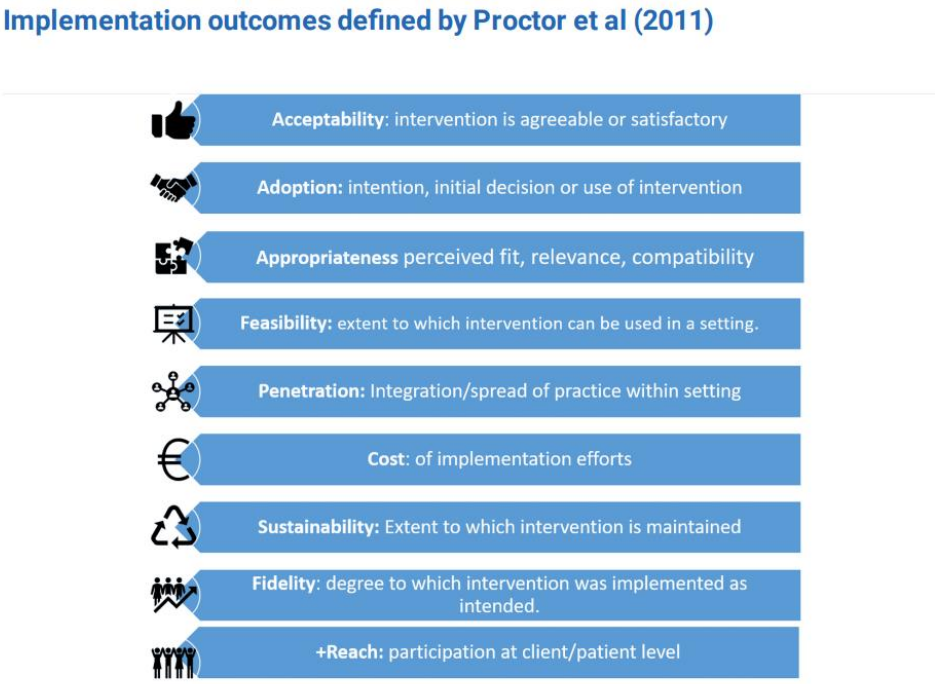


Figure 2. 1: Outcomes of Implementation Science

2.7 Utilisation of Implementation Science

Despite a myriad of TMFs used in healthcare in general, there is a significant gap for those used in maternity care[76]. Implementation science and the use of TMFs in maternity care literature is very limited with approximately only 8.9% of publications reviewed by Dadich and colleagues[76] reported the use of a TMF while 91.1% of studies reviewed focused on factors such as barriers and facilitators[76]. The use of implementation science-based theories is often not explicit in studies as finding a one-size-fits all approach is not feasible. Aligning evidence-based practice in healthcare can be challenging, largely because what clinicians do, how they do it, when they do it and who they do it too is shaped by myriad factors and processes[34]. To this end the use of implementation TMFs and strategies need to be customised based on the particular project. In an Irish context, for the

implementation of the National Bereavement Standards for pregnancy and perinatal loss, the authors develop an audit tool to identify the facilitators needed to successfully implement with an oversight led by various workstreams[77] however no explicit TMF is identified.

In Neonatal care research, publications are limited in terms of the use of implementation science to bridge the theory-practice gap. Coutts and colleagues use an implementation science framework to assess the barriers and facilitators in implementing Kangaroo Care in British Columbia Neonatal Intensive Care Units (NICU)[78]. These researchers conducted qualitative interviews and themed their outputs using the CFIR framework[61] and highlighted some barriers and facilitators to this practice introduction, namely organisational, individual and physical space factors. They concluded that although this is a evidenced- based practice to improve neonatal outcomes- there is no one-size fits all implementation plan, as each NICU has varying factors[78]. This is supported by many Implementation scientists that TMF's need to be adaptable as each implementation project is different but also other factors such as organisational, individuals, cultures etc. will vary across institutions and all need to be facilitated[56].

Similarly, Gephart and colleagues used implementation science methods to evaluate the feasibility and acceptability of introducing a Necrotising Enterocolitis (NEC) mentoring programme to provide specialist Tele Health advise to NICUs that would otherwise not have specialists[79]. These researchers used the integrated Promoting Action on Research Implementation in Health Services (i-PARIHS) framework and demonstrated that their approach was both feasible and acceptable to remote NICUs in the United States[79].

In terms of disruptive technology, Scantlebury and colleagues explored the benefits, barriers, and disadvantages of implementing an EHR into a maternity unit in the United Kingdom's National Health Service (NHS) context using the Normalisation Process Theory (NPT)[34]. The NPT has characterised a range of domains that assist healthcare professionals in understanding the purpose of (coherence), engage with (cognitive participation), use (collective action) and appraise (reflexive monitoring) of the EHR. This study highlighted some benefits, barriers and disadvantages which are transferable to other healthcare organisations such as previous failed implementations of EHRs, dual paper processes and lack of integration with other departments/systems[34] due to poor technology or poor workflow. They used the NPT to do a post hoc evaluation of EHR implementation[34].

Healthcare implementations are typically complex particularly when they consist of technological, organisational and behavioural change and often benefit from an overall process evaluation[32]. Process evaluation helps to understand not only the outcomes reached but the factors that promote and inhibit the intervention[32]. An effective implementation has been described as something that has been made workable and integrated into everyday healthcare[32]. The NPT was the focus of this thesis as it focuses in particular on the work required of stakeholders to embed and normalise an evidence-based change into routine practice[80] and was originally used to evaluate eHealth and telehealth interventions, however its use has now spread to other health-related and complex changes[81]. The use of the NPT has origins in sociology theorical frameworks but can be useful in complex healthcare interventions. May and

colleagues further explain that although the outcomes of the implementation are important, the social interactions and processes are equally important in achieving the outcomes[32]. The Normalisation Process Model (NPM) looks to describe, explain and predict[32]. The description typically explains the phenomena that inhibit or facilitate the implementation across social process in complex organisations[32]. These researchers further explain that a process can be broken down to 3 core elements of the Actor, the Object, and the Context[32]. For example, in an EHR Implementation the following could apply:

Table 2. 1: Core Elements of NPM and examples provided for this context.

Actor	Health Care Professionals
Object	Electronic Health Record
Context	Maternity Hospital

The explanation element of the theory related to the work of individuals as a collection of actions, actioned over time to achieving the outcomes of the implementation[32]. These researchers stress that, applied theories, are not simply ornamental but are tools that should be used to guide complex interventions such as electronic health records in the health care setting due to their complex nature[32]. The normalisation process theory is an excellent example of a process theory that can guide the work of individuals but cannot account for the diffusion and adoption[32]. Instead, this theory seeks to explain the embedding of complex healthcare interventions and the change becoming part of the everyday normal process of works[32]. The normalisation process theory, in conclusion, identifies, characterises and explains the key phenomena that both promote and inhibit the

implementation and embedding of complex interventions such as technologies and new health techniques[36]. The normalisation process theory provides a consistent framework that can be used to describe, assess and even enhance the implementation process [36].

2.8 The Normalisation Process Theory and Electronic Health Records

The NPT was developed and published as a seminal piece of work by Carl May and colleagues to provide a set of sociology tools to understand and explain the social processes through which new or modified practices are enacted or operationalised in the healthcare setting[35]. These researchers describe their theory as being different from other cultural transmission or innovation theories such as Rodgers' Theory of diffusion and explicitly call the NPT a theory of *action*[35]. They believe that to embed a practice into a healthcare setting, the starting point must look at what people actually do and how they work[35]. It is particularly appropriate for use in EHR implementations as it acknowledges that healthcare is a collective activity between professionals, patients, management organisations and requires a multitude of interactions[36] and this is particularly appropriate for EHR workflow development which will be discussed later in this thesis. A key strength of the NPT has been identified being its ability to identify how links between participants may be affected by the intervention and how that intervention could be modified to support the interactions[36] which is the key intricacies of EHR workflow development.

At a macro level the implementation of an EHR is a complex process with multiple factors to consider especially in the healthcare setting[8]. The NPT provides domains of work at the macro level to guide such a large-scale implementation[35]. The domains provided are Coherence, Cognitive Participation, Collective Action, and Reflexive monitoring. The table below summarises these domains and applies them to a large-scale implementation. Although these are described in a linear process, as with many implementation science TMFs, this is an iterative process that will require skipping steps and revisiting steps in the process.

Table 2. 2: Defines the Domains of Work of the NPT and applying the domains to an EHR implementation at a macro level.

Domain of Work	**Definition**	**Description**	**Example**
Coherence	Work that defines and organises the practice as a cognitive and behavioural ensemble[82]	Cognitive & behavioural layers of practice, appreciation and understanding of the practice as meaningful	The staff having an understanding of why the system is being implemented and includes their beliefs, behaviours and actions towards the EHR e.g. an understanding of the benefits or a perception of having the system forced on them without prior knowledeg[34,82].
Cognitive Participation	Embedding that defines and organises the actors/ participants implicated in a practice[82]	Routine embedding is dependent on actors and those factors that promote or inhibit participation	The health care professionals are engaged and committed to using the system and addressing the factors that promote and/or inhibit them from using the system. A willingness to invest time in the system e.g. training and support[34]
Collective Action	Work that defines and operationalises a practice[82]	Embedding is shaped on actors enacting it and work may need to reshape behaviours or actions[82]	The actual utilisation of the EHR by multiple individuals in a collective way and what factors promote/inhibit them from using it e.g. realising benefits of the system or negatively using a dual system with paper[34].
Reflexive Monitoring	Work that defines and organises the everyday understanding of a practice and is shaped by factors that promote or inhibit appraisal [82]	Appraisal and actors investing in it and understanding why	Have staff appraised the system and its impact on practice? E.g. identifying disadvantages (time consuming, technical issues) and advantages (timely access to information in one place)[34]

At a macro level the NPT is very useful in assisting the user to appreciate the multi-layered process in the everyday practice of applying the NPT to healthcare. At the micro level, the NPT ensures contextual integration, defined by skill-set workability with practices that are defined by their interactional workability and ensure relational integration[35]. As a starting point for a large-scale change, the first steps are to describe what is changing and for whom it's changing[36]. This is similar to a workflow assessment in terms of baseline EHR implementation. A framework should begin with a clinician designed workflow to address the flow of patient data[83]. At the micro level, an EHR implementation is the enactment of a series of workflows, in a concurrent manner across multiple health care providers, disciplines and settings. Addressing each workflow to the micro level can facilitate a successful implementation. The NPT can be used to address workflow development and workflow redesign. As a baseline, the NPT begins with the Coherence domain, that the actors will have an understanding and an appreciation of the practice as meaningful[35,36]. By involving specific healthcare practitioners to design their own workflows, there is a level of engagement and expertise into the overall aims of the practice and the process needed to achieve this[83]. The cognitive participation domain involves the actors commitment to a practice and addressing the barriers and facilitators that exist for the individual to undertake the practice[34,35]. The collective action domain involves the factors that inhibit or promote the actors enacting the practice such as using the system[34,35]. These could be related to software design, hardware issues, workflow problems, ICT literacy skills or system training. And finally, the reflective monitoring relates to

how well the actors/users have appraised the system and its impact on practice[34]. Implementation science can be an iterative process whereby re-evaluation is needed at various points in the implementation process throughout these domains[84].

The use of the NPT has been described in some complex implementations and these resonate clearly with implementing an EHR[36]; addressing items such as the intervention being easy to describe, being different from other interventions, involving participants who have a shared goal and purpose, identifying benefits for the participants, aligning with the overall organisational goals, what training is needed and how compatible is the change to normal work process[36]. Considerations such as - can the intervention be adapted or can participants provide feedback is equally important[36]. To this end the NPT is very appropriate for a complex intervention such as a hospital wide EHR implementation, using the key stages of the NPT – Coherence, cognitive participation, collective action, and reflective monitoring. Murray and colleagues provide an excellent example of defining the intervention at the implementation stage as being crucial e.g., for a software change - is the intervention the software change or the combination of the software change and the staff involved?[36]. The use of the NPT in complex healthcare changes is advisable because it considers and acknowledges the complexities of healthcare requiring multifaceted interactions between professionals, managers, patients, and others within the organisation[36]. The NPT allows for these interactions and any modification or supports that are needed throughout the process[36]. The NPT provides a framework for complex interventions in the healthcare settings[80] and has been used numerous times in

the literature to date to frame such complex interventions[85] used in both planning and development of interventions and also in evaluation and understanding of the implementation process[85].

2.9 Implementation science and an individual EHR workflow

As mentioned previously, an EHR implementation could be seen as a series of numerous workflow implementations. As a further enhancement of the NPT, which as discussed previously, focuses on the behavioural changes of an individual and is useful in assisting the user to appreciate the multi-layered processes in everyday practice on a large scale. The Action, Actor, Context, Target, and Time (AACTT) framework was also used in this research as a framework that requires detailed specifications of the behaviour targeted for change. The AACTT Framework was identified for use from the literature as it provides a practical tool for specific implementations, such as workflows, with the behaviour and actions of the actor specifically outlined in the correct context and time to achieve the target. The authors of the AACTT framework provide a very practical workflow example in their publication of using the AACTT to break down the steps of hand hygiene as a practical example of the AACTT in use[86]. The AACTT focuses on the person (actor) and what we want the person to do or to change[86]. The AACTT framework strives to design implementation interventions that will change behaviour of healthcare providers in the health care system[86] and ensures alignment between interventions and measured outcomes[86]. The utilisation of the AACTT framework was used in this thesis as an example of the implementation of a single new NICU workflow. The new workflow was to implement a process to

print medication infusion labels in the NICU using implementation science in one Level III NICU utilising the newborn EHR.

2.9.1 Background

The practice of ordering and recording the administration of complex Standard Concentrated Infusions (SCIs) is completed electronically in the Newborn's EHR. However, the process of labelling the syringe was a handwritten transcription process from the electronic order. Handwritten syringe infusion labels however, have been associated with infusion pump programming errors during a simulation study due to transcription errors[87]. Following software changes this project aimed to implement the printing of medication infusion labels directly from the newborn's EHR order and therefore avoid the handwritten labelling process. An implementation science framework was used to implement this evidence-based change.

2.9.2 Methods

The AACTT framework was used to implement this change into everyday clinical practice in the NICU setting. The AACTT workflow was particularly appropriate as it breaks down the necessary steps and identifies the areas for change which is similar to workflow development and adaption. The steps of the AACTT framework as applied to this project are displayed in Table 2.3 below.

Table 2. 3: The AACTT framework applied to implement a new workflow for printing medication infusion labels.

	AACTT Framework
A- Action	Print Syringe Infusion labels from the EHR Order
A- Actor	NICU Nurse
C- Context	Neonatal ICU Setting
T- Target	NICU patient with a new order for a Standard Concentrated Infusion
T- Time	After the order is placed and before preparing the infusion

2.9.3 Implementation

Following an assessment, a number of implementation strategies were identified and used to implement this new process. Training was required for all the actors involved in this workflow who were identified to be NICU Nurses, training materials were developed which included a paper based quick reference guides explaining the process in a step-by-step guide. Champions were identified as support during the process and included as trainers for the NICU Nurses. A key champion was the neonatal unit manager who supported the implementation and advised on the training plans and training times. A training plan was developed to ensure all training was delivered in a consist manner and all the required technology such as specific printers were procured and installed prior to the commencement of the change. The training plan was based on the steps outlined in the new workflow and the AACTT framework detailed in Table 2.3, identifying the action needing to be carried by the specific actor, in the correct context with an appropriate target and time. During the training of staff, it was quickly realised that some tailoring and adaption were required due to clinical demands. Therefore, the training schedule was adapted and more flexibility around timings

was introduced to best facilitate staff while they could still provide vital care to NICU patients.

2.9.4 Conclusion

The new process of printing SCI syringe labels was successfully implemented. Implementation science and in particular the AACTT framework as demonstrated in this research project is extremely useful in the acute healthcare setting. This study abstract was accepted at the Joint European Neonatal Societies Meeting (jENS) 2023 (Appendix 1) and presented as poster presentation (Appendix 2) on Sept 23rd, 2023.

2.10 Implications for Practice

The implications of using implementation science in clinical practice has been broadly outlined in this chapter with a specific focus on EHR implementation. The use of the NPT in large scale complex technological implementations has been valuable for practical learning[32–34] and in particular the AACTT has been very useful to implement a new workflow development in clinical practice. The use of one or more TMFs can be beneficial in implementing any evidence-based change to become part of everyday practice. The importance of using the appropriate ERIC strategies for implementation[68] and measuring outcomes can greatly enhance the evidenced based practice becoming part of everyday practice.

2.11 Implications for Policy

Although the use of implementation science and its relevance to policy has not been discussed in detail in this chapter, the use of implementation science is

valuable and can be used and embedded within a new policy or guideline for implementation. The field of implementation science and policy implementation have however evolved separately in recent times[88]. The role of policy in the implementation process is described as being under theorised[88] and often when included in policy structure, is used to identify contextual variables which are often not localised[61,89]. There has been some research into understanding and developing theories to bridge this gap and provide new frameworks to include researchers, policy-makers and implementers in better incorporating policy considerations for implementation efforts[88]. An implementation science framework can provide a structured pathway to achieve a successful implementation supported and embedded into a policy structure. The various TMFs can and should be modified or adapted based on the institute, the organisation or the evidenced based change being introduced supported by appropriate policy structure.

2.12 Implications for Research

The use of implementation science in research has great potential to guide research and the study of methods used to implement a practice[53]. Research can produce many new changes to practice and implementation science can promote the systematic uptake of these findings into clinical practice[53]. As research within the field of implementation science is evolving rapidly there is an extraordinary number of theories, models and frameworks being developed to suit various different practice changes and organisations[55]. The vast number of TMFs however can be overwhelming and difficult to navigate. Training would be beneficial to

familiarise oneself with the various categories of TMFs and find the most appropriate TMF(s) to use.

2.13 Conclusion

This chapter has summarised implementation science by outlining the taxonomy of TMFs and focusing in particular on the NPT. Implementation strategies and implementation outcomes which can be used to implement new policy and practices in the healthcare setting were explored. The use of implementation science in maternity and neonatal care specifically, was discussed using published work highlighting the explicit use and value of TMFs in these settings. The use of implementation science to guide and evaluate complex implementations such as EHR implementations was discussed and in particular the use of the NPT was appraised. The NPT is a theory of action and provides domains of work to guide complex interventions at the macro level of complex organisational EHR implementations and also at the micro level of workflow development to build the actions within EHR use in everyday practice. The NPT provides a useful framework to guide new complex practices becoming part of everyday practice. Finally, the use of the AACTT framework to implement a new workflow development related to EHR processes was outlined and the abstract and poster presentation included.

Published work on implementation science has been attached in Appendix 3 published in MIDIRS Midwifery Digest, Volume 33 Issue 2, June 2023[90].

Chapter 3

Introduction of a Single EHR for Maternity Units in Ireland

Publication (Appendix 4):

Sheehan OM, Greene RA, McKernan J, Murphy B, Cahill C, Cleary B, Lawlor F, Robson M. and MN-CMS National Project Team. Introduction of a Single Electronic Health Record for Maternity Units in Ireland: Outline of the Experiences of the Project Management Team. *JMIR Form Res*. 2023;7:e38938. doi:10.2196/38938

Link available here:

JMIR Formative Research - Introduction of a Single Electronic Health Record for Maternity Units in Ireland: Outline of the Experiences of the Project Management Team

Chapter 3- Introduction of a Single EHR for Maternity Units in Ireland

3.1 Abstract

Background

Electronic health records (EHRs) are being introduced worldwide. The change from paper to electronic records has not always been a seamless or quick process, however EHRs are viewed as central to updating modern health care especially organization structures and delivery of sustainable care with the potential for joint decision making with the patient.

Objective

The objective of this chapter is to outline how an EHR is being developed and implemented in Ireland. The focus is on the Maternal & Newborn Clinical Management System (MN-CMS) project which is the design and implementation of an EHR for all women and babies in the maternity services in the Republic of Ireland. This chapter aims to outline the lessons learned from the planning to optimisation stages of the project based on the Phase One Closure Report.

Methods

This chapter was developed following a document review of the project's final closure report after phase one and by discussions with the project management team.

Results

Key lessons learned from each stage of the project are highlighted.

Conclusion

This chapter explains how the national project management team are implementing the EHR and outlines the experiences and lessons learned and the challenges ahead following the phase one introduction. The MN-CMS is an example of a clinician led, patient focused, change management project from its inception to implementation. The introduction of EHRs is essential in modernizing healthcare and optimizing patient outcomes through accurate and appropriate use of data.

3.2 Introduction

Electronic health records (EHRs) are essential in attempting to update modern health care[2] and are being introduced worldwide across Europe, North America, Australasia and the Middle East[1]. The change from paper to electronic records has been described as complex[7] particularly in the hospital setting compared to private industry, due to the nature of the organizational setting that involves caring and curing, data security, confidentiality and data accuracy[8]. Many complex steps have been identified in the implementation of an EHR from procurement, design, building, testing, training through to adoption and optimisation[9]. A hospital wide EHR implementation needs to consider a number of organizational, human and technological factors as well as organizational structure, culture, technical infrastructure, financial resources, and coordination[8,9].

The need for digital information and connection has evolved in the last two decades[1] and in particular since the COVID19 Pandemic with a reliance on the digital world to connect. Over half the world's population (60.9%) use the internet and two thirds of the world's population (66.9%) have a mobile phone[91]. In Ireland, it is estimated that 3.68million (73.5% of the population) had a smartphone in 2021 with a projected 3.8million by 2024[92,93]. The delivery of safe and effective healthcare is dependent on the availability of accurate and up to date data in a legible, reliable and timely manner[5]. It is through the use of an EHR that health data can be available in the correct place at the correct time to enable timely clinical decision making.

3.2.1 Maternal & Newborn Clinical Management System

As mentioned in chapter 1, the introduction of the MN-CMS is on a phased basis across the country. Phase one of the implementation consisted of 4 maternity units. Prior to the introduction of the MN-CMS, the Information and Communication Technology (ICT) systems across the maternity units varies. Some units only use paper charts while other units have limited electronic systems. General Practitioners (GPs), who provide a shared-care model of ante natal care, in Ireland, use electronic medical records however their GP systems were not linked to the national hospital system. With the introduction of the MN-CMS, the pregnancy and birth records for pregnant women and their infants are now linked to the GP systems with MN-CMS through a messaging broker system called *Healthlink*. As with the development of all EHRs this project is a major change project not an ICT project; it involves multiple changes across all aspects of maternity services at individual level through to organization level. This project involves transitioning all maternity units over time to one single EHR in subsequent future phases of the project. Keeping the mother and baby at the center was the primary principle set out by the project board and it was envisioned that the MN-CMS would record practice and not decide practice[1].

3.2.2 Objective

The objective of this chapter is to outline how an EHR is being developed and implemented, and describe the key observations and lessons learned from the review of the project's phase one closure report and the national project team implementing the MN-CMS.

3.3 Methods

3.3.1 Overview

The methods used to develop these valuable outcomes were firstly through a document analysis of the MN-CMS phase one closure report, and by discussions with the project team. The phase one closure report was developed by the national project team through a series of "lessons learned workshops" which involved key stakeholders in each of the maternity units following each go-live event. The phase one closure report was published by the National Project Team in July 2018 and is not available online, however was accessed via the MN-CMS national team and is attached for reference in Appendix 5. Following each hospital's go-live, a lessons learned workshop was facilitated by the national project team with an approach of categorizing learnings through people, process, and technology. Each workshop had representation from key stakeholders from hospital management, project managers to end-users of the system. Clinicians including midwives, doctors, nurses, health and social care professionals, project managers all participated in interactive workshops which collated all feedback and lessons into the categories of people, process, or technology. From all this feedback, a phase one closure report was developed detailing the key lessons and experiences of the project team in implementing MN-CMS. This chapter is an analysis of that phase one closure report and details the different phases of the project from planning, implementation and optimisation which have been specified in the report. Through each phase some valuable lessons learned are

highlighted in the report and recommendations are generated for future phases of the project through consultation with the project team. These lessons from each project phase are presented in a similar format to Creswell's seminal piece of work on the evaluation of the UKs NHS Care Record Service[94].

This PhD candidate acknowledges that prior to any PhD research for this thesis, they assisted in Phase One of the MN-CMS project from 2015 until the finalization of phase one of the project in 2017 and the roles played are detailed below. This work was prior to the PhD being conceived in 2019.

- 2015: Employed as a NICU nurse educator at CUMH neonatal unit and part of my working role allocation was to contribute to the design and build of the system. I became a member of the NICU Workstream for the project.
- 2016: Employed as a NICU nurse educator at CUMH Neonatal Unit and part of my working role was assigned to testing of the system and providing some training to end users. At Go-live in CUMH in December 2016, I was a key support person for the go-live and supporting end users in the introduction of the EHR system.
- 2017 (February): Employed as a NICU nurse educator at CUMH Neonatal Unit and participated in the lessons learned workshop for CUMH as a key stakeholder.
- 2017 (July): Employment role change to MN-CMS Local System Administrator for CUMH. Contributed to the final Phase One Report as a reviewer and provided a site update for the report.

- 2018: Publication of the Phase One Closure report following the successful implementation of MN-CMS in the 4 phase one hospitals.

3.3.2 The Planning Phase

The origins of the project were the establishment of the MN-CMS project board whose aim were to establish a single record and a single source of truth for health-related data for all women and their babies in Ireland[1,38]. The board had oversight to procure and implement the EHR[38] and included stakeholders from the Institute of Obstetrics and Gynecology, the Faculty of Paediatrics, nursing and midwifery, pharmacists, representatives from the Department of Health and healthcare ICT[1,38]. Further stakeholders such as general practitioners and anesthetists were included as the project progressed. The establishment of the project board marked the beginning of a change-management project across the maternity services in the Republic of Ireland[1]. A patient representative was not included and should have been considered at this stage.

A needs assessment was developed to establish a design specification, and this was carried out by the project board members and senior healthcare managers[1,38]. The assessment was in consultation with the 19 maternity units in Ireland[38]. Following the design specification, the public procurement process commenced in 2011 with contracts signed in 2014[38]. The preferred vendor following public procurement was *Cerner*[1,38] (more recently acquired by Oracle and now referred to as *Oracle Cerner*). Finally, the MN-CMS team initiated the implementation program in 2014[38]. This procurement process was time consuming and strong

leadership was essential when planning and consolidating scope and in deciding on the preferred software vendor.

The MN-CMS national board had responsibility for ensuring a governance structure was in place[1,38]. This guaranteed a successful deployment of the EHR to the maternity service[1,38]. The deployment of phase one was with four units (two stand-alone units and two co-located units) from 2016 and will continue on a phased basis[38] based on the availability of public funding from the relevant government Departments[1,38]. A strong governance structure is a requirement for the success of a project.

Once the vendor had been appointed, numerous workstreams were established for each clinical area such as Maternity, Neonatal, Medications, Health and Social Care Professionals, order comms, clinical reporting, and research[38]. Representation was sought from each of the 19 maternity units in the country[38]. Each workstream developed multiple workflows based on their specific delivery of care such as the Maternity Booking Visit, return visits, admissions, labor and delivery, Elective and Emergency Caesarean Section, Stillbirth and Neonatal Death, Blood Transfusion, NICU admission and discharge[1,38]. One NICU workstream was established however in hindsight this should have been a NICU/ Newborn Workstream based on the patient rather than any one particular health care professional, as it led to different views and data entry for each health professional caring for well babies and NICU babies. A key to design and development was to sit down with multidisciplinary team experts and map out all current workflows; then design the new workflows with input from the system specialists. Adequate representation is essential for workflow development. Crossover of workstreams

is necessary e.g., NICU/Newborn leading to one baby chart design rather than different views for post-natal midwife and neonatal staff. Key lessons from the planning phase are outlined in Table 3.1.

Table 3. 1: Lessons learned from the planning phase of the MN-CMS implementation.

Planning Phase Lessons
• Patient representative at an early stage • Strong leadership needed for initial procurement • Strong governance structure required throughout the project • Involve the clinical teams and experts in workflow development

3.3.3 The Implementation Stage

The responsibility of the phase one implementation rested with the implementation team which was established in 2014[1,38]. This project team initially consisted of a small team with clinicians at the center of this team[1,38]. Overtime, the scale of the EHR implementation challenge highlighted that additional resources were required[38] and that clinical staff were instrumental in all elements of the project[38]. An adequately resourced project team is essential, and a realistic expectation of the commitment and responsibility expected should be clearly defined for those involved.

The previously mentioned clinical workstreams conducted the current state analysis working with the national project team and the vendor. This current state analysis mapped the current workflows of all the hospitals in the phase one sites[1,38]. This involved mapping the patient journey from the first referral to the hospital for care right thought to the discharge process following delivery for both

mother and baby[38]. Between the Maternity and NICU work streams approximately 54 workflows on average were mapped for each hospital[38]. This process required relevant clinical personnel familiar with their own area and delivery of care and a functional structure to achieve this. Figure 3.1 outlines this structure.

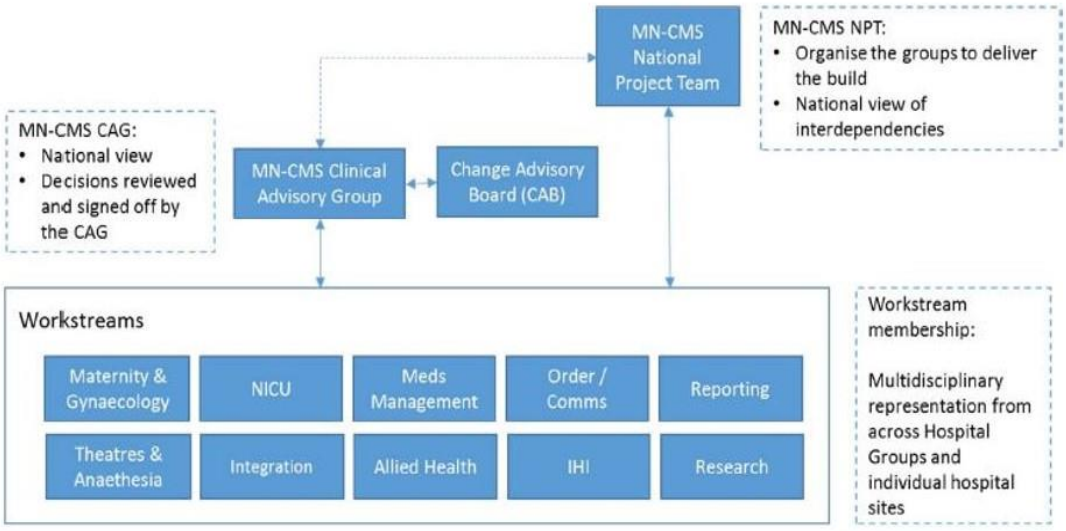


Figure 3. 1: Outline of the workstreams required for MN-CMS project.

The future state analysis was developed from the current state workflows[38]. This process transformed the patient journey into the new electronic environment of future state workflows that would be the foundation of design and build for the EHR[1,38]. The future state analysis is the key foundation for design and build of the system and gaining consensus across all sites is beneficial.

The design and build phase involved a collaborative approach across the national project team, the vendor and the workstreams[38]. This phase of the project was challenging due to the complexity involved in designing and configuring a comprehensive EHR[1,38], the workstreams had representatives from all 19 units. This complexity of this work was underestimated by all involved[38]. The

recommendations made were fed back to the national team and the vendor[38]. Inclusion from the broader workstream group is necessary to assist buy-in to the project. However, a smaller group, made up of clinicians and subject matter experts, made final decisions on the design and the vendor then completed the configuration and build[38].

The purpose of the Future State Validation was for the MN-CMS team and workstream members to present the system with the final design and build to those working in the Maternity Services[38]. It was an opportunity for attendees to gain an understanding of how it would work in their hospital by demonstrating various patient journeys and workflows[38] and allowed them get some hands-on experience of the system[1,38]. The future state validation needs to reach as many people as possible and champions from individual hospitals need to be engaged with the process.

In terms of changes to the system, there is a strict change control protocol in place since the completion of the design & build phase[1,38]. A requested change to the system may have significant knock-on effects to individual workflows or indeed individual units. To this end, weekly meetings are held to manage and review change requests by the Change Advisory Board (CAB)[38]. Requested changes to the system are assessed individually as one change for one unit may not be acceptable in another, all changes need to be agreed by all units and all workstreams affected before being implemented[38] in the live production environment, maintaining a national core. Changes are first implemented and tested in a test environment before progressing to production. A change control policy needs to be strict and adhered to, throughout the process. Impact on workflow and training needs to be

assessed with each change. A test or non-production environment is necessary to test the change prior to implementation in the live system.

The testing phase consisted of two phases- system and integration testing[38]. Test scripts were created, by clinicians, based on the clinical workflows and the various scenarios that might occur for both mother and baby[38]. The system testing phase involved testing the system against the workflows to ensure the design was functioning as expected[1,38]. Integration testing consisted of testing the systems with all other 3rd party systems (e.g., Patient Administration System (PAS) and Laboratory Information Systems (LIS))[38] . This testing was undertaken at each individual site based on different PAS and LIS systems and to validate their workflows[38]. Integration testing also included the testing of printers, wristbands and bar code scanners[38]. Device integration with the EHR for the neonatal vital signs monitors and ventilators and the fetal monitoring (Cardiotocograph monitoring) solution - FetaLink (FetaLink provides a graphical display of the relationship between fetal heart rates and contraction data in the EHR. It displays waveforms and annotations, which can be viewed in real-time by care providers in inpatient or outpatient settings[1] were all tested during this testing cycle[38]. These devices were tested using demo modes and simulations. The Downtime System Access Viewer (724) used to view the patient chart in the event of a planned or unplanned downtime also had to be tested at each site[38]. All Test Issues (TIs) were logged to an online portal accessed by the project team and vendor. Each TI was prioritized, fixed and re-tested and then closed by the clinical team of testers[1]. Testing takes time and a large team. The allocated team in this project was too small. The personnel involved in testing need to be subject experts and expert

users with on the ground clinical knowledge of the workflows and processes in each site.

The first steps prior to the deployment of MN-CMS were a Wi-Fi connectivity survey of each site and an assessment of the extra power points, data cables, and ports required for the new hardware was installed in each unit[38]. The additional infrastructure required to implement MN-CMS included computers on wheels, desktop computers, electronic whiteboards, printers, scanners, barcode readers[38]. The purchase of these items followed the national procurement process and was a multidisciplinary exercise involving ICT, Biomedical Engineers, End Users and Infection Control Teams[1,38]. Local ICT teams are essential and need to feel part of the project and issues arising need to be solved as a single local EHR team. On-going support by local ICT of hardware devices and connectivity is essential.

Approximately 2,500 staff benefited from training, across the four phase one sites[38]. Classroom based training consisted of one to three days duration depending on their system role[38]. Training course plans were prepared based on patient journey workflows, the train domain was populated and following a train the trainer program, training was provided to staff in each hospital by their peers[38]. These trainers initially provided intense training to a group of superusers (both trainers and superusers were an invaluable support for the early weeks of go-live to support colleagues in each clinical area[1,38]). The trainers localised their training plans for their specific hospitals and kept detailed training records to ensure that all staff attended training[38]. Logistic planning was essential to schedule the training and the backfilling in clinical areas as staff were released to train. Personnel need to be identified to deliver training and support to medical, midwifery, nursing,

other healthcare professionals and administration disciplines. These are vital roles, and some will be required after go-live. Providing a play domain (not available in this project) for staff post training would be beneficial – staff need to build their confidence through familiarisation and practice.

The go-live phase involved setting up of user accounts, deployment of passwords, data migration and the staffing of a twenty-four-hour, seven day a week command center to support staff over the go-live weekend and the post go-live early live support (ELS) period. Each go-live was supported on the ground by the members of the National Project Team, the vendor, team of engineers and solution specialists, project managers and staff from the other phase one sites[1,38]. Data migration began in the weeks coming up to go-live for all patients close to term (end of pregnancy) and for inpatients (women and babies) who were expected to remain for a period after go-live. If a woman delivered and was documented on paper before go-live, they remained on paper. Patients who attended in labor after the go-live time had delivery documentation on the EHR and completed their care on the EHR with appropriate agreed data documented including past history, allergies, medications and risk factors[1]. There was a 'wash through' period before all paper records were removed[1]. The go-live was a big bang, done over a weekend to allow a phased introduction of the EHR to inpatient care, then outpatient care after the weekend[1]. All ward managers should be trained as superusers, this ensures they can feel confident in supporting their ward staff over go-live. This was not achieved for our first go-live and the deficit was quickly recognized and corrected for future go-lives.

The go-live is the focus of the project from inception, it is the prize for the project team and the individual service. This is necessary to achieve the target worked on in the project. However, the local project team or an equivalent team of subject experts and expert users' needs to be in place before go-live and ready to carry on support and optimisation through training, assessment and development of workflows and associated documentation and identifying and getting fixes for identified risks in the new world of digital documentation. A clear transition team and a plan to assist with the adoption and optimisation of the new business model is needed before the go-live.

The implementation of electronic medicines management within an EHR offer the potential to streamline patient care and to engineer safe medication use processes[1]. Currently implemented within MN-CMS are Clinical Decision Support functionality including allergy checking, interaction checking, dose range checking, customized enterprise rules, weight-based dosing, prewritten order sentences and care plans[1,38]. Electronic prescribing has been demonstrated to promote safe and effective prescribing practices and to reduce the risk of errors[1,38]. The system facilitates clinical pharmacy services which have been demonstrated to improve patient outcomes and reduce the risk of serious patient harm[38]. The benefits of getting the medication management right will have implications for patient safety however it does need to be resourced adequately through funding and staff. Key lessons from the implementation stage are outlined in Table 3.2.

Table 3. 2: Lessons learned from the Implementation Phase

Implementation Stage Lessons
• Adequately resourced project team and clarity of the commitment needed is essential • Relevant clinical personnel to clearly outline workflows • The Future state analysis is the key foundation for the design and build • Design involves a wide team, but some final design decisions were made by a smaller group • The Future state validation needs to reach as many as possible to fully engage with the process • Strict change control process and approval is essential • Testing requires a large team of clinical users and subject matter experts • Local ICT involvement is essential • Peer trainers need to be engaged early and these vital roles are required post go-live in the support phase • All ward midwife/nurse managers should be trained as superusers ensuring they are confident to support their staff over the go-live period • A transition team is needed post go-live to assist with the adoption and optimization of the new business model • Medication management benefits can have positive implications for patient safety, but it does need to be resourced adequately

3.3.4 The Optimisation Phase

The medication management element of the EHR, was developed by the MN-CMS project team including clear order sentences with correct formulation dose[1]. Some medication errors were highlighted early post go-live as a key area that could be improved to enhance patient care. Enhancements such as the development of care plans, weight adjusted dosing among others led to safer prescribing[1]. The EHR allows enhanced assessment of medication error and while this takes resources and time and subsequent staff training, it is an essential element towards better patient safety.

The reductions in documentation time should allow for better records[1,38]. Staff can now avoid duplicating information (as they did on paper); an example is developing the baby chart transcribing information from the mother's chart – an instant transfer of agreed information saves time[1]. Easy access to records allows for all telephone consultations to be easily and clearly documented as part of the record[1,38]. On-going staff training is required to fully assist in the efficiency of their documentation[38].

In terms of data quality, routine data collection needs to be simple, clearly defined and an integral part of normal care and the responsibility of all healthcare staff[1,38]. The need for high quality and accurate data was recognized early in conjunction with European Union (EU) Directives[95]. Data quality personnel were put in place to check for data errors based on output reports[1,38]. Local information governance teams were set up to ensure the integrity of the data. The National Project team also has an Information Governance Group to deal with issues at a national basis for a single national system[1,38].

The MN-CMS now has the capability of producing clinical reports for audit, research, financial and management requirements. These reports have taken time to build and test, however they will be an invaluable data source in the future[1,38]. The reporting function has highlighted data quality issues related to poor data entry. Mitigation has been put in place; processes including the employment of data quality staff, daily data quality checks that highlight where issues arose from these checks, staff are then contacted and requested to complete the data they have omitted[1,38]. Based on normal care documentation, Ireland's maternity and neonatal service will have a high-quality database to assess the quality of that

care[1]. Demographic information for all patients will be easily accessible and data that would not have been available before will now be available[1]. Routine data collection needs to be simple, clearly defined and an integral part of normal care and the responsibility of all healthcare staff[1]. Detailed consideration to the data elements required in the planning and configuration is vital and proved valuable in this project. Ensuring staff know their responsibility for data quality when entering data needs to be part of their training. Data quality assessment is required and appropriate responses including identification of errors to staff, further training for staff and changes in configuration as required.

Patient involvement is necessary, and the project worked with the Women's Council of Ireland to develop women's focus groups to discuss the development of the EHR and take advice from patients[38]. One of the interesting lessons from this engagement was the belief that we had already digitized the care documentation – we were behind the public expectation. Patient access to their information was considered very important. MyHealthPortal will be a national online site designed for use by patients and their care givers[1,6,38]. Its purpose is to engage patients in self-care, joint decision making and empower them to take a more active role in their healthcare management[1,6,38]. This element of the MN-CMS project has not been set up to date. Prior to the EHR for the duration of their pregnancy women did have access to their paper medical charts. The MN-CMS board are committed to ensuring women have this access again[38]. This element is key as internationally, as there is an ambition towards providing Patient accessible EHRs (PAEHRs)[1,96,97]. There are, however, some limiting factors that include security and privacy concerns, legal constraints and low uptake of other online resources for patients[98].

Engagement with patient representatives early in the process is necessary. As go-live is approaching, inform patients during their visits of the expected changes and potential disruption as the hospital transitions to an electronic based record for their care.

MN-CMS trainers are an invaluable support to the local project teams and to the end users on the ground. Since go-live the four sites have engaged with their end users in optimisation sessions where new, advanced, and updated functionality has been taught. There is always on-going, or business as usual training of new staff and locum doctors being carried out throughout the year[38]. Keeping the initial trainers and superusers involved throughout the process will lead to them being champions and optimisation agents, in the future.

The MN-CMS has allowed clinical decisions support systems and educational links to be built into the system. These for example include visual color clues for abnormal values, the Irish Maternity Early Warning System (iMEWS), a sepsis alert algorithm and reference text from national guidelines. There is also education-oriented documentation including that for shoulder dystocia (Figure 3.2) and sepsis. The increased functionality of the EHR allows staff to fully engage with it and be assisted in the care they provide through built-in clinical decision support systems. Key lessons from the optimisation phase are outlined in Table 3.3.

Figure 3. 2: Example of educational documentation in MN-CMS; Shoulder dystocia.

Table 3. 3: Optimisation phase lessons learned

Optimization Phase Lessons
• Enhanced assessment of medication errors is essential towards adequate patient safety • On-going staff training required to fully assist documentation efficiency • Data Quality personnel need to be resourced early in the project and in post before go-live. A data strategy and framework need to be developed • For relevant reports- data entry requirements need to be planned and configured in advance. Ensure staff understand their responsibility is data accuracy and completeness • Engage with patient representatives through the go-live and informing them of potential disruptions • All trainers and superusers should be kept involved and fully utilized • Decision Support tools in the EHR assist staff in the care they provide

3.4 Discussion

Digital technologies have transformed private industries such as banking, finance, transportation, navigation, internet search, retail, and now EHRs may bring the same revolutionary change to healthcare[96]. Globally, however, the overall implementation of EHRs has not been as successful as anticipated and the benefits of EHRs have been slow to be realized[1]. It has been recognized that health information systems are needed but key events in recent years have highlighted the need for this even further[99]. Firstly, the global COVID-19 pandemic has accelerated the need for sharing of health data in the interest of public health[99] and secondly in Ireland the cyber security breach on the Irish Health Service Executive (HSE) in May 2021, underlined the need for trust in data information security and the protection of health data[99]. The data generated from a national EHR has the potential to save lives around the world[14]. The Goldacre Review in the United Kingdom's National Health Service (NHS) has identified that data stored on tens of millions of people could have a huge potential on improving patient outcomes and saving lives if it's used and analysed appropriately[14].

This paper has outlined the lesson learned in the Irish context for the development of the maternal and newborn EHR. The MN-CMS is an example of a clinician led, patient focused, change management project from its inception to implementation. The national project team maintained patient care at the core of the development and implementation of this EHR and have provided valuable lessons for future EHR implementations. The importance of clinical leadership was integral throughout the process from planning, implementation, and optimisation.

Additionally having the right people involved at the right stages of the project was essential. Challenges arose in terms of resourcing and often the same person was involved across multiple workstreams such as testing, training and change management[38]. The National Project team has since expanded and increased its resourcing since phase one. The key to on-going support and optimizing has been highlighted as essential to maintain the data quality and data input into the system. Regular data quality checks and on-going training is essential post go-live. The key recommendations are summarized in Table 3.4

Table 3. 4: Key summary of recommendations

Summary Recommendations
• Clinical leadership is essential throughout the project • Involving the right people at the right stages of the project e.g., Clinical staff needed for workflow development and ICT staff needed for hardware set-up. • Adequately resourced team for various stages e.g., clinical, medications, testing, training, support. • Strong governance structure and strict change control process • On-going support, training and optimization required • Data Quality surveillance and development of a data strategy and framework • Always keep the patient at the center of the project

Following the phase one implementation, the MN-CMS now encompasses 40% of all births in the Republic of Ireland[37] and provides the foundation of a national EHR[38]. The MN-CMS generates approximately 50 reports per day which guides both planning of care and epidemiological research and audit reporting. Reports generated include daily delivery lists, admission and discharge reports and reports for the General Register Office (GRO) to name but a few. The on-going deployment

of the MN-CMS is dependent on future funding and resourcing from the Irish Department of Health. Phase two has gained approval and will progress over the next two years incorporating all the tertiary centres in Irelands and 70% of births. Devin and colleagues assessed the impact of the introduction of MN-CMS in one tertiary site by measuring task distribution of Neonatal Intensive Care Staff[100]. This assessment concluded that the EHR introduction did not re-direct time away from direct patient care as other studies have reported[100]. Some EHR implementations have negatively redistributed time towards documentation and medication management and away from direct patient care[100]. The Irish Health Information Quality Authority (HIQA) propose that effective engagement (professional and public), technical and operational, legislative frameworks and governance structures are the cornerstone of informing policy on the collection, use and sharing of health data[99]. The MN-CMS has demonstrated these pillars in the EHR implementation.

The future of EHRs has an exciting future with new technologies such as vital signs to be automatically recorded into the chart, direct dictation to the record and even automated assistants that listen to the interactions between doctor and patient and from verbal cues record the information in the exam room[96]. Interactive patient portals will allow patients not only review their data (ensuring accuracy) but also input information prior to consultations and assist self-care as part of chronic disease management[1]. Following a public engagement in the Republic of Ireland, 82% of people want access to their own health information[101].

The volume of data contained in an EHR has significant potential to positively influence all of our lives if used correctly and adhering to all data protection and

legislation[1,14]. The potential to utilize data may be the greatest effect on healthcare and will come from data science using the information available in the EHR[1]. Data is the core of improvements in healthcare and with the correct and appropriate analysis improvements can be realized in quality, safety and cost-effectiveness of care across the entire health service[14]. The governance of data however is key to the continued success of the development of the EHR. Patients need to be informed of how their data is used, why it is used in a particular way and how it can improve care and conditions for themselves and others[1]. They also need to know their data is respected and entered correctly based on European General Data Protection Guidelines (GDPR) guidelines[95]. Academic institutions have realized the importance of health informatics and the importance of data retrieval, and they are now providing modules at undergraduate level to prepare medical professionals[102]. The Goldacre review recommend the introduction of trusted shared data platforms to rapidly capitalize on skills and data usage[14]. The introduction of new analysts, academics and innovators can provide well curated data and accessible technical documentation to improve patient outcomes[14]. The potential value of data science is well recognized in the ICT world; tech guru, Vinod Khosla, has suggested that "In the next 10 years data science will do more for medicine than all the biological sciences combined"[103]. It is likely that big data will assist us answer questions about the best care that would not be possible if we await randomized trial approaches[1]. Getting to this latter point in development requires significant work in the planning and development of the EHR, the change management to move from a paper environment, the need for ongoing training and optimisation to assist staff interaction with the system thereby enhancing the

data quality that will allow big data output to assist care. The change management process in moving to an EHR environment needs to be patient centred, clinician led, and ICT supported. Our experience shows some of the lessons we have learned.

3.5 Conclusion

This paper has outlined the implementation of a national EHR for mothers and babies in Ireland. The experiences and lessons learned from the national project team have been explored and summarized. Key recommendations are that clinical leadership and strong governance are essential as well as having an adequately resourced team. On-going training and optimisation are necessary, and data quality surveillance can lead to more accurate reporting from the system. The potential of accurate cumulative data from EHRs can have a positive influence on population health through appropriate analysis. Keeping the patient at the center of the project was always paramount. The MN-CMS has been successfully implemented into four maternity units in Ireland and encompasses 40% of births with a plan to expand further in the future.

Chapter 4

Workflows

Chapter 4- Workflows

4.1 Abstract

Background

Workflows are described as the nexus of all clinical activity and are a key organisational factor for a successful EHR implementation. A workflow consists of an orchestrated and repeatable pattern of activity, enabled by the systematic organisation of resources into process' that provide services or process information.

Objectives

The objectives of this chapter were to categorise the MN-CMS workflows, describe the transformation process from paper-based to EHR-based workflows and to assess certain neonatal based workflows for adherence to an implementation science framework.

Methods

The MN-CMS workflows will be reviewed and categorised by workstream speciality. The development of the MN-CMS workflows will be discussed. The AACTT framework will be used to retrospectively evaluate some NICU based workflows and to describe the creation of new EHR based workflows. Workflows were graded for their adherence to the AACTT framework. Workflows non-adherent to the framework were modified and a new workflow development is outlined in detail.

Results

The assessment of workflow adherence to the AACTT framework is a successful and useful tool. Equally the use of the AACTT framework is beneficial for new workflow developments.

Conclusion

The creation and adaption of workflows are essential in ensuring the appropriate design of the EHR as this is the thread which becomes the backbone of system testing, training, and leading to optimal reports from the system based on good data quality. The use of the AACTT framework has been a useful guide for workflow review and development.

4.2 Introduction

This chapter aims to highlight the importance of workflows and workflow mapping for Electronic Health Record (EHR) implementation. The importance of workflows will be highlighted and the particular workflows from the Maternal and Newborn Clinical Management System (MN-CMS) will be outlined. The process of workflow mapping will be detailed, and some NICU workflows will be retrospectively graded for adherence to a framework. and some particular workflows, which needed adaption post implementation will be highlighted. Finally, a new workflow development will be described in detail using a theoretical framework and implementation discussed.

4.3 Background Literature Review

A key organisational factor for a successful EHR implementation is workflow[2]. A workflow consists of an orchestrated and repeatable pattern of activity, enabled by the systematic organisation of resources into process' that transform materials, provide services, or process information[104]. In the healthcare setting, a clinical workflow e.g., admission or discharge process, is a series of steps enacted to perform a certain clinical activity[26] in order to preform and document certain aspects of patient care. A clinical workflow has been described as the nexus of all clinical activities[26]. The critical importance of workflows is alluded to in many reviews where the success of the EHR implementation is associated with the compatibility of the EHR system[23] and the end-user workflow[19,23,105]. Workflows are used as the foundation when moving from paper-based health records to EHRs and ensure that the software can support the recording of patient care.

Suboptimal workflows will eventually promote users working around the EHR[26] and drive dissatisfaction due to usability issues. Some EHR implementations can dramatically alter the task distribution, work process and efficiency of clinicians[106] due to poorly designed workflows. Numerous studies try to optimise workflow process' post go-live after the system is in use for some time with a number of inefficiencies being highlighted to correct the inefficiencies[30,31] and avoid the fragmented workflow processes leading to increased clinician burden[107]. Fragmented workflows are described by the frequency of task switching by clinicians during a workflow process[108] leading to inefficiencies. Clinical examples can be related to duplicated or complex data entry in the EHR, difficulty in finding information and indeed hardware issues such as printer availability or accessing a computer with the EHR software.

In the Republic of Ireland, the MN-CMS is a fully integrated national EHR for mothers and their newborns. The MN-CMS across four hospitals have approximately 1,600 unique users and generates a hive of activity with approximately 208,000 documents signed and over 5,000 diagnoses created monthly and over 125,000 medications administered per month. (Data generated from the background audit tool of the EHR system called Lights On Network (LON) for September 2023 activity).

The design and implementation process for MN-CMS was a collaborative approach with clinicians from various areas of maternity and newborn care coming together in an industry led way to design the future state of EHR work processes[109]. This process began with patient orientated workflow mapping. In a patient-oriented

workflow, the patient is the nucleus of the care episode[29]. Numerous workstreams were established with relevant stakeholders for each clinical area such as maternity, neonatal, medications, health and social care professionals, order communications, clinical reporting, and research[37,110]. Workstream membership included those key relevant stakeholders such as nurses, midwives, doctors, pharmacists, health and social care professionals, and administration staff. Each workstream developed multiple workflows based on their specific delivery of patient care such as the maternity booking visit, return visits, admissions, labour, and delivery, elective and emergency caesarean section, stillbirth and neonatal death, blood transfusion, neonatal intensive care unit (NICU) admission and discharge[110]. Workflow mapping of each healthcare journey is a complex process which aims to transform paper-based processes to the new EHR based work processes. The accuracy of this process, which will be described here, is a key step in the entire implementation as workflows are the foundations to the design, security access, testing and training of the system prior to actual clinical implementation.

4.4 MN-CMS Workflow review

At go-live in 2016, the MN-CMS team had created a total, of 117 workflows. The majority of workflows designed were around the women's health maternity and theatre related workflows with a total of 44 workflows. These workflows included delivery, booking, clinical handover and surgical scheduling and represented an individual process such as maternity or newborn admission, labour, delivery etc. These workflows formed the basis of the system with additional workflows

generated for various other workstreams and processes. The NICU Workstream developed an additional 17 workflows which included certain device integration workflows. Some workflows crossed over various workstreams e.g., Intravenous Line Care or Blood Transfusion. These "crossover" workflows are included in the Maternity count. The other workflows developed are listed in Table 4.1 below:

Table 4. 1: Workflow processes developed per Workstream prior to Go-Live

Workstream	**Number of workflows at Go-Live**
Maternity (including Theatre)	44
NICU (including device integration)	17
Gynae	1
Health and Social Care Professionals	10
Medication	21
Laboratory	11
Clinical Reporting	4
Clinical Research	9
Total	**117**

Workflow process mapping has been described in the literature involving healthcare but also involving industry[29,111]. Workflow evaluation and review in clinical practice is more frequently described in the healthcare literature and in particular in terms of workflow inefficiencies in the clinical setting[108,112]. Workflow mapping can also be described as process mapping particularly in business models[26]. Process maps and visual step-through of process, can be developed

using process maps[113]. Process maps are high-level depictions of the primary functional steps in the actual workflow[114]. In business models, process science combines knowledge from information technologies and management sciences, to run and improve operational processes (e.g., time or cost aspects) based on a model-driven perspective[115]. Healthcare is complex and EHR implementation in the healthcare setting is equally complex[7,8]. The MN-CMS team mission however describes the centrality of the patient to the design and workflow process[38]. The process mapping throughout the implementation[1,109,110] does have different objectives to business model objectives of cost and production efficiencies. MN-CMS also maintained a central role of clinicians throughout the process[1,110] and this is supported in the literature whereby workflow, usability, and patient safety can be enhanced through clinician-centred design of EHRs[114]. To describe and evaluate the workflow mapping of MN-CMS and fully incorporate relevant sciences, this researcher concluded that implementation science would be more useful as an evaluation model.

Implementation science, as described in chapter 2, is defined as the scientific study of methods to promote the systemic uptake of evidence-based practice and research findings into everyday routine practice and thereby improving the quality and effectiveness of healthcare[53]. Implementation science has a number of very useful theories, models, and frameworks to bring about change through implementing evidence-based care. For the purposes of this chapter, the researcher uses the AACTT Framework- The Actor, Action, Context, Target, and Time (AACTT). The AACTT framework was used in chapter 2 as a framework to implement a new workflow for NICU nurses printing medication infusion labels and

is particularly useful in workflows development and evaluation as it breaks down the necessary steps required to successfully execute a workflow.

4.5 Methodology

Firstly, the creation of the EHR based workflows are described from the paper-based processes and secondly, an evaluation of some of the NICU workflows are carried out. The AACTT framework was used in this chapter as being the most useful framework for workflow assessment. The AACTT framework focuses on the person (actor) and what we want the person to do or to change. AACTT strives to design implementation interventions that will change behaviour of healthcare providers in the health care system[86] and ensures alignment between interventions and measured outcomes[86]. The utilisation of the AACTT framework for workflow mapping is very appropriate and the specific steps are detailed in Table 4.2 below:

Table 4. 2: The AACTT Framework 1

	AACTT Framework
A- Action	Specify the behaviour that needs to change
A- Actor	Specify the person/clinician who needs to complete the action
C- Context	Specify the physical location or setting in which the action takes place
T- Target	Specify the person for whom the action is preformed
T- Time	Specify when the action is preformed

For the purpose of the workflow review in this chapter, the workflow will be graded using the AACTT framework and scored at either 0, 1, or 2 to determine if the workflow development was adherent to the framework. A score of:

0 = not adherent

1= partially adherent

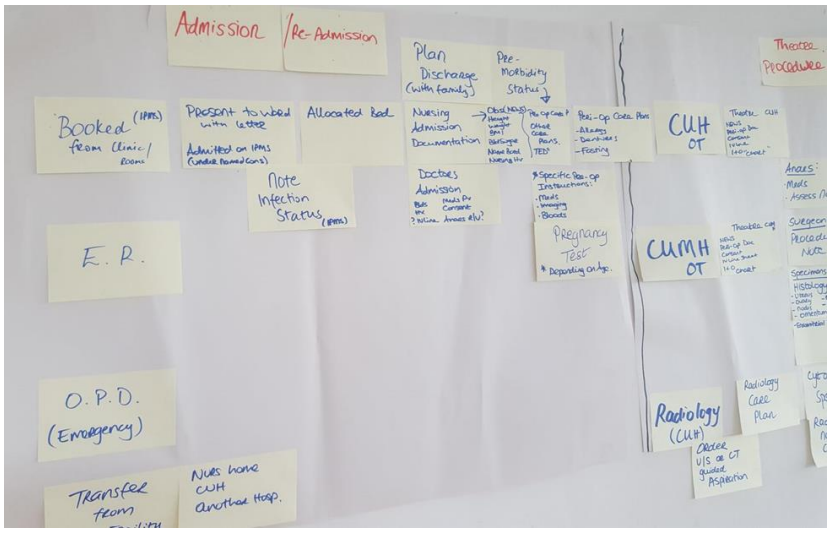
2= adherent

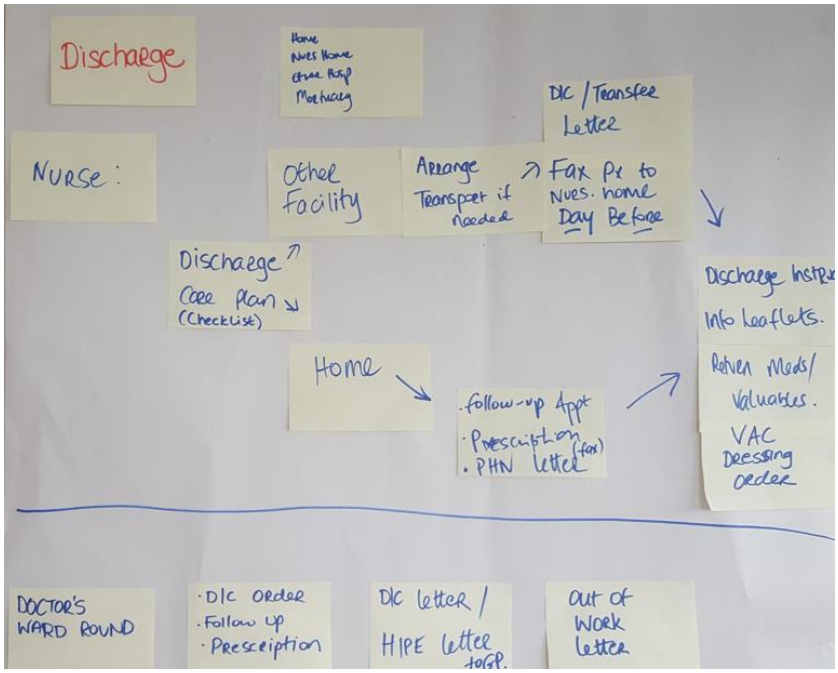
Where a workflow was not adherent, or partially adherent modifications to the workflow were implemented to improve compliance of the workflow.

4.5.1 Current State to Future State

The “current state” to “future state” is the process of moving a hospital from paper-based medical records to electronic, EHR based medical records by transforming their workflow processes. This is retrospectively described in this chapter and is important to document for health care as very limited evidence exists in the literature, most process mapping evidence arising from engineer practices. This transformative process begins with workflow mapping. Firstly, the current state (paper-based workflow processes) are documented and then these are transformed to electronic EHR based processes. A retrospective document analysis was undertaken for this transformative process for the multiple organisations. The visual process maps were designed using *swimlane* diagrams. In swimlane diagrams, each actor is assigned a lane, and the entire process is visualised from start to finish, showing what is done and by whom, in what sequence[29]. Firstly, to document the paper-based process, a visual walk-through was performed for each workflow e.g., admission. This involved engaging all

relevant actors in this process and stepping through the actions they take, in which context, at what time and in which order. Each action or step was documented on a sticky note and compiled in a process board for everyone to see. This could be easily changed or amended. An example of workflow mapping is provided in the images below:





Once agreed, these paper-based processes were designed on a software program called Microsoft Visio. Every scenario was covered in terms of the patient journey as much as was feasible. The current state review was intended to capture the paper-based patient flows to ensure continued care across this change process to an EHR. An example of this paper based current state workflow is shown is Appendix 6 as depicted from the Microsoft Visio software. This workflow was then transformed to the workflow of the EHR- based process that was needed to complete the admission process. This mapping allows for software designers to ensure the design elements were available in the chart, certain role-based access positions were available (e.g., NICU nurse, neonatologist) with the appropriate chart views and security privileges e.g., prescribing, ordering, or endorsing rights etc. The new workflow (appendix 7) depicts the EHR-based process for a neonatal admission which is role-based documentation tasks at a certain time to achieve the task of a complete admission and support delivery of patient care. This workflow is assessed below in table 4.3 and identifies that adherence to the AACTT framework was met in all categories. This workflow assessment essentially confirms that the workflow was designed and developed accounting for each of the domains in the AACTT framework: The action was clearly stated, the relevant actors were identified, the correct context was specified, the target of the process was identified, and the most appropriate timings were detailed in the correct sequence for each actor.

Table 4. 3: AACTT Framework to assess the NICU admission workflow.

	NICU Admission Workflow	Adherence
A- Action	Electronic documentation of admission to NICU	2
A- Actor	Doctor and NICU Nurse	2
C- Context	Neonatal Unit or Neonatal Intensive Care Unit	2
T- Target	The sick newborn needing admission	2
T- Time	At or soon after admission and stabilisation of newborn	2

To further support this workflow, checklists, or aide mémoire were developed later for users based on the correct workflow for nursing (appendix 8) and medical (appendix 9) staff. By users adhering to the correct workflow in the correct order, the EHR works for all users and will ensure data accuracy and data completeness which contributes greatly to data outputs for reports such as the Vermont Oxford Network (VON) reports. By ensuring and attaining a high level of quality data reports, the potential of EHR outputs can positively contribute to audit and quality improvement of care. Furthermore, the volume of data contained in an EHR has the potential to positively influence all our lives if used correctly and adhering to relevant data protection and legislation[1,14,110]. The value of workflow mapping is important and the order in which tasks can be performed and its resource allocation can be modified to improve clinical outcomes; clinical processes can be checked against recommended clinical guidelines to ensure adherence to best practices[115]. This process of workflow development for a neonatal unit admission is just one example of the 117 process and workflow developments undertaken during the design of the MN-CMS EHR.

Each workflow or clinical patient journey was then used as a basis for creating the testing scripts to test the software system. A test script is a set of instruction with expected results to test functionality of the software. Each test script was designed based on the workflow steps of the patient journey. Furthermore, training plans were developed from the workflows and the specific steps in the test scripts. End user training was based on an individual's role, actions within the EHR and interactions with the patient, over a continuum of time. To this end, workflows are the very foundation of the EHR, in terms of patient journey workflows, end user engagement with the system and ultimately data quality and completeness within the EHR.

4.6 Modifications of Future State Workflows

4.6.1 Apgar Scores

Although with every intention there is to capture each and every work and documentation process, there can be some areas that are overlooked. In the case of the neonatal workflows within MN-CMS, sometime after the successful go-live, it was observed that key newborn assessment scores were missing in a number of report outputs. The Appearance, Pulse, Grimace, Activity and Respirations score (APGAR) comprises of five components colour, heart rate, reflexes, muscle tone and respiration[116]. The Apgar score is a scoring system used to assess a newborn's health immediately after birth to determine the need for prompt intervention[116] and is as relevant today as it was when developed in 1953[116]. Data surveillance highlighted a gap in reporting of this key Apgar assessment scores for some

newborns in the period after go-live. A workflow analysis was therefore undertaken with the key actors (non-consultant hospital doctors (NCHDs) and midwives) and the context in which these data needed to be completed was explored. The Apgar scores (although belonging to the baby) were documented in the maternal record and copied to the baby chart. In the original workflow mapping, there were 2 scenarios identified of the well, healthy baby and the sick baby requiring admission to the Neonatal Unit. In the first scenario of the healthy baby, the midwife completed the assessment and documented the Apgar scores and in the second scenario, the sick baby who required NICU admission following resuscitation, the NCHD documented the Apgar score. Following go-live, however, there was a third scenario identified which was not identified until we were in the real-life scenario. The AACTT framework was applied to this workflow based on that scenario and assessed as below in table 4.4.

Table 4. 4: The AACTT framework assessment of the Apgar scoring before modification related to the actors involved.

	Newborn Apgar Score Documentation	Adherence
A- Action	Electronic documentation of Apgar Score	1
A- Actor	Doctor or Delivery Suite Midwife	1
C- Context	Labour Ward/ Delivery Suite	2
T- Target	The newborn details documented in the maternal record	1
T- Time	1 and 5 minutes after birth	1

This scenario involved the baby who needed initial paediatric care and assessment but then recovered sufficiently to return to routine care with their mother. It was this baby's Agar score that was not entered in a structured way by either the

midwife or the NCHD and left a number of newborns without any documented Apgar scores. Following this assessment, an adaption to the workflow was made and all actors involved had their actions modified to ensure a completed patient record was recorded. An educational memo was distributed to clearly outline the 3 scenarios and the actions needed by all involved (Appendix 10). This workflow adaption has improved the data completeness by addressing the actor required to make the change.

4.6.2 Neonatal Death Workflow

Another example of workflow changes needed post go-live of the EHR was around the process for documenting a neonatal death and the required date and time of death. This information is essential for report extracts to inform the Registrar of Births, Deaths, and Marriages of the National Civil Registration Service. Following a review of the workflow, after a baby was pronounced as deceased, the date and time of death was documented generally as a free text content in a medical note and was not extractable in a structured form. Following the report extract missing this key field, a new review of the workflow was undertaken. The workflow assessment based on the AACTT framework is displayed below in table 4.5:

Table 4. 5: The AACTT framework to assess the neonatal death workflow highlighting the target was the point of non-adherence to the workflow needing EHR modification.

	Neonatal Death Documentation	Adherence
A- Action	Structured documentation of Date and Time of Death	2
A- Actor	Consultant Neonatologist	2
C- Context	Neonatal Intensive Care Unit or Delivery Suite	2
T- Target	The newborn's HER	0
T- Time	After death has been pronounced	2

Following this a new additional documentation form was developed and implemented to capture the date and time of death in a structured way in order for it to be included in report extracts. Following the new change in workflow for the medical team, additional communications and training were put in place to ensure the relevant stakeholders were aware of the new work process.

4.7 New Workflow Development- Jaundice Treatment Graph

4.7.1 Jaundice Graphs

Following the successful implementation of the MN-CMS EHR in 4 hospitals from 2018, one vital element remained on paper due the lack of software build and that was the Neonatal Jaundice Treatment Graph. The software vendor was an American company who provided a neonatal jaundice graph based on the standards recommended by the American Academy of Paediatrics (AAP) which was the Bhutani nomogram[117] and a separate nomogram to determine the need for

phototherapy[118]. This, however, was not the gold standard used in Ireland and the United Kingdom for phototherapy treatment. The National Institute of Clinical Excellence (NICE) is the gold standard in Neonatal Jaundice Treatment thresholds and provide neonatal clinicians with a jaundice treatment graph based a specific gestation ages from 23weeks to >38weeks gestation[119]. Both the NICE graph and the AAP Bhutani graph also used different sample types for plotting; with a transcutaneous and a serum bilirubin level required for the AAP and a serum or point of care bilirubin level required for the NICE graph. Prior to this electronic implementation this graph was completed on paper with clinicians selecting the correct graph from printed supplies, transcribing patient details, time of birth, age in hours and then manually plotting the patient's bilirubin result onto the graph using the correct X and Y axis plotting (Appendix 11). This paper graph was only scanned into the patient's EHR when it was completed after 14 days of life and so was completely separate to their EHR record.

Neonatal jaundice is the most common condition needing medical attention in both term and preterm babies. Approximately 60% of term and 80% of preterm babies develop jaundice in the first week of life[119]. Jaundice refers to the yellow colouration of the skin and the whites of the eyes. Jaundice or hyperbilirubinemia is a condition where bilirubin accumulates, often due to the immaturity of the liver and the breakdown of fragile, immature red blood cells[119]. In most babies with jaundice there is no underlying disease, and this early jaundice is generally harmless. However, there are pathological causes of jaundice in the newborn, which, although rare, need to be detected[119]. To this end, neonatal jaundice

monitoring is critical is everyday care of newborns. Bilirubin levels from both point of care testing and serum laboratory levels are plotted against the appropriate gestational age graph correlating with the baby's age in hours. This graph can then determine the need for treatment. Treatment for jaundice is the use of phototherapy or light treatment to the exposed baby's skin for a number of days[119]. The following retrospectively details the implementation of the NICE jaundice graph into MN-CMS which occurred in 2019. This PhD candidate was employed as the NICU Workstream Lead and coordinated and facilitated the implementation- this is a retrospective review of that implementation and provides a workable example of workflow analysis through to successful implementation.

4.7.2 Aim

This new workflow was to implement a digital NICE Jaundice Treatment Graph fully integrated to the EHR, which would automatically select the correct graph based on gestational age and plot bilirubin levels directly from a third-party laboratory system to the EHR at the correct point in time, based on age and time of blood sampling. The digital graph could also display when phototherapy treatment was commenced and discontinued for a clear clinical picture.

4.7.3 Assessment needs prior to workflow design

Once the permission to reproduce the graph was received from Royal College of Obstetricians and Gynaecologists (RCOG) on behalf of the National Collaborating Centre for Women and Children's Health (NCC-WCH), the project

team convened the key persons with responsibility in the area. Key persons required for this project included the National NICU Workstream Lead, the National MN-CMS Order Communication (Laboratory) Workstream Lead, the vendor *Cerner* (now *Oracle Cerner*), a representative from each of the 4 hospitals Laboratory Information Systems (LIS) and neonatal subject matter expert from each of the 4 live sites.

4.7.4 Workflow Design

The initial steps included designing the clinical workflow that would be needed based on the key clinical staff accessing and using the graph in clinical practice (Appendix 12). Each workflow step was processed and stepped through ensuring all clinical scenarios were included. The AACTT framework[86] was useful to retrospectively identify the relevant actions needed by actors in the correct context, target and time (Table 4.6) and is graded accordingly for this workflow . Through the accurate workflow design- all clinical scenarios were identified and designed into the software build for the new graph with the correct views and access to the graph. The importance of the workflow design, then played a key role and formed the basis for testing and training. Test scripts were developed based on the workflow process to replicate the clinical scenarios and training plans were developed.

Table 4. 6: AACTT Framework for NICE Jaundice graph workflow including all relevant actors, in the correct context and adherence assessment.

	NICE Jaundice Treatment Graph Workflow	Adherence
A- Action	Launching the graph, ensuring key triggers such as Gestation Age and Date/Time of Birth are recorded in the HER	2
A- Actor	Nurse, Midwife, Doctor	2
C- Context	Post-natal ward and NICU	2
T- Target	All newborns requiring assessment	2
T- Time	From 0-14 days of life	2

4.7.5 Testing

The testing was completed by clinical staff with a neonatal background and medical scientists with a knowledge of LISs and interfacing. The graph was initially built in the non-PROD domain for testing. Each graph required a gestational age entered of between 23 and 38 weeks (16 different graphs to trigger the correct treatment threshold recommendations). Each gestational age graph was tested and compared to the gold standard on the NICE graph available from their website. Following verification of the treatment line thresholds, bilirubin results were added to the test patient's records and plotting was tested. Bilirubin results were entered from 2 sources- the point of care value entered directly into the patient EHR and a serum bilirubin level which was resulted from a LIS system in each of the four live sites which comprised of 4 different third-party LISs. Any test issues arising were fixed prior to deployment to the live production domain. One significant challenge encountered during the testing phase was the Unit of

Measure (UOM) of the Bilirubin. Again, as the EHR vendor was a US based company the UOM was mg/dL and the European graph deployed was worked on a UOM in µmols/L. To fix the issue a universal database change was made across the system to reflect the UOM used in Europe and on the new digital NICE Jaundice Graph.

4.7.6 Implementation Strategies

Prior to deployment a series of on-line demonstrations were provided to clinical staff in the 4 neonatal units live and a champion was identified in each site to continue the training and knowledge transfer. Training materials were developed as a support to training and reference tool. While clinical staff would always have known how to use the graph on paper, the key points on the digital graph were highlighted.

4.7.7 Go Live

The NICE Jaundice treatment graph was implemented in 2019 during day-time hours with no downtime experiences. Historical data for patients existing were uploaded seamlessly and all babies in neonatal units and post-natal wards had a digital jaundice treatment graph for clinicians to make treatment decisions for the vulnerable population. The NICE jaundice graph is shown in appendix 13. The graph is a dynamically loaded page and works based off the time of birth, a yellow line displays for “now” which is the time the page is loaded. It displays both, point of care and, serum bilirubin samples very clearly with a textual rendition of

recommended treatment e.g., none, phototherapy, or exchange transfusion. The graph also displays indicators when phototherapy treatment has started and discontinued based on data being entered in the EHR.

4.7.8 Outcomes

The implementation of the NICE jaundice graph was successful and has achieved a number of implementation science-based outcomes of success such as acceptability, feasibility, and sustainment. To date this is a vital part of neonatal daily workflows with an average of 550-page loads per day providing clinicians with up-to-date clinical information and the elimination of paper graphing. The graph is used routinely by staff caring for newborn babies which shows that it is acceptable, appropriate and is showing adoption of the workflow by staff. The fidelity of the project and new workflow has also been maintained as the new workflow was implemented as intended based on the NICE guidelines[119].

4.8 Results

The assessment of workflow adherence to the AACTT framework is a successful and useful tool. In the case of the admission workflow all elements were met however two other workflow examples presented were not met. The Apgar workflow and the neonatal death workflow highlighted issues with the actor and the target respectively (Table 4.7). Once the sticky point can be identified and rectified, the workflow process should flow. In these cases, those elements were corrected, and the workflow was adherent to the framework following adaptation.

Table 4. 7: Workflow reviews and results of adherence to the framework.

Workflow Name	Action	Actor	Context	Target	Time	Workflow Issue
NICU Admission	2	2	2	2	2	None
Apgars	1	1	2	1	1	Primarily actor with a ripple effect on others
Neonatal Death	2	2	2	0	2	Target
NICE Jaundice Graph	2	2	2	2	2	None

4.9 Discussion

This chapter has described the process of workflow mapping in the healthcare settings and the steps needed to ensure adherence to workflow development. The introduction of EHRs in healthcare can introduce significant changes to clinical work processes and workflows[120]. The creation and adaption of EHR workflows, therefore, are essential in ensuring the appropriate design of the EHR. Workflows are systems that help organise, specify, execute and coordinate the flow of work[121]. Workflows are the thread which becomes the backbone of system testing, training, and leading to optimal reports from the system based on good data quality[110]. The process of adequate workflow creation has been detailed here involving the relevant stakeholders. Workflow patterns are sensitive to any changes which necessitates precise and detailed workflow mapping for a successful EHR implementation[23,121]. Ensuring the workflows are feasible and acceptable to users can encourage the EHR becoming part of the everyday practice rather than an extra burden[26]. Workflow analysis was conducted in this chapter

and in particular, the adherence of workflows to a framework from implementation science. The design of workflows involves the relevant stakeholders, performing tasks in sequential order to achieve a desired outcome[26]. The AACTT framework[86] was chosen as being the most relevant tool. Utilising the AACTT framework, the admission workflow was evaluated as being adherent to the framework incorporating all the key contexts to be enacted in clinical practice. Two workflows needed amendments due to non-adherence or partial adherence in order to incorporate the relevant contexts. Finally, a new workflow development was retrospectively reviewed using the AACTT framework and the detailed implementation was described. The implementation of the new workflow, the NICE jaundice graph, incorporated all relevant components of the framework and provided the basis for the design, test, train and implement phases. The new workflow introduction of the jaundice graph worked well from the outset as each category of the AACTT framework was adhered to in the workflow development. Learnings from the previous workflow adaptions were key to the development. Ensuring the actors had a clear coherence of the actions needed in the correct target, context and time contributed to a successful implementation. To fully achieve a workable EHR, systems needs to ensure clinical, environment and workflows of individuals and multidisciplinary teams are fully considered[122]. The integration of the NICE jaundice treatment graph within the EHR is somewhat unique as many institutions will simply link out to a separate wed-based system[123] and so is rare to have achieved this in the MN-CMS. Equally the continuous evaluation and adaptation of workflows when necessary is essential. The end goal of correct and appropriate workflows is that users have a straightforward process

of patient data entry within the database which firstly, will provide bed-side clinicians with up-to-date clinical information and secondly, will provide outputs and extracts for data analyses[26]. Data capture and recording needs to be accurate for the patient[95] and relatively straight forward for the user. Structured data entry is useful in terms of chart review, having available up to date information on which to base clinical decision making and guide care decision. Standardised data can be used for informing audit and population-based health information such policy guidance. The importance of a strict change control policy is important for any system and needs to include a workflow impact assessment for any change[110]. The importance of appropriate clinical workflows is essential to avoid workarounds[26] and further workflow developments and workflow measurements will be discussed in subsequent chapters and publications. The focus will be around the evaluation of NICU daily care and ward rounds where workflows are quantitatively measured and very specific newborn feeding data entry, its accuracy and review of information will be assessed.

4.10 Conclusion

This chapter has demonstrated the importance of accurate workflow mapping to achieve the desired goal and outcome of the workflow. An outline of the importance of workflows has been highlighted and the need to avoid workarounds or fragmentation. The AACTT framework was beneficial to underpin the workflow development in a theoretical framework and grade the workflow adherence to the framework. The workflow process mapping has been outlined and some examples

of workflow adaption have been detailed based on their adherence to the AACTT framework. A new workflow development was retrospectively outlined. Appropriately designed workflows can underpin the EHR system and encourage appropriate and accurate data entry, which can be used to assess patient care and inform audit.

Chapter 5

Impact of an Upgraded Patient Summary Page: Measuring Workflow Compliance in a Neonatal Electronic Health Record

Publication (Appendix 14):

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Poster Presentations:

Sheehan O, Greene RA, Corcoran P, McKernan J, and Murphy B. ***Workflow Impact of the redesign of a Neonate Summary Page: A before and after comparison of a neonatal electronic health record.***

Presented at

1) The National Perinatal Epidemiology Centre (NPEC) Study Day, January 2023. Dublin, Ireland

2) Bright Futures Research Day, April 2023. College of Medicine and Health, University College Cork, Cork, Ireland.

3) 5th Joint European Neonatal Societies Conference (jENS), September 2023, Rome, Italy.

Chapter 5- Impact of an Upgraded Patient Summary Page: Measuring Workflow Compliance in a Neonatal Electronic Health Record

5.1 Abstract

Introduction The implementation of Electronic Health Records (EHRs) is a necessary step in modernising healthcare and enhancing the availability of patient data for healthcare providers. However, direct data acquisition from clinicians remains one of the largest obstacles in EHR optimisation. Workflow measurement is essential in assessing clinical workflow compliance and data entry into EHRs.

Aim This quantitative, descriptive study measured workflow compliance using pre- and post-measurements within a national EHR following an upgraded patient summary page.

Methods This study extracted data from the EHR software audit log files to measure workflow compliance for Neonatal Non-Consultant Hospital Doctors (n=29) from two independent samples and for NICU Nurses (n=76) using one sample, looking at timings related to keystrokes and mouse movements. Data were analysed using means and standard deviations. Mean differences and their 95% Confidence Interval were calculated and their statistical significance were calculated based on p values derived from paired t-tests for the NICU Nursing data and Independent t-tests for the NCHD data.

Results NCHDs displayed an increase in problem and diagnoses entries in the post phase compared to the pre phase, Problems increased by 317%, with a mean change of +5.2 (CI -7.9-18.4), Diagnoses increased by 47% with a mean change of +8.8 (CI-17.9-35.4) and Problems Reviewed increased by 250%, with a mean change of +4.9 (CI -9.1-18.9). Nursing documentation had some improvements in the post phase compared to the pre phase with more structured iView documentation increasing by 1.1% (CI 0.1-2.0%) and less clinical notes use which reduced by -0.7% (CI -1.2- -0.3%). Nurses had a significant reduction of EHR time per patient of 1 minute & 14 seconds.

Discussion This study has contributed positively to quantitatively assessing workflow within the EHR. The redesigned neonate patient summary page had some positive impact on workflow and EHR utilisation however more training would be beneficial. Workflows of both the nursing group and the medical group are inextricably linked together in an interdependent way.

5.2 Introduction

Healthcare can generate huge volumes of data daily[5]. The delivery of safe and effective healthcare can depend on the availability of accurate and up-to-date data in a legible, reliable, and timely manner[5,6]. The entry of structured data using discrete data fields not only standardizes data entry for direct patient care but also has potential advantages for secondary analysis and epidemiology research[125]. However, direct data acquisition from clinicians remains one of the largest obstacles to optimizing the Electronic Health Record (EHR)[125]. This article aims to describe a quantitative study that measured workflow compliance following an upgraded patient summary page in a national neonatal EHR using pre- and post-measurements of key users of the neonatal EHR.

5.3 Workflows

EHR implementation in the hospital setting can be complex[7,8]. However, it is a necessary part of modernizing healthcare and enhancing the availability of patient data for health care providers and promoting health equity[3]. The inability of an EHR system to meet the workflows of end-users and organizations is often cited as negatively impacting its success[19,24]. A clinical workflow is a series of steps enacted to perform a certain clinical activity, such as inpatient admissions to a health care facility[26]. In the clinical setting, workflows can be complex and multi-faceted with numerous interdependencies of various healthcare teams[26]. Creating and adapting both the technology and work practices in workflow development, is a key factor in implementing an EHR[8] and there is a need for flexibility in digital change transformation[7]. Suboptimal workflows will eventually promote users working

around the EHR[26] and drive EHR dissatisfaction due to usability issues[22,26]. Workflow measurement is essential in assessing compliance. Zheng and colleagues recommend measuring workflows by breaking them down to various tasks and using time-in-motion studies or audit logs[26]. Time-in-motion studies can be labor-intensive and subject to individual bias[26]. Whereas EHR system audit logs are useful for measuring various workflow activities objectively[26] and have been successfully validated and used in previous studies[126–129]. The Maternal and Newborn Clinical Management System (MN-CMS) is a national EHR for mothers and newborns in the Republic of Ireland. Recently, the neonatal EHR upgraded the patient summary page to upgrade the software and optimize the clinical information available to users. Software upgrades are necessary as they allow for new and improved functionality and/or fix any known bugs within the software[130]. To demonstrate the user interface change, the old and new patient summary EHR views are included in Appendix 15 and 16.

The new page was designed to view structured patient data in a summary format. Digital healthcare transformation to EHRs has been slow in the Republic of Ireland compared to the United States. There is typically an overreliance on free-text clinical notes rather than structured data entry such as problems, diagnoses, procedures, and orders from medical staff primarily. Furthermore, this impacts the nursing workflow with an overreliance on reviewing the medical free-text notes for plans of care. The new summary page was designed using an iterative action research approach described by Murphy and colleagues[109] to encourage a revised review, communication, and recording workflow. The purpose of this new patient summary page was to bring clinical information together, to improve the reviewing

and communication across disciplines without going further into silos of information to access data for care decisions. The purpose of this study was to measure workflow compliance using key workflow tasks based on these steps: Review (charts open, review times, endorsing results), Communicate (orders placed, problems, diagnoses and procedures entered) and Record (documentation type and times, number of documents signed).

5.4 Aim

This quantitative, descriptive study measured workflow compliance using pre- and post-measurements within a national EHR.

5.5 Method

The study population was neonatal users from one large tertiary hospital (approx. 7,000 births/year) with a level III Neonatal Intensive Care Unit (NICU) included: NICU nurses (n=76) and neonatal Non-Consultant Hospital Doctors (NCHDs) (n=29). Due to the routine NCHD rotation and change-over of personnel, NCHD data were collated from two independent samples of NCHDs, one before and one after the upgrade. The data were gathered one month prior to the implemented change and one month after the change. This study extracted data from software audit log files. These files included timing data related to keystrokes and mouse movements from all EHR users. This data report captured a user's activity based on categories structures, such as chart review times, documentation times, orders, problems and diagnosis, medication administration, and general timing in the EHR. These are defined in Table 5.1.

Table 5. 1: Definition of EHR Functions and categories as described by the log files.

Note: This provides explanations of the log file outputs for each user. This was adapted from Overhage and McCallie[128]

Chart Review	Review clinical results, observations, and notes in the EHR broken down by using different areas of the chart e.g., Mpage, document viewer, flowsheets
Documentation	Recording documentation and creating notes
iView	Interactive view - contains various data points related to patient care, observations in a structured and organized way
Powerform	Structured form of data entry at patient level e.g., admission form
Powernote	Structured form of medical note with paragraphs containing history, physical examination, plan of care.
Clinical Note	Free text note
Macro	Predefined entry selection for PowerNote at paragraph level e.g., well baby physical exam
Orders	Writing orders includes various categories e.g., patient care, diet, consults, referrals
PowerPlan	Group of patient orders e.g., care orders, medications, laboratory etc.
Problems and diagnoses	Reviewing and updating the patient's problem list
Other	Non-categorized EHR times from specific activities or categories of activities that are too small to uniquely represent
Care Compass	Multi Patient Organizer with patient summary and tasks
Medication Administration	Documentation of Medications Administered

An example of the audit log files for one month of a single user for both the pre and post phase are displayed in Figures 5.1 and 5.2, where the distribution of EHR time is displayed in percentages.

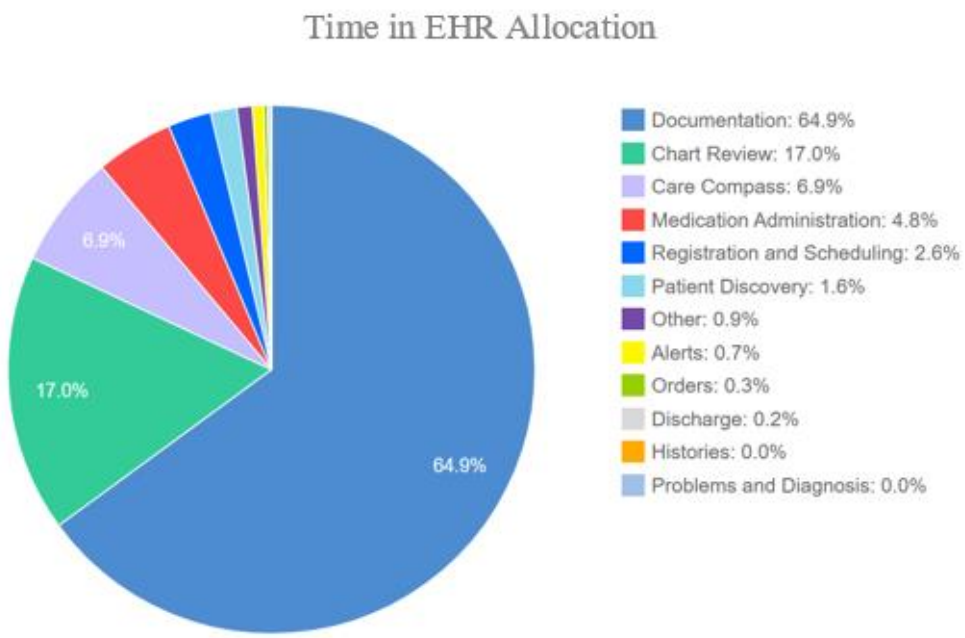

Figure 5. 1: Example of the audit log for one user for one month during the pre-measurement phase; displaying a breakdown of time distribution in the EHR described in percentages.

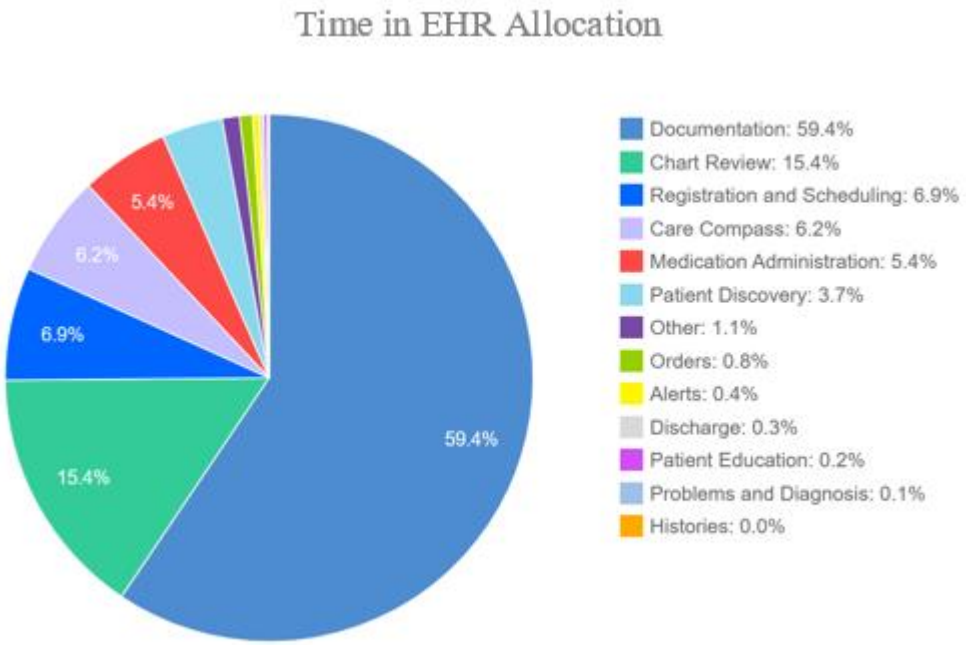

Figure 5. 2: Example of the audit log for one month during the post-measurement phase.

5.6 Data Analysis

All data with participant identifiers were removed and imported to IBM SPSS 27 for analysis[131]. Each metric, for both groups, was described using means and standard deviations. Mean differences and their 95% Confidence Intervals were calculated, and their statistical significance was assessed based on p values derived from paired t-tests for the NICU nurse data and independent t-tests for the NCHD data. Independent t-tests were used for the NCHD group because they were two independent samples pre and post rotation changeover. The significant p-value was set at 0.05 (5%) meaning a p-value <0.05 was a statistically significant result. Some specific metrics such as entry of procedures, problems, diagnoses, and orders were also reviewed in total numbers and directly compared to hospital activity such as birth rates and neonatal unit occupancy. The workflows being

examined were the routine daily medical patient review tasks (such as documentation, placing orders) and the daily nursing care workflows. Data points varied by discipline due to the difference in end-use workflow practices. Nursing workflows focus on documentation, medication administration and some specific orders. Medical team workflows focus on entering problems, diagnoses, procedures, placing orders and documenting medical notes. The workflows were subdivided into reviewing, communication, and recording for each group.

- *Review* data points being measured for this study consisted of documentation review and flowsheet review, charts opened, and endorsing results.
- *Communicate* data points were identified as those structured entries that would enhance communication across the multi-disciplinary team, such as orders placed, problems, diagnoses and procedures entered.
- *Recording* data points consisted of documentation methods, structured and free text documentation.

These data points are listed in Figure 5.5. Some data points were gathered by running specific reports against the database, such as procedures entry and results endorsement. A pre- and post-comparison was conducted between each value for each user.

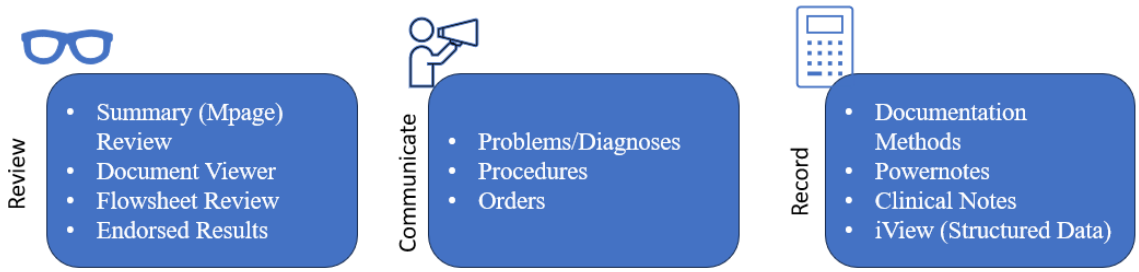

Figure 5. 3: Workflow Evaluation points

5.7 Results

The NCHD group had a reduction in the number of charts opened with a mean reduction of 301 charts (CI -552.4- 51.1, p= 0.019) and the number of documents signed showed a mean reduction of 101 documents (CI -192.6- -10.0, p= 0.031). However, this group did display an increase in problems created by +317% with a mean change of +5.2 (CI -7.9-18.4, p= 0.426). Problems reviewed increased by +250%, with a mean change of +4.9 (CI -9.1- 18.9, p= 0.484), albeit from low baseline levels, and there was a large increase in the number of diagnoses created by +47% which was a men increase of 8.8 (CI -17.9- 35.4, p= 0.510). The total orders placed showed a mean reduction of 21.7 orders (CI -48.9- 5.6, p= 0.117) which was a 36.8% reduction; this was a larger reduction than the activity reduction and so does not support an improvement in this data entry. Endorsing laboratory results from either an inbox or pool was consistently well managed in the pre- and post-phase. The NCHD results are presented in Table 5.2.

Table 5. 2: NCHD Pre and Post

					95% Confidence Interval of the Difference		
	Pre-Mean	Post Mean	Mean Change	(% Change)	Lower	Upper	p value
Review							
Charts Open	965.5	663.8	-301.7	-31.3	-552.4	-51.1	0.019
Communicate							
Total Orders Placed	58.9	37.2	-21.7	-36.8	-48.9	5.6	0.117
Powerplans Selected	15.5	10.2	-5.3	-34.2	-12.2	1.7	0.132
Orders – Consults	4.3	2.8	-1.5	-35.8	-3.8	0.8	0.182
Orders- Referrals	6.8	3.3	-3.4	-50.8	-7.3	0.4	0.080
Orders- Diet	0	0.2	0.2		-0.1	0.4	0.161
Orders- Patient Care	5.4	2.8	-2.5	-46.9	-4.7	-0.3	0.025
Procedures Documented	0.3	0.3	0.0	-6.7	-0.5	0.5	0.936
Problems Created	1.7	6.9	5.2	317	-7.9	18.4	0.426
Diagnoses Created	18.7	27.5	8.8	47	-17.9	35.4	0.510
Problems Reviewed	2.0	6.8	4.9	250.8	-9.1	18.9	0.484
Record							
Documents Signed	302.3	201.0	-101.3	-33.5	-192.6	-10.0	0.031
Clinical Notes Signed	5.4	3.5	-1.9	-34.8	-5.5	1.8	0.305
Powernotes Signed	237.8	142.9	-94.9	-39.9	-167.3	-22.5	0.011
Macros Used	46.7	29.2	-17.5	-37.5	-41.7	6.8	0.151
Average Documentation Time (Secs)	359.0	435.2	76.2	21.2	-23.9	176.2	0.131
Total Clicks per Note	963.4	1029.3	65.9	6.8	-132.6	264.5	0.505

The NICU nursing group spent most of their time in the EHR documenting, with little variance in the pre- and post-measurements (see results in Table 5.3). Documentation methods had some reportable changes in the post phase with more structured (iView) documentation with a mean increase of 1.1% (CI 0.1-2.0%, p=0.024) and less free-text clinical notes use which reduce by 0.7% (CI -1.2- -0.3%, p=0.003) which would be consistent with the workflow compliance for this group.

Table 5. 3: NICU Nurse Pre and Post

				95% Confidence Interval of the Difference		
	Pre-Mean	Post Mean	Mean Change	Lower	Upper	p value
Review						
Chart Review	18.1%	18.4%	0.3%	-1.1%	1.7%	0.648
Chart Review Mpage	54.9%	55.3%	0.4%	-2.4%	3.1%	0.785
Chart Review Documents	35.2%	32.9%	-2.3%	-5.5%	0.9%	0.155
Chart Review Flowsheets	6.7%	6.5%	-0.2%	-1.4%	1.1%	0.811
Chart Review Clinical Notes	1.3%	1.3%	-0.1%	-0.6%	0.5%	0.850
Chart Review Other	1.8%	2.3%	0.5%	-0.1%	1.1%	0.131
Care Compass	4.1%	4.5%	0.4%	-0.2%	1.0%	0.195
Communicate						
Consults	0.2	0.2	0.0	-0.2	0.2	0.885
Diet Orders	0.2	0.2	-0.1	-0.1	0.0	0.208
Patient Care Orders	0.3	0.2	-0.1	-0.1	0.0	0.251
Record						
Documentation	63.2%	61.6%	-1.6%	-3.5%	0.3%	0.095
Documentation – iView	96.3%	97.3%	1.1%	0.1%	2.0%	0.024
Documentation - Clinical Notes	1.5%	0.8%	-0.7%	-1.2%	-0.3%	0.003
Documentation- Powerforms	2.1%	1.8%	-0.4%	-1.1%	0.4%	0.299
Documentation- Other	0.1%	0.1%	0.0%	-0.1%	0.2%	0.722

Medication Administration	6.4%	6.7%	0.3%	-0.5%	1.0%	0.490
Secondary Analysis						
Time in EHR per Patient (mins/secs)	13:22	12:08	-01:14	-02:24	-00:04	0.037
Time in EHR per Shift (hr/mins/secs)	01:19:05	01:03:53	-00:15:11	-00:18:25	-00:11:57	<0.001
Clicks per Patient	266.3	249.2	-17.0	-34.9	0.8	0.061

NICU Nurses spent 18% of their time in the chart review measurement category, which had minimal variance in the pre-, and post-measurements displaying and post phase increase of 0.3% (CI -1.1- 1.7%, p= 0.648). However, they had 17 fewer clicks per patient (CI -34.9- 0.8, p= 0.061). There was no change in nurses placing orders and this data point remained consistent, displaying no improvement. A secondary analysis found statistically significant time reductions for nursing time in the EHR with a time saving of 1 minute and 14 seconds per patient (CI -02:24- -00:04, p=0.037).

5.8 Discussion

Few studies from the literature have studied both nursing and medical workflows together[132]. This study has examined both and it is apparent from this study that the workflows of the nursing group and medical group were inextricably linked together in an interdependent way. The workflow measurement following this upgrade has shown some increase in problems and diagnoses entry by senior NCHDs which is cautiously reported as this was not displayed consistently throughout this group as senior registrars entered these data more than junior doctors, so they were not statistically significant and displayed wide confidence intervals. There have been suggestions that the use of the diagnoses entry should have specialized physician training[133]. Furthermore, a lack of face-to-face clinical discussion of the patient's diagnoses can lead to more fragmented data entry in the EHR[133]. Documenting such relevant data points to the patient's EHR can ensure an overall review would be easier and more consistent for all multidisciplinary users to gain an updated status on a patient's condition. The reduced

documentation by doctors may be due to an overall reduced activity in the post-measurement phase with birth rates reduced by 45 births (7.2%) and neonatal unit occupancy reduced by 19.6%. The pre phase had a neonatal unit average occupancy of 35.8 inpatient babies per day and the post phase had 28.8 inpatient babies per day which is a reduction of 7 inpatients babies on average per day in the post phase. With less patients, there can be less documentation notes to enter into the EHR. The reduced post-period order entry was not consistent with the facility's reduced activity, however. The ordering process such as fluid and diet orders are still not entered in a structured format and could be reflective of the different health systems between Ireland and the United States- based EHR vendor. The benefits of using orders and order sets creates an opportunity for enhancing awareness for the unique health care needs of an individualized patient and can provide an opportunity for greater collaboration between different health care providers across the multidisciplinary team[134].

This study has demonstrated that the majority of beneficial findings were among NICU nurses. Nursing documentation in the post phase improved with statistically significant increase in structured documentation and reduction in free text note writing. The nursing group also had a significant reduction of time in the EHR per patient. This reduced time in EHR was measured per patient and so was independent of the reduced activity and occupancy in the facility. Reduced nursing documentation time using EHRs may possibly be associated with more time being directed to clinical care[135] and thus highlighting the significant benefit of this nursing time saving following the introduction of this upgrade. Nursing data entry into EHR systems is essential in planning care[136] and therefore, the usability of EHR

systems is a key factor for nurses[132,137,138]. Poor EHR usability has been associated with adverse nursing outcomes such as burnout[137,138] and poor patient outcomes such as mortality and readmission[137]. Furthermore, excess EHR screen time can lead to emotional distress, physician burnout, reduced patient contact and may contribute to increased medical errors[139,140]. It is essential that EHR design aims to maximize the clinician's time spend interacting with and providing care to their patients[141].

5.9 Implications to Practice

Increasing the usability of EHR systems can have a positive impact on data entry, reducing workload burdens and increasing the reliability of records[136]. The use of audit logs for clinical practice could potentially provide some excellent opportunities for optimisation and improving usability of systems. It could be used to identify issues and offer users further training and optimisation in their workflows.

5.10 Implications to Policy

Although, there are European directives on accurate data recording[95], Ireland would benefit from local and national policy guidance in EHR data entry to improve the reliability of records for both nurses and doctors who interact with an EHR.

5.11 Implications to Research

Although this study contributed greatly to the quantitative measurement of workflow analysis, some further research would be beneficial to contribute

further to this topic. Further research using log files from a European perspective would be beneficial rather than a US comparison based on significantly different health care structures. Additionally, more nursing data variables are needed to describe their EHR usage across different health services and countries such as documentation times, chart review times and medication administration times. In this way different nursing specialties can be directly compared, and optimisation plans can be introduced. Further qualitative studies around attitudes and perceptions of users to software changes would be beneficial.

5.12 Limitations

Unfortunately, due to the prolonged restrictions in healthcare, from the COVID-19 Pandemic, the training plans for implementation were dramatically altered to facilitate learning in a socially distanced way. Users were provided with a video of the new summary page's functionality rather than in person classroom sessions. Although training completion was reported to be 80% by the facility, a reasonable recommendation following this review is that further training and optimisation would be beneficial to both groups. The user's knowledge and ability to use health information technology was not assessed in this study.

5.13 Conclusion

The introduction of the upgraded summary page has demonstrated some very positive changes and adoption to utilizing the EHR optimally. Post workflow change analysis has demonstrated the majority of beneficial findings were among the NICU nursing group with more structured data entry. Significant time savings

were demonstrated in the nursing group which can have positive impacts on patients care delivery. This study has demonstrated the useful benefits of EHR workflow measurement by quantifiably measuring tasks associated with the workflow.

Chapter 6

Improving the quality of newborn feeding documentation in an EHR using a mixed methods approach

Publication (Appendix 17):

Sheehan OM, Greene RA, Corcoran P, McKernan J, Murphy B. (2024) *Improving the quality of newborn feeding documentation in an EHR using a mixed methods approach.* Journal of Neonatal Nursing (In Press) https://doi.org/10.1016/j.jnn.2024.07.025.[142]

Poster Presentation:

Sheehan OM, Greene RA, Corcoran P, McKernan J, Murphy B. Action Research to improve the quality of newborn feeding documentation in an EHR.

Presented at:

1) National Perinatal Epidemiology Centre (NPEC) Study Day, Jan 2024, Portloaise, Ireland
2) Child and Family Nursing Conference, April 2024, Cork, Ireland

Chapter 6- Improving the quality of newborn feeding documentation in an EHR using a mixed method approach

6.1 Abstract

Introduction: Newborn feeding is key to infant growth and survival. Accurate feeding documentation can inform care decisions and planning of care. A nutritional dashboard is available within the Electronic Health Record (EHR) which accumulates feeding data in a graphical display.

Purpose: To improve the quality of newborn feeding documentation for post-natal ward babies and babies in the Neonatal Intensive Care Unit (NICU).

Design and Methods: This study was conducted across 4 hospital sites using the national newborn EHR. A multidisciplinary end user expert group (n=38) was established. Qualitative thematic analyses from this group were used to design new feeding data entry and review elements. A focus group (n=5) was conducted to evaluate the post change using reflexive thematic analysis. Quantitative pre-post design was used to assess feeding documentation for both post-natal ward baby charts (n=134) and NICU baby charts (n=188). Descriptive statistics and Pearson's chi-square were used to assess pre-post differences and statistical significance. The use of a nutritional dashboard was assessed using system audit logs and analyzed using Poisson regression testing in this mixed methods study.

Results: Three themes were identified in the pre qualitative phase: (1) Complex data entry, (2) Difficulty in reviewing data and an (3) Unreliable nutritional dashboard. This expert group collaborated to develop a new design for data entry and review. Quantitative analysis showed post-natal ward babies had improvements in structured feeding documentation by 91.6% (from 17.9% to 34.3%) (p= 0.031) in the post change phase. NICU data feeding documentation improved by 25% (from 72.3% to 90.4%) (p=0.001) in the post change phase. Use of the nutritional dashboard however reduced in the post period. Following the post change focus group in one site four themes emerged: (1) Benefits to EHR recording, (2) Resistance to digital change, (3) Accurate data reliable results and (4) Complex case prioritization.

Conclusion: This study has positively demonstrated improvements in the quality of newborn feeding documentation within the patient's EHR can be achieved through a collaborative multidisciplinary approach optimising EHR design.

Practice Implications: The benefit of a multidisciplinary approach to EHR design is paramount to promoting superior quality data entry compliant with individual workflows.

6.2 Introduction

Infant nutrition has a key role to play in growth and development, and can have a profound impact on society in terms of reducing obesity and chronic disease prevention [143]. The first year of life is a period of rapid growth and development [143]. Infants born prematurely face numerous challenges including being vulnerable to suboptimal nutrition [144]. Premature infants are born at a critical time of brain development which can involve some complex and precisely programmed neurodevelopmental events [145,146]. This in turn poses a risk to the preterm brain being vulnerable to numerous insults and consequently leading to a high incidence of lifelong neurodevelopmental, cognitive, behavioral, and motor impairments [145,146]. Nutritional support can play an important role in the neurodevelopment of the preterm infant [147]. Early nutritional is one of the interventions that can act to modify the development of the preterm brain and perhaps mitigate any long term neurodevelopmental outcomes[147]. As the postnatal nutritional support may not optimally match the third trimester intrauterine growth, this can lead to high rates of faltering growth for preterm infants [148] and it is for this reason that postnatal nutritional support should be optimized [148–151]. To assist clinicians in making decisions around nutritional optimisation; having accurate and timely information can assist in care planning and nutritional progression [152]. Within an Electronic Health Record (EHR), the use of data to extract information and develop into knowledge to support clinical decision making, is described as a critical success factor for an organization [153]. Some elements of clinical data are routinely used to guide clinical care such as measurable attributes of blood pressure, heart rate and temperature. Nutrition and growth also need to be closely monitored to overcome

any nutritional deficits during this critical growth phase particularly transitioning from parenteral nutritional to enteral nutrition [144]. Real life challenges have been identified around data quality in clinical organizations attempting to extract data in relation to newborn feeding [154] and highlight the need for the EHR to show an accurate view of the real clinical situation of patients [154,155]. Systematic errors associated with the information systems structure can hinder accurate data quality [156]. The dimensions of data quality vary and include accuracy and reliability, timeliness, coherence, accessibility and relevance[157]. The quality of data input can strongly influences the quality of the results [153,158] and interpretation of data into knowledge. Since the beginning of modern nursing, nursing data have been the most potent source of data for planning and improving the quality of care[136]. The importance of documenting newborn feeds can contribute to the plan of care and promotes consistency and safety of the infant [152]. The benefits of careful documentation regarding the quality of the feed can communicate the infant's progress to the wider interdisciplinary team and has been identified as a crucial aspect of care [152].

6.3 Background

The Maternal and Newborn - Clinical Management System (MN-CMS) is a national project implementing a single national EHR for maternity and neonatal services in Ireland [37]. The MN-CMS newborn EHR contains various data points on newborn feeding for both well babies on post-natal wards and babies admitted to the Neonatal Intensive Care Unit (NICU), completed by the midwife and NICU nurse. The MN-CMS project was instrumental during the EHR design in developing

a nutritional dashboard for infants which provides a graphical display of daily intakes consisting of nutritious and non-nutritious parenteral fluids and enteral feeds. The enteral graph of the nutritional dashboard is populated by the feeding data entries in the EHR (See Figure 6.1). The nutritional dashboard displays enteral feeds based on feed type (breastmilk or formula) and by method the milk was received (teat or tube). This graphical display of feeding progress has the potential to enhance feeding and nutrition review for the entire multidisciplinary team and contribute to the knowledge to support clinical decisions, however due to data quality issues based on feeding input, the graphical display is sometimes unreliable. The well post-natal ward infants also have inconsistent feeding documented in their EHR as a dual paper process is maintained. This causes difficulties in reviewing feeding progress particularly if care is transitioned when transferred from post-natal ward to the NICU due to numerous duplicated data fields. This mixed methods research study aimed to review the current workflows to change the systematic format of feeding data entry within the EHR for post-natal ward and NICU babies, to enhance compliance with the data completeness and correctness. A consistent data entry format was developed for all users to input all infant feeds. All changes to the national MN-CMS system were carried out in accordance with the strict change control pathways in place.

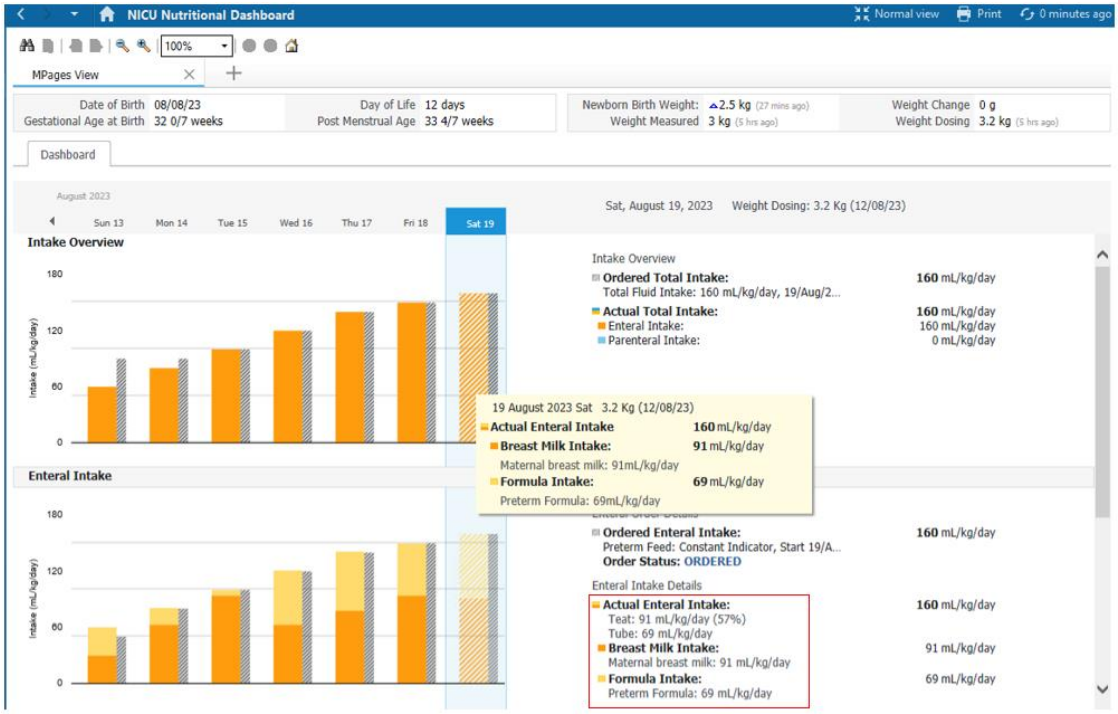

Figure 6. 1: NICU Nutritional Dashboard

6.4 Purpose

This study aimed to 1) improve the data quality in relation to newborn feeding for well healthy newborns on post-natal wards and those admitted to the NICU and 2) improve the utilization of the NICU Nutritional Dashboard.

6.5 Setting

Ethical approval was granted for the inclusion of all four hospitals in this study who utilize the EHR and from the project's information governance group. Separate ethical approval was granted for Site A (ECM 4 (c) and SREC 2024-194), Site B (ECM 4 (c)), Site C (REC-2022-007) and Site D (EC17.2022). Three hospitals were tertiary referral sites with Level III NICUs (Neonatal Intensive Care Units), and one site was a local maternity unit. A mixed methods approach was utilized to address the

research questions. Qualitative and quantitative assessment evaluations before and after the development and implementation of the changes in EHR data were used to evaluate the revised data entry format for all users to input all infant feeds. Qualitative methods were used to gain an understanding and opinions from the different disciplines engaging in newborn feeding within the EHR and quantitative methods were used to objectively measure the data inputted and reviewed within the EHR for newborn feeding.

6.5.1 Qualitative Methods

6.5.1.1 Pre-Implementation Qualitative Methods

For the pre implementation qualitative assessment, a purposive sample of subject matter experts from all 4 hospital sites were included and therefore established the multidisciplinary expert group, with representation from all relevant disciplines who use the EHR daily and members of the national project team. Forty-one participants were invited to take part. In total 38 participants engaged in the group and signed a voluntary consent to participate in the study. The consent and participant information leaflets provided to participants are included as appendices- Site A & B (Appendix 18), Site C (Appendix 19) and Site D (Appendix 20). The sample representation (n=38) is displayed by discipline in Table 6.1. There was a larger number of nurses and midwives than there were medical, dietetic, lactation consultants for example but this mirrors the staff mix in the clinical area. The expert group was coordinated by the author (OS) who is the NICU workstream lead for the MN-CMS project and has an in-depth knowledge of the EHR.

Table 6. 1: Expert group representation

NICU Nurses	5
Midwives	13
Neonatology Consultants	2
Neonatal Non-Consultant Hospital Doctors (NCHD) and Advanced Nurse Practitioners (ANP)	2
Dietitians	3
Lactation Consultants	6
National Project Team	7
Total	**38**

This expert group was used to identify the current issues and "sticky points" around poor data entry for all infants both on post-natal wards and NICU. They were instrumental in deciding the EHR changes to improve the data capture through their valuable identification of issues and their understanding of what needed to be captured. Due to COVID19 restrictions in healthcare facilities, the group met via teleconference on five occasions lasting for one hour each. Sessions were recorded and a transcript generated from the teleconference application. These transcripts were verified by the lead author, who was the coordinator of the group sessions. The first group session, which had a wide representation of all disciplines across all four sites, was used to understand the current workflows and issues and opinions were identified from various perspectives. The subsequent sessions (sessions 2-5) had various members at different times who contributed to the final design of the EHR feeding entry and review changes. Not all members were present for all sessions but there was always good multidisciplinary representation. The main topics explored with the group for the initial meeting were data entry in the EHR, data review in the EHR and use of the nutritional dashboard. Topic guide questions are outlined in Appendix 22. Reflexive thematic

analysis was used to analyse the qualitative data based on the Braun and Clarke 6 step process of familiarization of the data, generating initial code (descriptive codes), searching for themes, reviewing themes, defining and naming themes and finally producing the report[51].

6.5.1.2 Post Implementation Qualitative Methods

A post implementation qualitative focus group was conducted in Site A, 16 months after the implementation of the changes. Site A was chosen based on the quantitative results to understand user engagement and opinions of the change. A purposive sample type was used to include six expert users who were invited to participate in a focus group sent by hospital email and five consented to participate[1]. The sample was chosen based on a representation of key users of the EHR in terms of newborn feeding. The focus group consisted of key users representing their different disciplines- a NICU nurse, a neonatal dietitian, a consultant neonatologist, and two post-natal ward midwives. A lactation consultant was also invited to participate but was unable to join the focus group. The participant information leaflet and the consent form are included in appendix 21. A topic guide was developed and is attached in Appendix 22. The focus group was conducted over Microsoft Teams meeting, facilitated by the author (OS) and other members of the research team and lasted 43minutes. The session was recorded, and a transcript was generated from the meeting software. The

[1] The focus group was a purposive sample chosen from the original expert group by my supervisor, Dr Brendan Murphy, to ensure a reduction in selection bias.

transcript was validated against the video recording with minor amendments made. NVivo 14 Software was used to assist data analysis based on the Braun and Clarke process of reflexive thematic analysis[52]. Double independent coding was conducted, discussion of the initial codes and a review of the coded data was completed. The final list of codes was developed by merging the databases. The codes were then refined into themes after a discussion between researchers. A final write-up of the findings, supported by a selection of quotes was completed by the lead author (OS) and reviewed by the rest of the research team.

6.5.2 Quantitative Methods

The data quality and completeness were quantitatively assessed by reviewing newborn EHR data for inpatient newborns in the four hospitals included in this study. Data were collected for a 24-48-hour period looking at the feeding entry of newborn inpatients, receiving nutritive milk feeds (>40mls/kg/day), on a selected date to obtain pre and post measurements. The sample size was calculated to detect a 20% improvement in data entry for both NICU babies (n=188) and the post-natal ward babies (n=134). The sampling method was convenience sampling of newborn inpatients in the NICU or Post-natal ward. There was a separate pre and post sample cohort for both groups, the NICU group had 94 pre and 94 post and the post-natal group had 67 pre and 67 post. The post data was collected approximately two months after the changes were implemented. Key data entry for accurate population of the nutritional dashboard were identified using the dimensions of quality based on the Health Information and Quality Authority (HIQA) framework [157] as the primary measure of completeness. The dimensions of

data quality are accuracy and reliability, timeliness, coherence, accessibility, and relevance [157]. When each of these dimensions were met- the data quality was considered complete and accurate to populate the nutritional dashboard. These are displayed in Table 6.2 with an example of the EHR data entry to achieve the dimensions of data quality.

Table 6. 2: Dimensions of data quality

Dimensions of Data Quality	**EHR Data Entry**
Accuracy and reliability	Appropriate feed data entered e.g., feed type, feed method, feed volume etc.,
Timeliness	Correct time column entry
Coherence	Clearly entered using discrete data entry
Accessibility	Completed in the correct feeding section
Relevance	Entry completed per feed

Additional data points were also captured and compared in the pre and post phase. Data were analyzed using SPSS 28 using descriptive statistics of cross tabulation and Pearson's chi-square test assessed the pre-post difference and statistical significance. Significance was set at 5% (0.05) meaning that a p valve of <0.05 was significant. The use of the nutritional dashboard was evaluated by extracting data log files from the EHR database to evaluate the number of times a user launched the nutritional dashboard page to open the graphical display. The statistical software program, Stata, was used to assess the launches per day and the cumulative launches over the 7-day period. Poisson regression tests were used to assess the pre-post change.

6.6 Results

6.6.1 Pre-Implementation Qualitative Findings

Using thematic analysis, three overarching themes were identified: (1) Complex data entry (2) Difficulty in reviewing the data and (3) Unreliable nutritional dashboard. The outputs from the expert group consultations varied by each of the disciplines based on their different work practices and their need to either enter or review the information.

Theme 1: Complex Data Entry

NICU nurses and post-natal ward midwives in particular spoke about how complex the feeding documentation was and how it was time consuming. They commented on how there were too many options for various feeds, and they often don't separate different feed types on data entry as this is too cumbersome. The NICU nursing group felt the data entry was too complex (particularly with multiple feed types) with too many options and difficulty in seeing the total volumes per kilogram per day (mls/kg/day). NICU nurses also referenced multiple data entry points duplicated when newborns were moved from post-natal ward care to NICU care.

> *"When a baby is moved from the wards to the neo there is a feeding method newborn and feeding method NICU to complete but I'm only feeding the baby once!"*
>
> *NICU Nurse, Site A*

Nurses felt the data entry was complex and frustrating to enter correctly in separate time columns as designed. Nurses also commented that for some documentation- they had no structured data entry space to add this information such as "a reason formula was given".

Midwifery staff on the post-natal wards either did not enter structured data in the EHR or maintained a dual system of paper feeding charts which were either scanned into the EHR or transcribed in. They mentioned that it was too time consuming to do and they would enter data often at the end of a shift.

> *"We get the mums to write down the feeds for the day and then we put them in the chart (EHR) at the end of the shift."*
>
> *Post-natal ward Midwife, Site D*

Theme 2: Difficulty in reviewing the data

Dietitians, lactation consultants and medical staff in particular found reviewing information was difficult. Complex feeds with additives were difficult to review and users often clicked through 24-48 hours of feeding data rather than seeing an overall summary picture.

> *"The review of feeding is problematic to look at it at a glance and see 24-48hrs – you need to click through iView just to get an idea of what's happened."*
>
> *Neonatologist, Site D*

The dietitians also noted difficulty finding the first feed and that there was a lack of information around the first breastmilk or buccal breastmilk administration. Neonatologists, NCHDs (Non-Consultant Hospital Doctors) and ANPs cited difficulty in reviewing the information and inability briefly to see the "key firsts" e.g., first feed, first breastmilk. Lactation consultants voiced concerns around key national reports and the difficulty in gathering information for these reports due to the poor data completeness of newborn feeding and often newborn charts didn't even have scanned feeding charts.

> *"Sometimes you'd find a feeding chart scanned in (to the EHR) and sometimes not."*

Lactation Consultant, Site A

Theme 3: An Unreliable Nutritional Dashboard

Dietitians and medical staff cited rarely reviewing the nutritional dashboard due to perceived inaccuracies of the display. They did acknowledge the nutritional dashboard had potential for reviewing the intake and tracking feeding progress, however, due to inaccuracies it was unreliable, and they lacked trust in it.

> *"The dashboard really has great potential to review the intake and track the progress but again there's too many options for all the different feeds and combined feeds are problematic and this makes the dashboard too inaccurate to reply on…."*
>
> *Dietitian, Site C*

Dietitians noted that the complex and combined feeds were difficult to order and to review, the complex feed entry was often inaccurate leading to inaccuracies in the nutritional dashboard which could have immense potential if accurate. The medical group found that the nutritional dashboard was "just not right or correct" for use on ward rounds or presenting patients as the data entry was probably not correct in the first place.

6.6.2 Implementation of Feedback

Following the group review and redesign of the current feeding entry, work began as outlined below and followed a similar format as described by Sutton and colleagures[159]. The EHR provided two views – one for midwives for the post-natal

ward baby and one for the NICU staff and the sick neonatal baby with often duplicated data entry points.

1. A side-by-side analysis was made of both views and a comparison was made to determine which data elements were consistent and which were duplicated.
2. Common and essential data points were identified, aligned, and eliminated if deemed not essential to capture.
3. Responses to the duplicates were aligned to provide consistency.
4. More conditional logic was built into responses i.e., based on the selection of responses, additional relevant responses would open. These would remain hidden if not selected.
5. New data capture was agreed for inclusion e.g., reason for formula feeding, type of breastmilk and administering buccal breastmilk and an ability to record the mls/kg/day per feed.
6. Commonality of the design was decided and agreed by the stakeholders.
7. A new flowsheet was built for the purpose of reviewing all the feeding data in one place.
8. The agreed design was built in the pre-production (test) environment and demonstrated to the group.

Following a detailed demonstration to the group, some minor design adjustments were made, and the group identified some key encouragement points in promoting this to the end users. An implementation plan was developed with the group for each of their sites. The strategies identified for implementation were

training, identifying champions and communication via newsletters and memos. Two short information training videos were developed for the data entry for midwives (5.5minutes) and for the NICU nurses (6.5minutes) and distributed to nominees on each site to disseminate along with a quick reference guide. Each group member was identified as champions for this change and provided support and encouragement to end users. The final design was built into the live environment at an agreed time once training was complete and memos were distributed to the users.

Once the design was complete and agreed, the expert group were asked what could encourage adoption of the new changes. The group mentioned that users had been asking for changes and these should represent their request for change and make it easier to enter feeds and capture all the required information. A member of the national project team highlighted that every patient has a right to accurate data being recorded in their EHR.

> *"Every patient has a right to data accuracy….and they should have correct information around care being recorded."*
>
> *Member of the National Project Team of MN-CMS*

A doctor noted that we need to stress the why we are doing this:

> "…. the *key is almost to start with the why, why are we making this change at all? It's to try and make it better and, and bring our care more centered around one of the key things that as all health care providers ….[that] we do for babies, which is to nourish them and to do it in a way that doesn't matter where the baby is….the mother and baby and wherever they are in their feeding journey and in their care journey in the hospital"*
>
> *Neonatologist, Site A*

6.6.3 Quantitative Results

6.6.3.1 Post-natal ward newborns

For the postnatal ward newborns, the overall completed structured data entry across the 4 sites increased from 17.9% to 34.3% showing a statistically significant increase of 91.6% (p=0.031). The cumulative results for the post-natal ward data entry are displayed in table 6.3. There was also a notable increase in key structured data points of feed type and oral volume with increases of 80.4% and 123.8% respectively. Although the aim of this study was to improve the structured data entry, some post-natal ward staff documented newborn feeding in an unstructured way by free text notes or handwritten feeding charts scanned into the EHR. As these captured newborn feeding, they were accounted for in the data collection as *other* documented feeding records for newborns. Overall, across four sites, the other feeding documentation increased by 63.4% to 68.7% of the sample having some feeding documented in their EHR. The new data changes included the reason for formula feeding and this was completed in 85% of applicable cases for post-natal ward newborns having previously not been captured.

Table 6. 3: Post- Natal Ward cumulative data completeness

	Pre (%)	Post (%)	Change (%)	P Valve
Feed Type	19.4	35	+80.4	0.047
Oral Volume	16.4	36.7	+123.8	0.014
Feeding Method	29.9	43.3	+44.8	0.106
Formula Type	16.4	53.8	+228	<0.001
Feed Tolerance	47.8	80.6	+68.6	<0.001
Structured Data Complete	17.9	34.3	+91.6	0.031
Other Documentation	41.8	68.7	+63.4	0.002

The structured data completeness for each site is displayed in table 6.4. Only one individual site (D) showed a significant improvement which was not, however, demonstrated across all four sites. Site A displayed little improvement in structured data entry in the post phase.

Table 6. 4: Individual site data quality compliance

Site	Pre (%)	Post (%)	Change (%)	P Value
A	0	5	N/A	0.311
B	40	60	+50	0.371
C	10.5	15.8	+50.5	0.631
D	31.6	68.4	+116.5	0.023

6.6.3.2 NICU Newborns

The NICU chart review across the 4 hospital sites showed a data completeness to populate the nutritional dashboard significantly increase of 25% from 72.3% to 90.4% (p= 0.001). The NICU data points collected following the chart review are displayed in table 6.5 and display the cumulative results of data completion across all four hospital sites.

Table 6. 5: NICU- Cumulative data completeness results.

	Pre (%)	**Post (%)**	**Change (%)**	**P Valve**
Feed Type	75.5	90.4	+19.7	0.007
Oral Volume	93.8	100	+6.6	0.048
Tube Volume	91	100	+9.9	0.016
Feeding Method	64.9	86.2	+32.8	<0.001
Formula Type	74.5	94.1	+26.3	0.006
Additives	83.3	89.7	+7.6	0.415
Feed Tolerance	48.9	73.4	+50	<0.001
Feed Order	42.6	26.6	-37.5	0.021
Fluid Order	63.8	52.1	-18.3	0.104
ND* Complete	72.3	90.4	+25	0.001

*Note: *ND refers to the Nutritional Dashboard and all data inputted into the EHR accurately populated the dashboard*

The individual sites are displayed in table 6.6. Three sites (A, C and D) showed an increase in completeness and one site (B) remained static.

Table 6. 6: Individual site data quality compliance (NICU)

Site	Pre (%)	Post (%)	Change (%)	P Value
A	70	93.3	+33.2	<0.02
B	75	75	0	1.00
C	76.7	90	+17.3	0.166
D	70	90	+28.6	0.053

The *Feed Type* data entry point is especially important to capture as it allows the categorization of feed types such as breastmilk, term formula, preterm formula etc. in the reviewing process of nutritional intake. Overall, across the four NICUs this data point improved, increasing by 19.7% with statistical significance (p=0.007). The individual sites are displayed in table 6.7. Site A showed an increase in this feed type data point from 70% to 93.3% in the post phase, an increase of 33% completeness (p=<0.02). This data point was noted as being problematic in cases of complex feeds or with more than one feed type being administered such as combinations of breastmilk and formula.

Table 6. 7: Individual sites to populate the Feed Type

Site	Pre (%)	Post (%)	Change (%)	P Value
A	70	93.3	+33.3	<0.02
B	75	75	0	1.00
C	83.3	90	+8	0.448
D	73.3	90	+22.8	0.095

The *feeding method* (e.g., via bottle teat or tube) data entry was often duplicated in the pre phase however accuracy and completeness increased by 32.8% over four sites (p= <0.001) with the new design. New data entry captured in the post phase such as, the reason for formula feeding, was recorded accurately across all four

sites in 66% of relevant cases having not been recorded previously in a structured event set. The type of breastmilk (fresh or refrigerated or previously frozen) can now be captured for newborn feeding and was done so in 56% of relevant cases.

6.6.3.3 Nutritional Dashboard

There was a 5.7% reduction in launches of the nutritional dashboard overall across the four hospitals in the post period which was not statistically significant (p= 0.115) and may account for some usual variation. Reviewing each hospital separately, hospital A had a significant reduction in launching the page with a 23.7% reduction (p=<0.001). Hospital B, albeit with small numbers had a 45% increase in usage (p=0.339), hospital C had a 5.5% increase (p=0.272), and hospital D had a 12.6% reduction (p= 0.178). This is displayed in Figure 6.2 below.

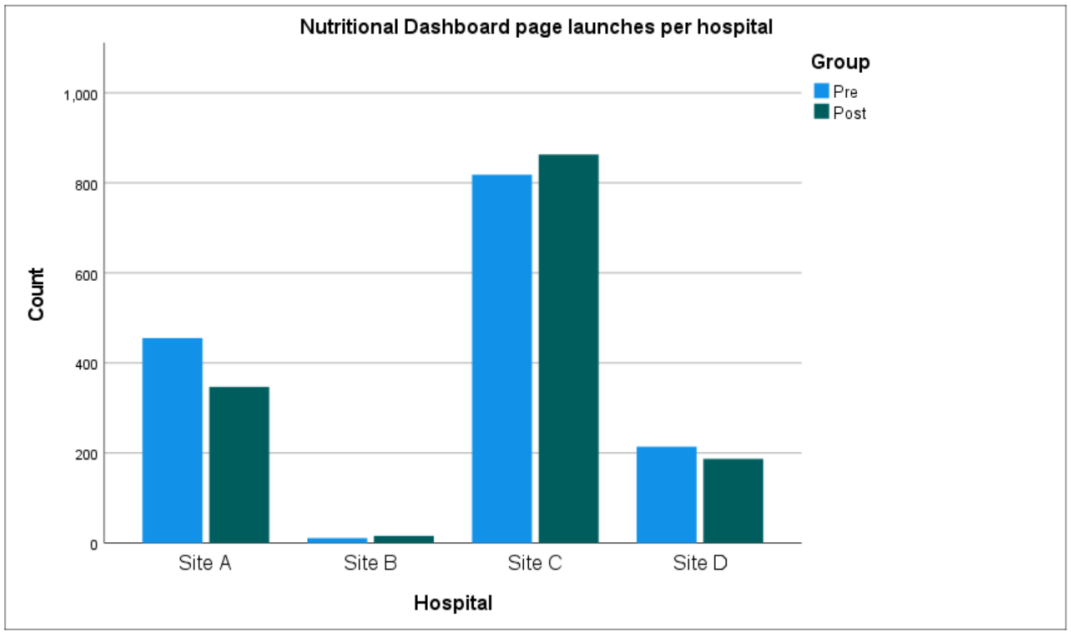

Figure 6. 2: NICU Nutritional Dashboard page launches by hospital

Note: Site B is a smaller unit and has the lowest number of births per year however Sites A, B and C are comparable tertiary sites

The launching of the page by position showed an increase by NICU Nurses of 8.2% (p=0.119) and dietitians by 15.2% (p= 0.247) and significant reduction by medical staff by 24% (p=<0.001). Other positions are represented in table 6.8 and graphically displayed in figure 6.3.

Table 6. 8: The use of the nutritional dashboard by user positions

Position	Pre	Post	% Change	95% CI		P Value
NICU Nurse	758	820	+8.2	0.98	1.19	0.119
Medical	520	392	-24	0.66	0.86	<0.001
Dietitian	125	144	+15.2	0.91	1.46	0.247
Lactation Consultant	18	12	-33.3	0.32	1.38	0.277
Pharmacist	61	44	-27.9	0.49	1.06	0.099

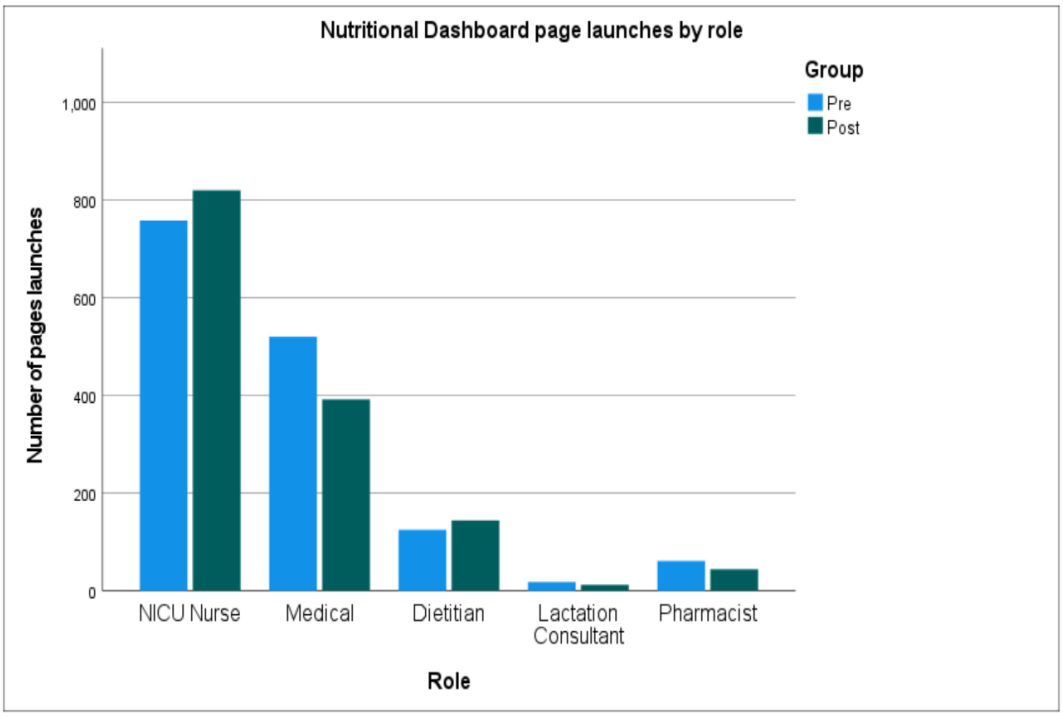

Figure 6. 3: NICU Nutritional Dashboard page launches by user roles

6.6.4 Post Implementation Qualitative Findings

As mentioned earlier, Site A was chosen to conduct a post phase analysis focus group due to the inconsistency of the quantitative results found within the hospital. Post natal data completeness within the EHR at Site A (as represented in Table 6.4) increased from 0 to 5% (p= 0.311) whereas, NICU data completeness in Site A, significantly increased from 70% to 93.3% (p = < 0.02) as represented in Table 6.6. Post Natal data in Site A was also not consistent with the sites B, C and D. A focus group in site A was therefore facilitated to gain an insight into the users' perceptions and opinions.

Four Themes were identified through the reflexive thematic analysis.

Theme 1: Benefits to EHR Recording

Primarily the NICU staff (NICU nurse, neonatologist and neonatal dietitian) highlighted that the new changes in the EHR were positive changes. They reported the changes were easy to use, more user-friendly with less duplication and in fact did not add to their workload. The NICU staff found some newly added functionality allows them to capture new information which they were not able to enter before:

> *"The input data now you know the little drop-down boxes and we're able to put it in that the baby's getting buccal EBM [Expressed Breast Milk] and things like that. So, you know things that we weren't able to before."*
>
> *NICU Nurse, Site A*

The NICU nurse also reported it was easier to enter complex feeds and the EHR views being aligned reduced duplication of fields between post-natal and NICU

babies. The neonatologist and neonatal dietitian reported that reviewing data from the EHR had improved particularly for NICU babies:

> *"And so, a lot of the, the NICU settings, it's, it's much easier, takes a lot of the stuff that you don't need to see out of the way.*
> *So I yeah, I, I think it's definitely easy to find what they're on."*
>
> *Neonatologist, Site A*

The NICU nurse reported that although more detailed information is being inputted, handover was easier now in the post phase as the as the information was readily available:

> *"…but that's actually handier for us when we're looking back, like giving report, we can say, oh, he took two bottle feeds, you know, didn't complete them and they took a long time."*
>
> *NICU Nurse, Site A*

Theme 2: Resistance to Digital Change

The second theme identified from the data analysis was the resistance to the digital change. The post-natal ward staff reported that they maintain a dual process of paper records (as they did before) with some digital EHR input retrospectively or when they had time to enter data. They reported they never documented all the baby feeds in the EHR before and so this was a change of practice for staff, and they were not informed about nor had adequate training on the new changes.

> *"We never documented all of the baby's feeds, and so we always just mmmm use the bedside feeding chart and that would be scanned in then…."*
>
> *Post-natal ward midwife, Site A*

The post-natal staff reported the new changes were more labour intensive and they didn't have the appropriate time to enter the data and suggested needing additional staff for data entry.

> *"……An extra workload, so that's the problem and it's probably one that gets pushed to the end of the day."*
>
> *Post-natal ward midwife, Site A*

There was a perceived lack of prioritising of data being entered into the EHR in the post-natal wards as it was perceived that the detailed feeding was not necessary and not needed for babies on the post-natal ward.

> *"It's hard to see….. Well, you know …… why the extra effort for something that actually you know, we're not really utilizing that information."*
>
> *Post-natal ward midwife, Site A*

Paper charts were deemed essential for the post-natal ward as they were consistently completed by parents and staff and were the most reliable source of information for reviewing feeding.

> *"I suppose most the time you'd be in the room anyway, and it would be like generally the most accurate assessment of the Feeding is still the, the paper chart that's in the room with the with the parents."*
>
> *Neonatologist, Site A*

Theme 3: Accurate Data, Reliable Results

With accurate data inputted, the neonatologist and dietitian in particular, found the EHR more reliable to use and would get a clearer clinical picture of the newborn's feeds and feeding progress for which to use for clinical decisions. With accurate data inputted, it was recognised that using the nutritional dashboard was

reliable and useful to trend intake over a number of days. NICU staff in particular reported positively on use of the dashboard in this scenario

> *"I, I must say I, I mean, I've always liked it….I mean, it's again….Yeah, it's….It's as reliable as the data that goes in if the data goes in it, it gives a very nice, very quick look that you don't have to go into iView or, or now into results and figure out what proportion they're getting…."*
>
> *Neonatologist, Site A*

> *"But it is very useful I think when they're, once they're established on feeds and you know just you can see that"*
>
> *Neonatal Dietitian, Site A*

It was also acknowledged by the NICU staff that if inaccurate data was inputted into the EHR, then the results were not reliable to use

> *"And, but I suppose it's only as reliable as the person that's entering the data. So, you know, sometimes there might be a mix up that someone might put the feed volume …. or you know the mls per kilo per day in the feed volume and then it completely skews the results from that, you know, so I'd still would go to iView or results for the most accurate intake."*
>
> *Neonatal Dietitian, Site A*

The EHR data was also deemed unreliable when the data wasn't entered contemporaneously or available in real-time for reviewing a patient. Post-natal ward staff may enter data retrospectively at the end of a shift and so this would not be available during daytime reviews

> *"I mean if I look back in at historic charts, it may well be complete, but it's not contemporaneous so if you look at a chart, say you're going in now and you want to see what the last two or three feeds are, then it's likely or there's a real possibility they won't be documented……If you came back to that same baby in the evening, it very well might be….."*
>
> *Neonatologist, Site A*

Theme 4: Complex Case Prioritisation

A solution proposed by the group to the challenges exposed was to prioritise complex cases when entering the data to reduce the midwife's workload and optimise the use of the EHR. This was because the detailed feeding data entry was only deemed necessary in specific clinical scenarios, namely those sick babies in the NICU and not necessarily needed for the well post-natal ward babies. There was an opinion that as the detailed data regarding feeds was not needed or reviewed on the post-natal ward, then the structured EHR data entry was not needed in these cases and so was not entered. The detailed data entry and review of feeding was however certainly necessary for the more complex or sicker babies in the NICU.

> *"And so, a lot of the, the NICU settings, it's, it's much easier, takes a lot of the stuff that you don't need to see out of the way. So, I yeah, I, I think it's definitely easy to find what they're on. I don't think we use it much for the [post-natal] floors."*
>
> *Neonatologist, Site A*

The detailed and automatic calculations of feeding intake was looked at as being important for the NICU and the users would be more invested in data entry that contributes to these calculations however not so much in the post-natal wards as these data would not be used. The suggestions that a simpler assessment of feeds would be more appropriate for the post-natal ward was suggested as being more feasible or acceptable to this clinical area

> *"But, and we don't need it on every baby is the reality of it. And I think they're in again, it's part of the problem is that if you have staff that are pushed doing other things, it is down the list of priorities because you do things that you feel are worth doing. And I do wonder if at times we know this is worth doing in the Neo [NICU]. Its maybe hard to convince a very busy Midwife, up in the floor, so maybe*

…..suggesting on those babies you're worried about having it more contemporaneous and accurate and contributing to your overall assessment of the baby…..And we know the chart can flag things that you….. it can give you early warning signs and if if we use it that way and yeah, it may be a better way of using it on the floors [post-natal ward].”

Neonatologist, Site A

6.7 Discussion

This study aimed to improve newborn feeding documentation within an EHR and began by exploring the redesign of newborn data entry using a multidisciplinary approach. This study identified that users found the newborn feeding data entry complex and time consuming to complete, with some duplication and having too many options to complete. Likewise, reviewing the information was problematic due to the complex data entry and gathering national reports was difficult as the information often could not be found or was not entered in a structured format. The key contributions of the multidisciplinary team were used to redesign the newborn feeding data entry within the EHR; to reduce the complexity, and duplication for users and ultimately improve the data quality of newborn feeding. The improvement of data quality was observed across the NICU and most post-natal wards through the quantitative chart review. A post change implementation focus group was facilitated in one site as a post-natal ward improvement was not detected. The findings of this post implementation focus group show that although users identified benefits to accurate EHR recording particularly for the NICU, there was some resistance to digital change identified for the post-natal ward. This was due to a perceived lack of prioritization of the data entry and expressed lack of time to complete the task. It was suggested that more complex case prioritizing for NICU babies was needed, as these are clinically more complex and more accurate

data recording is necessary for their management. The second aim was to improve the use of the nutritional dashboard by all users and although the use did not show a general improvement, NICU nurses' use of the dashboard did show an improvement. This functionality may need more education and champions to promote its use. The continuing improvement of data completeness of the feeding data entry will ensure more accuracy of the dashboard and may improve users overall trust of the dashboard for clinical use. Changes to documentation within an EHR have implications for accuracy, efficiency, user satisfaction, and workflow[160] which were positively demonstrated in this study. The key data points of feed type and feed method improved in accuracy due to alignment and reduced duplication of the data entry. Accurate data entry through thoughtful and detailed documentation can provide information that promotes continuity of care for newborn feeding [152]. Some studies identify poor data quality in feeding documentation as a limitation of their study [161,162]. This study has used both qualitative and quantitative methods to engage end users in EHR design and has streamlined feeding data entry, reduced duplication, and improved data completeness which will be beneficial for clinical review, quality improvement, audit and research. Post implementation qualitative analysis has found that NICU users positively perceived the new changes for the appropriate patients and utilized the accurate data for clinical review. Post-natal ward users reported some resistance to the digital change and a lack of perceived benefit for detailed data entry on well babies against busy workloads. This is an area where staff need more engagement and training on the benefits of EHRs and in particular, their outputs through structured data entry. The potential of using structured data from EHRs is

the core of improvements in healthcare [14] and nurses are seen as an integral part of the team in improving data quality and data obtained by nurses in EHRs have become the most crucial source in planning care [136]. With the correct and proper analysis improvements can be realized in quality, safety, and cost-effectiveness of care across the entire health service [14].

6.8 Limitations

Limitations of this study included a convenient sample of newborn charts from the four hospitals using the national newborn EHR. The post implementation qualitative focus group was a smaller group than the pre implementation group. This consisted of one site being evaluated based on the quantitative results showing a poor adoption of the structured entry. This small focus group was used to explore user engagement and opinions of the change. This project was interrupted by a criminal cyber-attack on the Irish health service data infrastructure and delayed the overall implementation of the changes from the initial multidisciplinary group meeting.

6.9 Strengths

The strengths of this research include the mixed methods approach that facilitated exploring perceptions of users but also objective change. The purposive sampling ensured representation of all relevant stakeholders, and the different participants in each group ensured multiple experiences. The post implementation qualitative research focusing on a single unit (which showed the lack of improvement),

allowed further exploration into their specific challenges. And finally, the first author (OS) with a strong expertise in NICU and the EHR facilitated engagement with the group.

6.10 Implications for Practice

This study has contributed positively to improving data completeness around newborn feeding. The benefit of a multidisciplinary approach to EHR design is paramount to promoting superior quality data entry compliant with individual workflows. Further education, training, and awareness of the benefits of structured data entry and the nutritional dashboard is needed.

6.10 Implications for Research

Qualitative research makes an important contribution for EHR design and optimisation. The establishment of an expert multidisciplinary group is essential in the design of the EHR as each member has a unique viewpoint based on their individual workflows and uses of the EHR, be it data entry or data review. The use of a focus group has provided an in-depth insight and rich qualitative data to understand opinions and beliefs of an EHR.

6.11 Implications for Policy

Although the Irish Medical Council (IMC) gives some guidance to medical staff on recording accurate, timely, and up-to-date medical records in either paper or electronic form, the Nursing and Midwifery Board of Ireland (NMBI) give guidance only pertaining to paper records. The NMBI, who provide professional guidance to

nurses and midwives, advise regular documentation of narrative notes to document patient care and progress [163]. These guidelines are relevant to paper records but do not support nurses recording clinical structured data in EHRs. A key recommendation from this study is that the nursing and midwifery professions need professional guidance for recording clinical care in a structured electronic format as health services embark on digital transformation.

6.12 Conclusion

Data completeness significantly improved across all four hospitals for newborn feeding in a national newborn EHR. Accurate recording of feeding can communicate the newborn's progress across the multidisciplinary team. This study has positively demonstrated that a collaborative multidisciplinary approach through an expert group and a focus group, can improve EHR design and gain beneficial insights to users' beliefs and opinions around data and EHRs. This collaborative approach between EHR users and system designers can improve EHR design and data quality through more accurate and complete data in the patient's EHR.

Chapter 7

Discussion & Conclusion

Chapter 7 – Discussion & Conclusion

7.1 Discussion

There has been vast array of emerging technologies over the years which can impact the way the way we live our lives and the way we work[164]. Technology has evolved since Alan Turing's first computer in the 1940's and 50's to highly sophisticated automation and artificial intelligence. Artificial Intelligence (AI) in 2023, was named as the *word of the year* by Collins Dictionary who define AI as "the modelling of human mental functions by computer programmes"[165]. The development of AI begins with data. With large amounts of data, it is possible to improve decision-making functions[164] and contribute to AI functionality. These significant technology changes, of digitalisation from paper-based systems, seen in everyday life, are equally seen across many industries such as transport, banking and indeed in healthcare. The digitalisation of healthcare from paper-based patient charts to fully integrated electronic health records (EHRs) is a necessary step in modernising healthcare[3]. EHRs have evolved since they were first introduced in the 1960's on mainstream computer consoles within an individual institution, to fully integrated EHRs available on shared platforms for multiple users[102]. Electronic health records began as problem based, billing and scheduling systems but have since evolved to providing the availability of patients' medical information, easy to read, in almost any location in the world[102]. EHRs have the ability to capture individualised healthcare data at source. Safe and effective healthcare delivery is dependent on accurate and up to date clinical information being available to the entire multidisciplinary team[166]. It is through the use of an

EHR that health data can be available in the correct place and at the correct time to enable clinical decision making in a timely manner[110]. Information and Communication Technology (ICT) facilitate EHRs, which make healthcare data available and facilitate communication across the entire healthcare team, the healthcare organisation locally, regionally and at national levels. The availability of such healthcare data being readily available can inform a patient's clinical care across time and can also inform audit, quality improvement, business intelligence and research. EHRs facilitate the transformation of data into information and to knowledge to provide and improve patient care.

The importance of eHealth solutions in healthcare delivery has been recognised as benefiting patients, healthcare professionals, and healthcare organisations[11]. EHRs have been implemented across many health systems around the world however the benefits have been slow to be realised[1] until recent events such as the COVID19 Pandemic[99]. During the pandemic there was a greater need to share health data in the interests of public health[99]. The COVID19 Pandemic has highlighted the need for accurate and timely access to health data locally, nationally, and internationally. The pandemic has highlighted the importance of electronic health data for the development of policies in response to health emergencies[167]. The implementation of EHRs is often isolated within individual hospitals, trusts, and health systems rather than taking a national perspective on implementation. Some countries have implemented a shared data platform, whereby individual systems contribute standardised patient data to a single domain. Singapore and Serbia have been successful with this approach[18,168] however the United Kingdom have encountered issues with this approach[2,169],

with calls for a renewed attempt to achieve a national EHR[169]. Serbia have identified that government legislative directives, workflow processes and training have been facilitators to the success of this implementation, for their population of over 6 million[168]. The Republic of Ireland's eHealth programme is a key enabler of the overall Sláintecare health programme for Ireland, providing key availability of healthcare data for citizens that will keep people well in their community or at home, and support better acute care[12]. This is to be enabled through many programmes such as, the national COVID19 vaccination system, electronic discharge summary, shared care records, community patient management system and ePrescribing[12]. The MN-CMS EHR has aligned with these strategic goals encompassing a fully integrated EHR with patient data availability, ePrescribing, electronic discharge summaries and communication with GPs for women and newborns.

The European Commission's report entitled the European Health Data Space (EHDS) calls for ensuring the timely access to personal electronic health data for treatments, research, innovation and patient safety[167]. This in turn can be used for statistical purposes and policy making or personalised medicine[167]. Furthermore, the EHDS aims to support the EU's digital transformation by 2030 aiming to provide 100% of EU citizens with access to their medical records[167]. Nationally, the Department of Health's Health Strategy Report 2021-2023 commits to the Sláintecare Implementation plan which is a cross political party plan of health care, with envisioned improved health and wellbeing for all and care available in the right place at the right time[170]. The Department of Health have identified data, technology and digitalisation as a key enablers of this strategy[170].

The Sláintecare Implementation Plan has proposed €33 million revenue and €93 million capital funding to contribute to eHealth improvements in Irish healthcare[12]. This funding will leverage technologies to modernise healthcare delivery and support timely and informed decision making[12].

The implementation of the MN-CMS EHR in Ireland has the potential to design the most cost-effective model of care and establish a national epidemiological database for mothers and their newborns[38]. Both the National Perinatal Epidemiology Centre (NPEC) and the MN-CMS strive to improve Irish maternity and newborn care through direct data acquisition and analysis and align with the national eHealth strategy.

This thesis has described the implementation of an EHR and the importance of accurate data acquisition through correctly mapped workflows. Data capture at source is greatly enhanced by proper workflow analysis, clinician engagement and an embedding of the processes into everyday practice.

The introduction of EHRs in healthcare, facilitate healthcare data being available in the correct place at the correct time to enable timely clinical decision making[110]. Safe and effective healthcare is dependent on the availability of accurate and up-to-date data in a legible, reliable and timely manner[5]. Although, EHRs are essential in healthcare, their implementation and adoption to everyday practice is often complex in the hospital setting[7,8]. Workflows have been identified as a key organisational factor for a successful EHR implementation[2]. Suboptimal or fragmented workflows can alter task distribution, promote workarounds and

increase inefficiencies in EHR use[26,106,107]. The success of an EHR implementation is associated with the EHR system[23] and the end-user workflow[19,23,105].

7.2 Conclusion

This thesis has explored the implementation of a national maternal and newborn EHR in Ireland. The research began looking at scientific frameworks for an implementation project in healthcare and the many theories, models, and frameworks from the research area of implementation science were explored. Implementation science provided some excellent practical frameworks and strategies for real-world implementation of evidence-based care, including its use in the complexity of an EHR implementation. The research focused next on the specific implementation of the MN-CMS from the phase one pilot sites. This research highlighted the various phases of the project, and the key lessons learned from each phase, interpreted from the phase one closure report from the implementation team and this PhD candidate. One key area developed from the implementation science research and the EHR implementation study was the key role workflow design played in the implementation process. The research for this thesis developed to look at workflows and workflow mapping and explored some key examples of workflow adaption and the successful introduction of new workflows using an implementation science framework- the AACTT Framework. The research further developed quantifiably measuring workflow compliance of an upgraded patient summary page, the final study of this thesis examined enhancing data to achieve improved care in the specific area of newborn feeding. This involved end users in the specific design of these specific EHR elements.

Although there are a myriad of factors influencing the success of an EHR implementation, this thesis has focused on the key element of workflows in the implementation and optimisation process. The thesis is broadly outlined in figure 7.1 and the summary of the implications for clinical practice, research and health policy the research contained in this thesis are summarised in chapter 8.

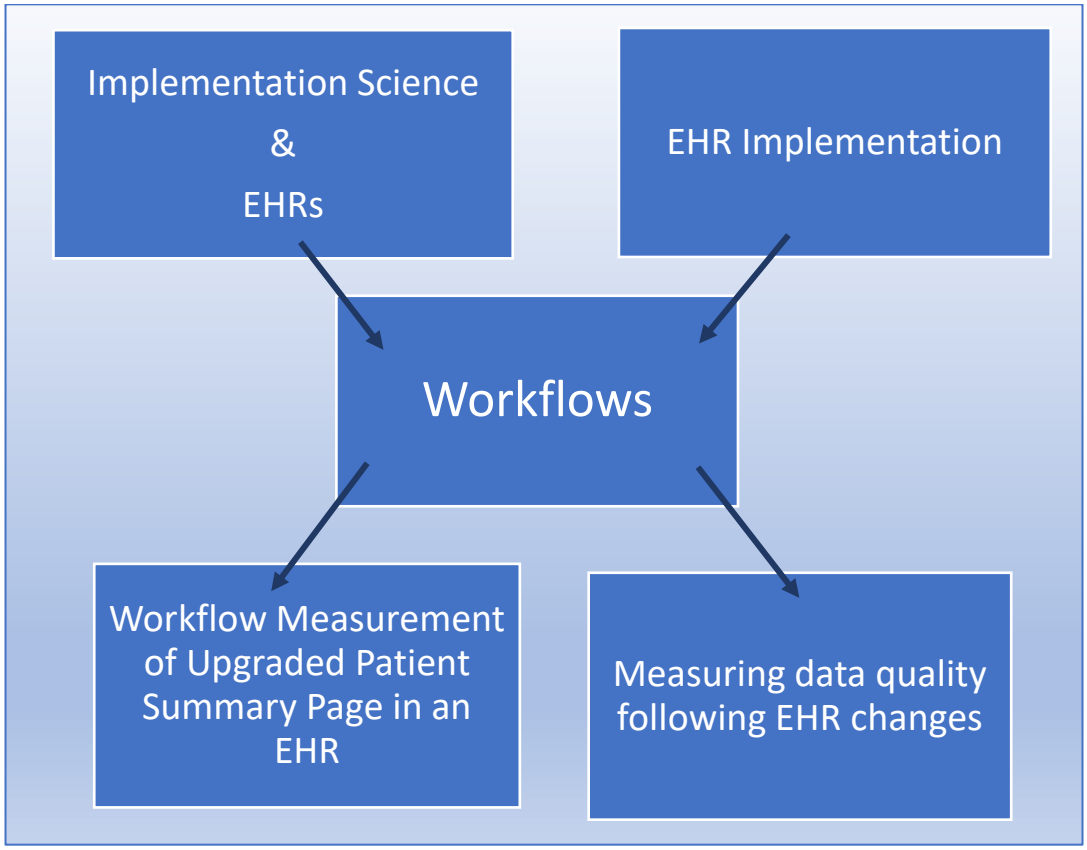

Figure 7. 1: Broad outline of Thesis

Chapter 2 summarised implementation science by outlining the taxonomy of Theories, Models and Frameworks (TMFs), implementation strategies, tailoring strategies and implementation outcomes which can be used to implement new policy and practices in the healthcare setting. The use of implementation science

in maternity and neonatal care specifically, was discussed using published work highlighting the explicit use and value of TMFs in these settings. The use of the Normalisation Process Theory (NPT) specifically was appraised. The NPT is a theory of action that provides domains of work to guide complex interventions at the macro level of complex organisational EHR implementations and also at the micro level of workflow development to build the actions within EHR use in everyday practice. The NPT provides a useful framework to guide new complex practices becoming part of everyday practice. The second framework used in this thesis was the Action, Actor, Context, Target, and Time (AACTT) framework to implement a new workflow development related to the implementation of printing medication infusion labels in neonatal intensive care . This thesis has found implementation science is very valuable, as it will practically identify the process for implementation and identifies the key actors, the actions needed at the correct time to achieve the target.

Chapter 3 of this thesis has outlined the implementation of a national EHR for mothers and babies in Ireland. The experiences and lessons learned from the national project team were explored and summarised. Key recommendations are that clinical leadership and strong governance are essential as well as having an adequately resourced team. On-going training and optimisation are necessary, and data quality surveillance can lead to more accurate reporting from the system. The potential of accurate cumulative data from EHRs can have a positive influence on

population health through appropriate analysis. Keeping the patient at the centre of the project was always paramount. The key summary recommendations are:

- Clinical leadership is essential throughout the project.
- Involving the right people at the right stages of the project e.g., Clinical staff needed for workflow development and ICT staff needed for hardware set-up.
- Adequately resourced team for various stages e.g., clinical, medications, testing, training, support.
- Strong governance structure and strict change control process
- On-going support, training and optimisation required.
- Data Quality surveillance and development of a data strategy and framework
- Always keep the patient at the centre of the project

Chapter 4 has demonstrated the importance of accurate workflow mapping to achieve the desired goal and outcome of the workflow. An outline of the importance of patient focused workflows has been highlighted and the need to avoid workarounds or fragmentation. The AACTT framework was beneficial to underpin the workflow development in a theoretical framework and grade the workflow adherence to the framework. Workflow process mapping was outlined, and some examples of workflow adaption have been detailed based on their adherence to the AACTT framework. A new workflow was implemented for the NICE jaundice graph. Appropriately designed workflows can underpin the EHR system and encourage appropriate and accurate data entry, which can be used to assess patient care and inform audit.

The pre-post quantitative evaluation of an upgraded patient summary page within an EHR has demonstrated some very positive changes and adoption to utilising the EHR optimally in chapter 5 of this thesis. Post workflow change analysis demonstrated more structured data entry for the NICU nursing group and some increase in problem and diagnosis entry by the NCHD group albeit not consistently demonstrated throughout this group. Significant time savings were demonstrated in the nursing group which can have positive impacts on patients care delivery. This study has demonstrated the useful benefits of EHR workflow measurement by quantifiably measuring tasks associated with the workflow. The research was unique studying both nurses and doctor's workflows as most studies look at a single group of healthcare worker. The workflows of both doctors and nurses are linked together and can impact each other.

Finally, chapter 6 of this thesis involved clinician end users in the specific design of the newborn feeding within the EHR and quantifiably measured the data completeness of newborn chart. Users of the EHR contributed valuably to designing the data entry and provided valuable opinions and understanding to the research. Improvements in data completeness were observed across the NICU and most post-natal wards through the quantitative chart review. A further post implementation focus group conducted contributed greatly to the understanding users have around the prioritization of data for NICU and pot-natal ward babies, while identifying benefits to EHRs and also the resistance to the digital change. Accurate recording of feeding can communicate the newborn's progress across the multidisciplinary team. This study has positively demonstrated that a collaborative

multidisciplinary approach can improve EHR design and data quality through more accurate and complete data in the patient's EHR.

7.3 Strengths and Limitations

This strengths of this thesis have shown the benefits of using TMFs from implementation science in workflow development and EHR implementation. This is the first research to use implementation science to evaluate and develop EHR workflows. The use of quantitative research was useful in measuring workflow compliance and the use of qualitative research (used in Chapter 6) was useful to engage end users and explore their perceptions in EHR design to improve data quality. This thesis has uniquely examined and measured both medical and nursing workflows as they are inextricably linked together in patient care delivery. The different participants involved in the research (Chapters 3 & 6) has included multiple clinicians from different disciplines and has contributed greatly to this research in terms of improving EHR implementation and engaging end users in the process. The outcomes and finding of this research can be used to positively contribute to the future of digital transformation of healthcare in Ireland including the continued implementation of the Maternal and Newborn- Clinical Management System.

Limitations identified for this thesis include the research being focused on one EHR in one Health System which may limit the generalisability of findings. Limitations were also identified in terms of COVID19 restrictions and the necessity to adapt training and implementation plans for EHR changes from face-to-face, to online

and video training. The Irish health service was also subject to a criminal cyber-attack in May 2021, and this also delayed some of the research related changes being implemented in the EHR however it did not stop any of the projects.

7.4 Overall Summary Conclusion

This research has examined the benefits of implementation science research, in particular the Normalisation Process Theory and the AACTT framework, in EHR implementation and the key role of workflow evaluation and development. The implementation of the national Maternal & Newborn - Clinical Management System EHR was reviewed comprehensively, with valuable lessons learned produced. While recognising that an EHR implementation is a complex process with a myriad of influencing factors, this thesis focused on the importance of workflow design and development. Using primarily quantitative methods with some qualitative methods in chapter 6, this thesis has supported the key recommendations that clinical involvement in EHR design and adequate workflow mapping are essential to a successful EHR implementation.

Chapter 8

Implications for Clinical Practice, Research and Health Policy

Chapter 8: Implications for Clinical Practice, Health Policy and Research

8.1 Implications for Clinical Practice

This thesis has made many valuable contributions to clinical practice. The value of implementation science in healthcare practice for evidence-based changes has been highlighted with a clinical example provided using the AACTT framework of workflow development for implementing a new workflow to print syringe medication infusion labels. The use of the NPT has been appraised for large scale EHR implementations and the importance of identifying appropriate ERIC strategies for clinical implementation has been outlined (Chapter 2).

The introduction of EHRs is a complex process and includes many influencing factors, this thesis has contributed very valuable lessons learned from the MN-CMS EHR implementation which have been outlined clearly in terms of each project phase. These lessons can be utilised for subsequent phases of the project and are now available published in the literature for national and international review (Chapter 3).

This thesis focused on workflows as a key enabler of EHR implementation. The development of the MN-CMS clinical workflows was described, and the importance of clinical involvement was highlighted for appropriately mapped clinical workflows. Appropriate workflow mapping with role based *swimlanes* can map the process of each healthcare team member for the entire patient journey (Chapter 4).

The background audit logs used in Chapter 5 as the data collection method, could provide some valuable learning for helping clinicians optimise use of the

system in clinical practice. The EHR system audit logs can be used to identify issues and offer users further training and optimisation in their workflows (Chapter 5).

The final study presented in this thesis has contributed positively to improving data completeness around newborn feeding. The benefits of involving multiple clinicians from different disciplines in EHR design is essential in promoting improved quality data entry, compliant with individual workflows. Continued education, training, and awareness of the benefits of the structured data entry and the use of the nutritional dashboard are needed (Chapter 6).

8.2 Implications for Healthcare Policy

The use of implementation science is valuable and can be used and embedded within a new policy or guideline for implementation of evidence-based changes in healthcare. An implementation science framework can provide a structured pathway to achieve a successful implementation and can be modified or adapted based on the institute, the organisation or the evidenced based change being introduced. The literature suggests further work is needed in theory development to better incorporate policy considerations for implementation efforts to include researchers, policy makers and implementers[88] (Chapter 2).

A number of policy recommendations have been presented from chapter 3 including the necessity of clinical involvement in EHR procurement. Once system design has been agreed by clinicians, a strict change control process is necessary to ensure only approved changes are made design and also a robust data strategy is needed to ensure data quality is optimised. Policy should include adequate

resources and implementation teams to ensure a successful implementation (Chapter 3).

Policy needs to ensure that the team structures are in place for workflow development. Workflow design must ensure that the workflow itself is appropriate and adherent to relevant clinical policies and guidelines involving the correct actors preforming the correct tasks in adherence to their scope of work practice (Chapter 4).

The European Union provide directives on accurate data recording[95]; however, Ireland would also benefit from local and national policy guidance in EHR data entry for both nurses and doctors who interact with an EHR. This would contribute to improving the reliability of records and the available healthcare data for citizens. The development of a national data dictionary would be beneficial to standardize all data elements throughout the health service organisation (Chapter 5).

Although the Irish Medical Council (IMC) gives some guidance to medical staff on recording accurate, timely, and up-to-date medical records in either paper or electronic form, the Nursing and Midwifery Board of Ireland (NMBI) give guidance only pertaining to paper records. The NMBI, who provide professional guidance to nurses and midwives, advise regular documentation of narrative notes to document patient care and progress[163]. These guidelines are relevant to paper records but do not support nurses recording clinical structured data in EHRs. A key recommendation from the study presented in chapter 6, is that the nursing and midwifery professions need professional guidance for recording clinical care in a

structured electronic format as health services embark on digital transformation in Ireland (Chapter 6).

8.3 Implications for Future Research

Clinical research can recommend many new changes to practice and implementation science can promote the systematic uptake of these findings into clinical practice[53]. As research within the field of implementation science is evolving rapidly there is an extraordinary number of theories, models and frameworks being developed to suit various different practice changes and organisations[55]. The vast number of TMFs however can be overwhelming and difficult to navigate. Training would be beneficial to familiarise oneself with the various categories of TMFs and find the most appropriate TMF(s) to use (Chapter 2).

Future research could include an implementation review of future phases of the MN-CMS project implementation. The potential of data extraction and analysis from the EHR could potentially contribute greatly to population health for mothers and their newborns. Data science could potentially provide data and data platforms to improve patient outcomes. Future research and developments need to include the development of a patient portal providing a person with full access to their own or their child's healthcare data (Chapter 3).

More research is needed on workflow development in healthcare-based literature. Other industry led models in particular, engineering provides useful process mapping methods for workflow development, however improvements in productivity or financial are the generally the desired outcomes rather than patient

care-based outcomes. Theories, models, and frameworks from implementation science are useful in workflow development research and have been used in this thesis for the first time. Additional for future research would be beneficial in this area (Chapter 4).

This study contributed greatly to the quantitative measurement of workflow analysis and is particularly useful as a model for future research to objectively measure workflow compliance within an EHR. Additional future qualitative research exploring opinions and perceptions would also be beneficial to complement quantitative findings. Further research using background audit log files from a European perspective would be beneficial rather than a US comparison based on significantly different health care structures. Additionally, more nursing data variables are needed to describe their EHR usage across different health services and countries- most studies on workflow analysis studies look at medical workflows. In this way different nursing specialties can be directly compared, and optimisation plans can be introduced (Chapter 5).

The involvement of multiple clinicians from different disciplines is recommended in any research evaluating EHR usability and design, as each member has a unique viewpoint based on their individual workflows and uses of the EHR. Qualitative research makes an important contribution for EHR design and optimisation through providing an in-depth understanding of perceptions and beliefs (Chapter 6). Using mixed methods approaches to research in EHR workflow evaluations provides both objective data and an useful understanding of users perceptions (Chapter 6).

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Appendix 1: Implementing a process to print medication infusion labels in Neonatal Intensive Care Units using implementation science.

Sheehan OM, Bradfield L, McNabola G, Finch K, Kehoe B, Cleary B, Murphy BP, McKernan J, Greene RA.

Background

Medication errors are the most common type of medical errors in neonatal units. Sick newborns receiving high risk and complex infusions are at greater risk of medication errors. In one tertiary neonatal unit in the Republic of Ireland, the practice of ordering and recording the administration of standard concentrated infusions (SCIs) was completed on the National Newborn Electronic Health record (EHR). However, the process of labelling the syringe was a handwritten process followed by manual programming of the infusion pump. Handwritten syringe infusion labels, however, have been associated with infusion pump programming errors during simulation studies due to transcription errors. Following the software development, this project introduced the printing of medication labels directly from the ordered SCI in the EHR.

Methods

Implementation Science was used to implement this change into clinical practice. Implementation science is the study of methods, translating research into practice. The framework used was Action, Actor, Context, Target, and Time (AACTT Framework). The ACCTT framework focuses on the person and the actions needed to achieve the outcome. The AACTT framework breaks down the necessary steps and identifies the areas for change which is similar to workflow development and adaption.

	AACTT Framework
A- Action	Print Syringe Infusion labels from the EHR Order
A- Actor	NICU Nurse
C- Context	Neonatal ICU Setting
T- Target	NICU patient with a new order for a Standard Concentrated Infusion
T- Time	After the order is placed and before preparing the infusion

Results

Following assessment, a number of implementation strategies were identified and used to implement the new process. Training was required for all nursing staff; training materials were developed and distributed, champions were identified as support during the process and all required technology was acquired and in place prior to go live. Flexibility and adaption were required around training due to clinical need and clinical activity.

Conclusion

The new process of printing labels directly from the EHR Order was successfully implemented. Implementation Science is extremely useful in the acute healthcare

setting. Implementing change around complex processes for sick newborns can be aided by implementation science strategies and evaluations.

Appendix 2: Poster Presentation; Implementing a process to print medication infusion labels in NICU using implementation science.

NATIONAL PERINATAL EPIDEMIOLOGY CENTRE

Implementing a process to print medication infusion labels in Neonatal Intensive Care Units using implementation science

Sheehan, OM [1,3], Bradfield, L [2], McNabola, G [2], Finch, K [2], Kehoe, B [3], Cleary, B [3], Murphy, BP [3,5], McKernan, J [4], Greene, RA [1,2,3,4]

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Introduction and Objective

Medication errors are the most common type of medical errors in neonatal units[1]. Sick newborns receiving high risk and complex infusions are at greater risk of medication errors. In one tertiary neonatal unit in the Republic of Ireland, the practice of ordering and recording the administration of standard concentrated infusions (SCIs) was completed on the national newborn Electronic Health record (EHR). However, the process of labelling the syringe was a handwritten process followed by manual programming of the infusion pump. Handwritten syringe infusion labels, however, have been associated with infusion pump programming errors during simulation studies due to transcription errors[2]. Following the software development, this project introduced the printing of medication labels directly from the ordered SCI in the EHR.

Method

Implementation Science was used to implement this change into clinical practice. Implementation science is the study of methods, translating research into practice. The framework used was Action, Actor, Context, Target, and Time (AACTT Framework). The ACCTT framework focuses on the person and the actions needed to achieve the outcome[3]. The AACTT framework breaks down the necessary steps and identifies the areas for change which is a similar process to workflow development and adaption[3]. Mapping workflows is a key process in successful EHR implementation[4,5]

AACTT Framework	
A- Action	Print Syringe Infusion labels from the EHR Order
A- Actor	NICU Nurse
C- Context	Neonatal ICU Setting
T- Target	NICU patient with a new order for a Standard Concentrated Infusion
T- Time	After the order is placed and before preparing the infusion

Figure 1: AACTT Framework detailing the breakdown of steps required to successful implementation

Following assessment, a number of implementation strategies were identified and used to implement the new process. Training was required for all nursing staff; training materials were developed and distributed, champions were identified as support during the process and all required technology was acquired and in place prior to go live. Flexibility and adaption were required around training due to clinical need and clinical activity.

Results

The new process was implemented successfully, and end users routinely use the process to label high risk infusions daily. The measure of success in implementation science includes user acceptability and adoption based on the new workflow changes. This has been achieved and is being sustained since implementation. Handwritten labelling has been eliminated and replaced with printed labels directly from the SCI order.

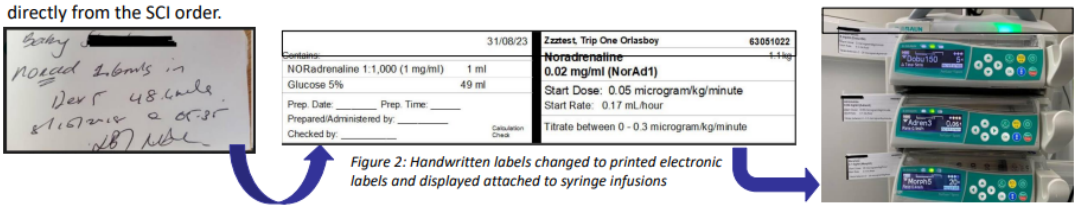

Figure 2: Handwritten labels changed to printed electronic labels and displayed attached to syringe infusions

A barrier to this implementation process was identified as hardware issues and working printers. Facilitators to this implementation were local champions and single-sign-on access to computers with a tap card process allowing users to move to computers with specific syringe label printers.

Conclusions

The new process of printing labels directly from the EHR order was successfully implemented. Implementation science is extremely useful in the acute healthcare setting. Implementing change around complex processes for sick newborns can be aided by implementation science strategies and evaluations.

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Appendix 3: MIDIRS Midwifery Digest Publication

Complex health care changes: can implementation science help?

Orla Sheehan, Brendan Murphy, Paul Corcoran, Joye McKernan, Richard Greene

ORIGINAL

Summary

In this paper we review the concept of implementation science and its use in health care, and in the area of electronic health record (EHR) implementation. We describe the theories, models, and frameworks, followed by implementation strategies and implementation outcomes. The use of implementation science in maternity and neonatal care is explored and the use of implementation science guiding EHR implementations in complex health care settings is discussed. Finally, we explore the Normalised Process Theory (NPT) in detail, as applied to EHR implementation and workflow development.

Implementation science

Implementation science is defined as the scientific study of methods to promote the systemic uptake of evidence-based practice and research findings into everyday routine practice, thereby improving the quality and effectiveness of health care (Eccles & Mittman 2006).

Implementation science has emerged primarily to advance evidence-based population health; it aims to address the challenges of implementing research-based findings into health care practice and health policy across all health care spaces (Foy et al 2015, Nilsen 2015).

Early implementation science was empirically driven without any real theoretical frameworks (Nilsen 2015); its main goal is to bridge the gap between theory and practice. There are as many as 100 terms to describe this knowledge translation into practice (Esmail et al 2020) such as translational research, dissemination and implementation (D&I) research or, most commonly, implementation science.

Implementation science in itself is the study of methods, to identify barriers and facilitators across multiple contexts and develop strategies to address these barriers and facilitators (Nilsen 2015).

Theories, models and frameworks

Over the past 20 years the use of structured theories, models and frameworks (TMF) has emerged and is being recognised in implementation science in order to facilitate implementation (Nilsen 2015). Nilsen (2015) provides a very useful taxonomy of TMF based on a narrative review of selective literature, including books and prominent implementation science journals. The terms 'theories', 'models' and 'frameworks' are often used interchangeably in implementation science (Nilsen 2015), however Nilsen (2015) has categorised the TMFs into the following:

Table 1. Categories of theories, models and frameworks

Process models	Describes/guides the process
Determinant frameworks	Determinants acting to identify barriers/ facilitators
Classic theories	Psychology/sociology theories
Implementation frameworks	Understanding of all aspects of the implementation process, including organisation level
Evaluation frameworks	Appraisal of specific aspects of implementation to determine success

Implementation strategies

Implementation strategies are the 'how' we implement and are just as important as 'what' we implement. An implementation strategy is defined as the method or technique used to enhance the adoption, implementation, sustainment and scale-up of a program/practice (Proctor et al 2013).

Implementation strategies can be used to address contextual barriers or enablers during different phases of implementation (Powell et al 2015a). For example, training alone cannot be the only strategy used to implement change, particularly if the organisational level of poor culture is not addressed (Lewis et al 2018).

Utilisation of strategies should align with the barriers and facilitators identified in various stages throughout the project, for example, if leadership is needed then the strategy needs to identify and prepare champions; if there are gaps in knowledge then training should be the strategy.

Powell et al (2015b) collated expert recommendations for implementation change (ERIC); this publication of ERIC strategies clearly outlines numerous strategies that can be used for implementation projects (Powell et al 2015b). Recently, there has been further analysis of ERIC strategies and the need to describe the actions involved with each strategy (McHugh et al 2022). McHugh et al (2022) have developed a taxonomy of behavioural change techniques associated with ERIC strategies and recommend integrating this taxonomy in implementation projects, to focus on the behaviours needed to apply a strategy.

Implementation outcomes

Implementation outcomes are deliberate and purposeful actions to implement changes to treatments, practices, or services (Proctor et al 2011). Implementation science outcomes include acceptability, adoption, appropriateness, feasibility, penetration, cost, sustainability, fidelity, and reach; each of these can be used to evaluate the process and outcome of implementation (Proctor et al 2011).

Utilisation of implementation science in maternity care

Despite a myriad of TMFs there is a significant gap for those used in maternity care (Dadich et al 2021). Implementation science and the use of TMFs in maternity care literature is very limited: only 8.9 per cent of publications reviewed by Dadich et al (2021) reported the use of a TMF, while 91.1 per cent of studies reviewed focused on factors such as barriers and facilitators (Dadich et al 2021).

The use of implementation science-based theories is often not explicit in studies as finding a one-size-fits-all approach is not feasible. Aligning evidence-based practice in health care can be challenging, largely because what clinicians do, how they do it, when they do it, and who they do it to, is shaped by myriad factors and processes (Scantlebury et al 2017). To this end, the use of implementation TMFs and strategies needs to be customised based on the particular project.

In neonatal care research, publications are limited in terms of the use of implementation science to bridge the theory–practice gap. Coutts et al (2021) use an implementation science framework to assess the barriers and facilitators in implementing kangaroo care in British Columbia neonatal intensive care units (NICUs).

Coutts et al (2021) conducted qualitative interviews and themed their outputs using the consolidated framework for implementation research (CFIR) framework (Damschroder et al 2009). They highlighted some barriers and facilitators to this practice introduction, namely organisational, individual, and physical space factors. They concluded that, although this is an evidence-based practice to improve neonatal outcomes there is no one-size-fits-all implementation plan, as each NICU has varying factors (Coutts et al 2021). Many implementation scientists recognise that TMFs need to be adaptable: each implementation project is different but also other factors, such as organisational, individuals and cultures, vary across institutions and all need to be taken into account (Esmail et al 2020).

In terms of disruptive technology, Scantlebury et al (2017) explored the benefits, barriers, and disadvantages of implementing an EHR into a maternity unit in the United Kingdom's National Health Service (NHS) context using the Normalised Process Theory (NPT). The NPT has characterised a range of domains that assist health care professionals in understanding the purpose of (coherence), engage with (cognitive participation), use (collective action) and appraise (reflexive monitoring) an EHR.

Scantlebury et al (2017) used the NPT to do a post-hoc evaluation of EHR implementation. Their study highlighted some benefits, barriers and disadvantages which are transferable to other health care organisations, such as previous failed implementations of EHRs, dual paper processes and lack of integration with other departments/systems (due to poor technology or poor workflow).

The Normalised Process Theory (NPT) and electronic health records

Health care implementations are typically complex, particularly when they consist of technological, organisational, and behavioural change, and often benefit from an overall process evaluation (May et al 2007). Process evaluation helps to understand not only the outcomes reached but the factors that promote and inhibit the intervention (May

et al 2007). May et al (2007) describe an effective implementation as something that has been made workable and integrated into everyday health care.

The NPT has its origins in sociology theoretical frameworks but it can be useful in complex health care interventions and has developed from the Normalised Process Model (NPM). May et al (2007) further explain that, although the outcomes of the implementation are important, the social interactions and processes are equally important in achieving the outcomes.

The NPM aims to describe, explain, and predict social process in complex organisations (May et al 2007). May et al (2007) explain that a process can be broken down to three core elements: the actor, the object, and the context. For example, in an EHR implementation the following could apply:

Actor = health care professionals

Object = electronic health record

Context = maternity hospital

The NPT was developed and published as a seminal piece of work by Carl May and colleagues to provide a set of sociology tools to understand and explain the social processes through which new or modified practices are enacted or operationalised in the health care setting (May et al 2009).

May et al (2009) describe their theory as being different from other cultural transmission or innovation theories, such as Rogers' 2003 theory of diffusion, and explicitly call the NPT a theory of *action*. They believe that, to embed a practice into a health care setting, the starting point must be what people actually do and how they work (May et al 2009), and the first steps to describe what is changing and for whom it is changing (Murray et al 2010).

This is similar to a workflow assessment in terms of baseline EHR implementation. A framework should begin with a clinician-designed workflow to address the flow of patient data (Humphry & Erickson 2022). At the micro-level, an EHR implementation is the enactment of a series of workflows, in a concurrent manner, across multiple health care providers, disciplines and settings. Addressing each workflow to the micro-level can facilitate a successful implementation. The NPT can be used to address workflow development and redesign.

As a baseline, the NPT begins with the 'coherence domain', that the actors will have an understanding and an appreciation of the practice as meaningful (May et al 2009, Murray et al 2010). Involving specific health care practitioners to design their own workflows, means that there is a level of engagement and expertise with the overall aims of the practice and the process needed to achieve them (Humphry & Erickson 2022).

The 'cognitive participation domain' involves the actors' commitment to a practice, and addressing the barriers and facilitators that exist for the individual to undertake the practice (May et al 2009, Scantlebury et al 2017).

The 'collective action domain' involves the factors that inhibit or promote the actors enacting the practice, such as using the system (May et al 2009, Scantlebury et al 2017). These could be related to software design, hardware issues, workflow problems, ICT literacy skills or system training.

Finally, 'reflective monitoring' relates to how well the actors/users have appraised the system and its impact on practice (Scantlebury et al 2017). Implementation science can be an iterative process whereby re-evaluation is needed at various points in the implementation process throughout these domains (Kirchner et al 2020).

Conclusion

In this paper, implementation science has been broadly summarised and its use in the maternity health care setting highlighted. The use of implementation science to guide and evaluate complex implementations, such as electronic health record (EHR) implementation, was discussed.

Normalised Process Theory (NPT) is a theory of action and provides domains of work to guide complex interventions. The NPT provides a useful framework to guide new complex practices becoming part of everyday practice. The use of implementation science is valuable in guiding health-care-related changes in maternity and neonatal settings.

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Appendix 4: JMIR Formative Research Publication: Introduction of a Single Electronic Health Record for Maternity Units in Ireland.

Viewpoint

Introduction of a Single Electronic Health Record for Maternity Units in Ireland: Outline of the Experiences of the Project Management Team

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Abstract

Electronic health records (EHRs) are being introduced worldwide. The change from paper to electronic records has not always been a seamless or quick process; however, EHRs are viewed as central to updating modern health care, especially organization structures and delivery of sustainable care with the potential for joint decision-making with the patient. The objective of this viewpoint paper is to outline how an EHR is being developed in Ireland. The focus of the Maternal & Newborn Clinical Management System project is the design and implementation of an EHR for all women and babies in the maternity services in the Republic of Ireland. The paper also outlines the lessons learned from the planning to the optimization stage of the project. The paper was developed through discussions with the project management team and their completed reports that outline the lessons they acquired from each project stage. Key lessons learned from each stage of the project are highlighted. This viewpoint paper explains how the national project management team is implementing the EHR and outlines the experiences and lessons learned and the challenges ahead following the phase one introduction. The Maternal & Newborn Clinical Management System is an example of a clinician-led, patient-focused, change management project from its inception to implementation. The introduction of EHRs is essential in modernizing health care and optimizing patient outcomes through the accurate and appropriate use of data.

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KEYWORDS

baby; babies; data management; data quality; electronic health record; health management; implementation; information management; Ireland; lessons learned; management system; maternity; maternal; mother; newborn; optimization; planning; pregnant; pregnancy; project management

Introduction

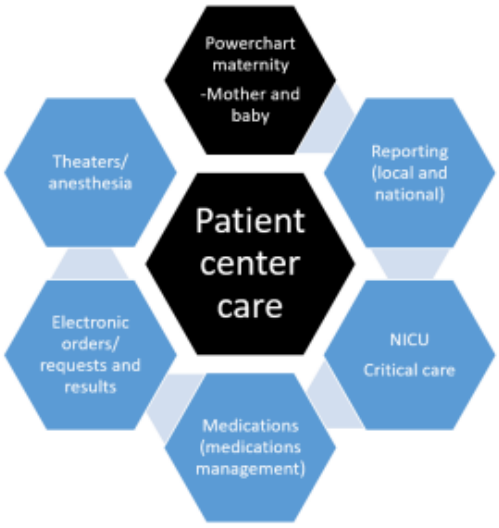
Electronic health records (EHRs) are essential in attempting to update modern health care [1] and are being introduced across Europe, North America, Australasia, and the Middle East [2]. The change from paper to electronic records has been described as complex [3], particularly in the hospital setting compared to private industry, due to the nature of the organizational setting that involves caring and curing, data security, confidentiality, and data accuracy [4]. Many complex steps have been identified in the implementation of an EHR from procurement, design, building, testing, and training through to adoption and optimization [5]. A hospital-wide EHR implementation needs to consider a number of organizational, human, and technological factors as well as organizational structure, culture, technical infrastructure, financial resources, and coordination [4,5].

The need for digital information and connection has evolved in the last 2 decades [2] and in particular since the COVID-19 pandemic with a reliance on the digital world to connect. Over half the world's population (60.9%) use the internet and two-thirds of the world's population (66.9%) have a mobile phone [6]. In Ireland, it is estimated that 3.68 million (73.5% of the population) had a smartphone in 2021 with a projected 3.8 million by 2024 [7,8]. The delivery of safe and effective health care is dependent on the availability of accurate and up-to-date data in a legible, reliable, and timely manner [9]. It is through the use of an EHR that health data can be available in the correct place at the correct time to enable timely clinical decision-making.

Maternal & Newborn Clinical Management System

The Maternal & Newborn Clinical Management System (MN-CMS) pathfinder project is the design and implementation of an EHR for all women and babies in the maternity and gynecology services in the Republic of Ireland [10]. The MN-CMS is a significant development in health care, the first electronic national system in maternity and newborn care anywhere in the world. The introduction of the MN-CMS is a necessary step in modernizing health care and it aligns with the strategic goals of the Department of Health and the eHealth Ireland digital roadmap [11]. At an international level, this national EHR implementation is the first of its kind as no other country has achieved a fully interoperable national EHR within the community or acute care settings [5,12,13]. The MN-CMS includes all the relevant processes required including order communication, medications, anesthesia, and theater as well as all clinical documentation for maternity, newborn, and gynecology (see Figure 1). Laboratory orders are a closed loop of order communication from initial order placement to laboratory results and clinical endorsement and review of results. Medications are fully electronically prescribed with assisted decision support and electronic recording of administration. The MN-CMS has the potential to design the most cost-effective models of care and establish a national epidemiological database [14], which will inform national clinical care, audit, research, and business intelligence.

Figure 1. Connected elements of the MN-CMS project including Maternity, neonatal intensive care unit (NICU), Medications and Reporting. MN-CMS: Maternal & Newborn Clinical Management System.



As of 2016, the Republic of Ireland had a population of 4,761,865 [15] (with an estimated 5.01 million in April 2021 [8]) with an average of 65,000 births a year [15]. The maternity units in Ireland vary in size: The smallest unit has about 1000 deliveries per year, and the largest unit has over 9500 deliveries [16]. The information and communication technology (ICT) systems across the units vary. Some units use only paper charts, while other units have limited electronic systems. General practitioners, who provide a shared-care model of antenatal care, in Ireland, use electronic medical records; however, the

system was not linked to the national hospital system. With the introduction of the MN-CMS, the pregnancy and birth records for pregnant women and their infants are now linked to the general practitioner systems with MN-CMS through a messaging broker system called *Healthlink*. As with the development of all EHRs, this project is a major change project not an ICT project; it involves multiple changes across all aspects of maternity services at the individual level through to the organization level. This project involves transitioning all maternity units over time to 1 single EHR. Keeping the mother and baby at the center was the primary principle set out by the project board, and it was envisioned that the MN-CMS would record practice and not decide practice [2].

Aim

The aim of this paper is to describe the key observations and lessons learned from the national project team implementing the MN-CMS.

Methods

Overview

The methods used to develop these valuable outcomes were through discussions with the project team, post go-live workshops focused on lessons learned, and the phase one closure report developed by the national project team in conjunction with key stakeholders. Following each hospital's go-live phase, a lessons-learned workshop was facilitated by the national project team with an approach of categorizing learnings through people, process, and technology. Each workshop had representation from key stakeholders from hospital management, project managers, to end users of the system. Clinicians including midwives, doctors, nurses, health and social care professionals, project managers all participated in interactive workshops which collated all feedback and lessons into the categories of people, processes, or technology. From all this feedback, a phase one closure report was developed detailing the key lessons and experiences of the project team in implementing MN-CMS. This paper describes the feedback from the workshops, discussion with the project team, and the phase one closure report categorizing the learnings in the various stages of the project, which include planning, implementation, and optimization.

The Planning Phase

The origins of the project were the establishment of the MN-CMS project board whose aim was to establish a single record and a single source of truth for health-related data for all women and their babies in Ireland [2,14]. The board had oversight to procure and implement the EHR [14] and included stakeholders from the Institute of Obstetrics and Gynecology, the Faculty of Paediatrics, nursing and midwifery, pharmacists, and representatives from the Department of Health and Healthcare ICT [2,14]. Further stakeholders such as general practitioners and anesthetists were included as the project progressed. The establishment of the project board marked the beginning of a change management project across the maternity services in the Republic of Ireland [2]. A patient representative was not included and should have been considered at this stage.

A need-based assessment was developed to establish a design specification, and this was carried out by the project board members and senior health care managers [2,14]. The assessment was in consultation with the 19 maternity units in Ireland [14]. Following the design specification, the public procurement process commenced in 2011 with contracts signed in 2014 [14]. The preferred vendor following public procurement was *Cerner* [2,14] (more recently acquired by Oracle and now referred to as *Oracle Cerner*). Finally, the MN-CMS team initiated the implementation program in 2014 [14]. This procurement process was time consuming, and strong leadership was essential when planning and consolidating scope and deciding on the preferred software vendor.

The MN-CMS national board had responsibility for ensuring a governance structure was in place [2,14]. This guaranteed a successful deployment of the EHR to the maternity service [2,14]. The deployment of phase one was with 4 units (2 stand-alone units and 2 colocated units) from 2016 and will continue on a phased basis [14] based on the availability of public funding from the relevant government departments [2,14]. A strong governance structure is a requirement for the success of a project.

Once the vendor had been appointed, numerous work streams were established for each clinical area such as maternity, neonatal, medications, health and social care professionals, order communications, clinical reporting, and research [14]. Representation was sought from each of the 19 maternity units in the country [14]. Each work stream developed multiple workflows based on their specific delivery of care such as the maternity booking visit, return visits, admissions, labor, and delivery, elective and emergency cesarean section, stillbirth and neonatal death, blood transfusion, neonatal intensive care unit (NICU) admission and discharge [2,14]. One NICU work stream was established, however, in hindsight; this should have been a NICU or newborn work stream based on the patient rather than any particular health care professional, as it led to different views and data entry for each health professional caring for well babies and NICU babies. A key to design and development was to sit down with multidisciplinary team experts and map out all current workflows; then design the new workflows with input from the system specialists. Adequate representation is essential for workflow development. Crossover of work streams is necessary, for example, NICU or newborn leading to 1 baby chart design rather than different views for postnatal midwife and neonatal staff. Key lessons from the planning phase are outlined in Textbox 1.

Textbox 1. Lessons learned from the planning phase of the Maternal & Newborn Clinical Management System (MN-CMS) implementation.

Planning Phase Lessons

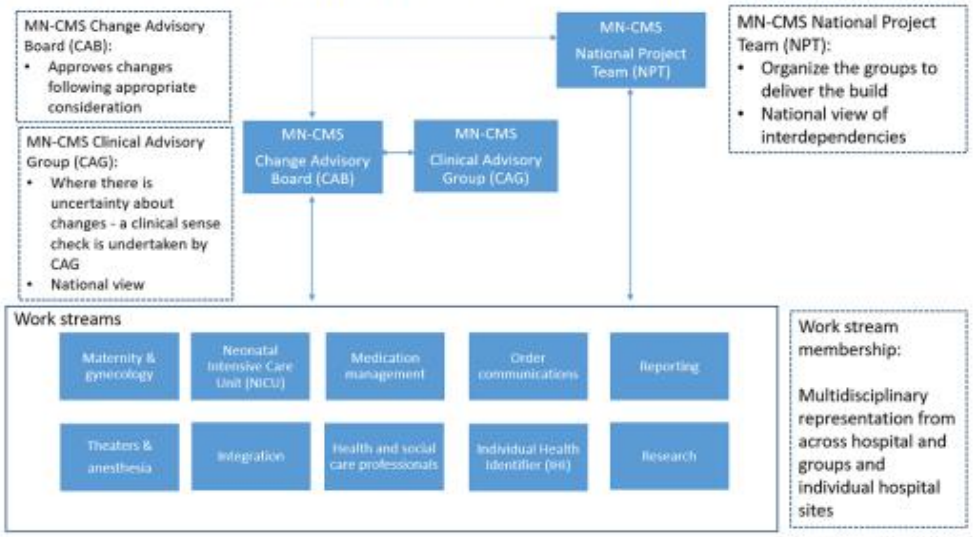
- Patient representative at an early stage
- Strong leadership needed for initial procurement
- Strong governance structure required throughout the project
- Involve the clinical teams and experts in workflow development

The Implementation Stage

The responsibility of the phase one implementation rested with the implementation team that was established in 2014 [2,14]. This project team initially consisted of a small team with clinicians at the center of this team [2,14]. Over time, the scale of the EHR implementation challenge highlighted that additional resources were required [14], and that clinical staff were instrumental in all elements of the project [14]. An adequately resourced project team is essential, and a realistic expectation of the commitment and responsibility expected should be clearly defined for those involved.

The previously mentioned clinical work streams conducted the current state analysis by working with the national project team and the vendor. This current state analysis mapped the current workflows of all the hospitals in the phase one sites [2,14]. This involved mapping the patient journey from the first referral to the hospital for care right through the discharge process following delivery for both mother and baby [14]. Between the maternity and NICU work streams, approximately 54 workflows on average were mapped for each hospital [14]. This process required relevant clinical personnel familiar with their own area and delivery of care and a functional structure to achieve this. Figure 2 outlines this structure.

Figure 2. Outline of work streams required for MN-CMS project. MN-CMS: Maternal & Newborn Clinical Management System.



The future state analysis was developed from the current state workflows [14]. This process transformed the patient journey into the new electronic environment of future state workflows that would be the foundation of design and build for the EHR [2,14]. The future state analysis is the key foundation for the design and building of the system, and gaining consensus across all sites is beneficial.

The design and build phase involved a collaborative approach across the national project team, the vendor, and the work streams [14]. This phase of the project was challenging due to the complexity involved in designing and configuring a comprehensive EHR [2,14]; the work streams had representatives from all 19 units. This complexity of this work was underestimated by all involved [14]. The recommendations made were fed back to the national team and the vendor [14]. Inclusion from the broader work stream group is necessary to assist buy-in to the project. However, a smaller group, comprised of clinicians and subject matter experts, made final decisions on the design, and the vendor then completed the configuration and build [14].

The purpose of the future state validation was for the MN-CMS team and work stream members to present the system with the final design and build to those working in the maternity services [14]. It was an opportunity for attendees to gain an

understanding of how it would work in their hospital by demonstrating various patient journeys and workflows [14] and allowed them to get some hands-on experience with the system [2,14]. The future state validation needs to reach as many people as possible, and champions from individual hospitals need to be engaged with the process.

In terms of changes to the system, there is a strict change control protocol in place since the completion of the design and build phase [2,14]. A requested change to the system may have significant knock-on effects on individual workflows or indeed individual units. To this end, weekly meetings are held to manage and review change requests by the Change Advisory Board [14]. Requested changes in the system are assessed individually as 1 change for 1 unit may not be acceptable in another, all changes need to be agreed by all units, and all work streams affected before being implemented [14] in the live production environment, maintaining a national core. Changes are first implemented and tested in a test environment before progressing to production. A change control policy needs to be strict and adhered to, throughout the process. The impact on the workflow and training needs to be assessed with each change. A test or nonproduction environment is necessary to test the change prior to implementation in the live system.

The testing phase consisted of 2 phases—system and integration testing [14]. Test scripts were created, by clinicians, based on the clinical workflows and the various scenarios that might occur for both mother and baby [14]. The system testing phase involved testing the system against the workflows to ensure the design was functioning as expected [2,14]. Integration testing consisted of testing the systems with all other third-party systems (eg, patient administration system and laboratory information systems) [14]. This testing was undertaken at each individual site based on different patient administration and laboratory information systems and to validate their workflows [14]. Integration testing also included the testing of printers, wristbands, and barcode scanners [14]. Device integration with the EHR for the neonatal vital signs monitors and ventilators and the fetal monitoring (cardiotocograph-monitoring) solution—FetaLink (FetaLink provides a graphical display of the relationship between fetal heart rates and contraction data in the EHR. It displays waveforms and annotations, which can be viewed in real time by care providers in inpatient or outpatient settings [2]) were all tested during this testing cycle [14]. These devices were tested using demo modes and simulations. The Downtime System Access Viewer (724) used to view the patient chart in the event of a planned or unplanned downtime also had to be tested at each site [14]. All test issues were logged to a web portal accessed by the project team and vendor. Each test issue was prioritized, fixed, and retested and then closed by the clinical team of testers [2]. Testing takes time with a large team. The allocated team in this project was too small. The personnel involved in testing need to be subject experts and expert users with on-the-ground clinical knowledge of the workflows and processes in each site.

The first steps prior to the deployment of MN-CMS were a Wi-Fi connectivity survey of each site, and an assessment of the extra power points, data cables, and ports required for the new hardware was installed in each unit [14]. The additional infrastructure required to implement MN-CMS included computers on wheels, desktop computers, electronic whiteboards, printers, scanners, and barcode readers [14]. The purchase of these items followed the national procurement process and was a multidisciplinary exercise involving ICT, biomedical engineers, end users, and infection control teams [2,14]. Local ICT teams are essential and need to feel part of the project, and issues arising need to be solved as a single local EHR team. Ongoing support by local ICT of hardware devices and connectivity is essential.

Approximately 2500 staff benefited from training, across the 4 phase one sites [14]. Classroom-based training consisted of 1-3 days duration depending on their system role [14]. Training course plans were prepared based on patient journey workflows, the train domain was populated, and following a train-the-trainer program training was provided to staff in each hospital by their peers [14]. These trainers initially provided intense training to a group of superusers (both trainers and superusers were an invaluable support for the early weeks of go-live to support colleagues in each clinical area [2,14]). The trainers localized their training plans for their specific hospitals and kept detailed training records to ensure that all staff attended training [14]. Logistic planning was essential to schedule the training and the backfilling in clinical areas as staff were released to train. Personnel need to be identified to deliver training and support to medical, midwifery, nursing, other health care professionals, and administration disciplines. These are vital roles, and some will be required after go-live. Providing a play domain (not available in this project) for staff post training would be beneficial—staff need to build their confidence through familiarization and practice.

The go-live phase involved setting up of user accounts, deployment of passwords, data migration, and the staffing of a 24-hour, 7-day-a-week command center to support staff over the go-live weekend and the post go-live early live support period. Each go-live was supported on the ground by the members of the National Project Team, the vendor, the team of engineers and solution specialists, project managers, and staff from the other phase one sites [2,14]. Data migration began in the weeks coming up to go-live for all patients close to term (end of pregnancy) and for inpatients (women and babies) who were expected to remain for a period after go-live. If a woman delivered and was documented on paper before go-live, they remained on paper. Patients who were attended in labor after the go-live time had delivery documentation on the EHR and completed their care on the EHR with appropriate agreed data documented including past history, allergies, medications, and risk factors [2]. There was a "wash-through" period before all paper records were removed [2]. The go-live phase was a big bang, done over a weekend to allow a phased introduction of the EHR to inpatient care, then outpatient care after the weekend [2]. All ward managers should be trained as superusers, this ensures they can feel confident in supporting their ward staff over go-live. This was not achieved for our first go-live, and the deficit was quickly recognized and corrected for future go-lives.

The go-live phase is the focus of the project from inception—it is the prize for the project team and the individual service. This

is necessary to achieve the target worked on in the project. However, the local project team or an equivalent team of subject experts and expert users' needs to be in place before go-live and ready to carry on support and optimization through training, assessment, and development of workflows and associated documentation and identifying and getting fixes for identified risks in the new world of digital documentation. A clear transition team and a plan to assist with the adoption and optimization of the new business model are needed before the go-live phase.

The implementation of electronic medicines management within an EHR offers the potential to streamline patient care and to engineer safe medication use processes [2]. Currently implemented within MN-CMS are clinical decision support functionality including allergy checking, interaction checking, dose range checking, customized enterprise rules, weight-based dosing, prewritten order sentences, and care plans [2,14]. Electronic prescribing has been demonstrated to promote safe and effective prescribing practices and to reduce the risk of errors [2,14]. The system facilitates clinical pharmacy services which have been demonstrated to improve patient outcomes and reduce the risk of serious patient harm [14]. The benefits of getting the medication management right will have implications for patient safety; however, it does need to be resourced adequately through funding and staff. Key lessons from the implementation stage are outlined in Textbox 2.

Textbox 2. The implementation phase of a lesson learned.

Implementation stage lessons

- Adequately resourced project team and clarity of the commitment needed is essential
- Relevant clinical personnel to clearly outline workflows
- The Future state analysis is the key foundation for the design and build
- Design involves a wide team, but some final design decisions were made by a smaller group
- The Future state validation needs to reach as many as possible to fully engage with the process
- Strict change control process and approval is essential
- Testing requires a large team of clinical users and subject matter experts
- Local information and communication technology involvement is essential
- Peer trainers need to be engaged early and these vital roles are required post go-live in the support phase
- All ward midwife or nurse managers should be trained as superusers ensuring they are confident to support their staff over the go-live period
- A transition team is needed post go-live to assist with the adoption and optimization of the new business model
- Medication management benefits can have positive implications for patient safety, but it does need to be resourced adequately

Optimization Phase

The medication management element of the EHR was developed by the MN-CMS project team including clear order sentences with correct formulation dose [2]. Some medication errors were highlighted early post go-live as a key area that could be improved to enhance patient care. Enhancements such as the development of care plans, weight-adjusted dosing among others led to safer prescribing [2]. The EHR allows enhanced assessment of medication error, and while this takes resources and time and subsequent staff training it is an essential element toward better patient safety.

The reductions in documentation time should allow for better records [2,14]. Staff can now avoid duplicating information (as they did on paper); an example is developing the baby chart transcribing information from the mother's chart—an instant transfer of agreed information saves time [2]. Easy access to records allows for all telephone consultations to be easily and clearly documented as part of the record [2,14]. Ongoing staff training is required to fully assist in the efficiency of their documentation [14].

In terms of data quality, routine data collection needs to be simple, clearly defined and an integral part of normal care, and the responsibility of all health care staff [2,14]. The need for high-quality and accurate data was recognized early in conjunction with European Union directives [17]. Data quality personnel were put in place to check for data errors based on output reports [2,14]. Local information governance teams were set up to ensure the integrity of the data. The National Project team also has an Information Governance Group to deal with issues on a national basis for a single national system [2,14].

The MN-CMS now has the capability of producing clinical reports for audit, research, financial, and management requirements. These reports have taken time to build and test; however, they will be an invaluable data source in the future [2,14]. The reporting function has highlighted data quality issues related to poor data entry. Mitigation has been put in place; processes including the employment of data quality staff, daily data quality checks that highlight where issues arose from these checks, and staff are then contacted and requested to complete the data they have omitted [2,14]. Based on normal care documentation, Ireland's maternity and neonatal service will have a high-quality database to assess the quality of that care [2]. Demographic information for all patients will be easily accessible, and data that would not have been available before will now be available [2]. Routine data collection needs to be simple, clearly defined, and an integral part of normal care and the responsibility of all health care staff [2]. Detailed

consideration of the data elements required in the planning and configuration is vital and proved valuable in this project. Ensuring staff know their responsibility for data quality when entering data needs to be part of their training. Data quality assessment is required and appropriate responses including identification of errors to staff, further training for staff, and changes in configuration as required.

Patient involvement is necessary, and the project worked with the Women's Council of Ireland to develop women's focus groups to discuss the development of the EHR and take advice from patients [14]. One of the interesting lessons from this engagement was the belief that we had already digitized the care documentation—we were behind the public expectation. Patient access to their information was considered very important. MyHealthPortal will be a national web-based site designed for use by patients and their caregivers [2,11,14]. Its purpose is to engage patients in self-care, joint decision-making and empower them to take a more active role in their health care management [2,11,14]. This element of the MN-CMS project has not been set up to date. Prior to the EHR for the duration of their pregnancy, women did have access to their paper medical charts. The MN-CMS board is committed to ensuring women have this access again [14]. This element is key as internationally, as there is an ambition toward providing patient-accessible EHRs [2,18,19]. There are, however, some limiting factors that include security and privacy concerns, legal constraints, and low uptake of other web-based resources for patients [20]. Engagement with patient representatives early in the process is necessary. As go-live is approaching inform patients during their visits of the expected changes and potential disruption as the hospital transitions to an electronic-based record for their care.

MN-CMS trainers are an invaluable support to the local project teams and to the end users on the ground. Since go-live, the 4 sites have engaged with their end users in optimization sessions where new, advanced, and updated functionality has been taught. There is always ongoing, or business-as-usual training of new staff and locum doctors being carried out throughout the year [14]. Keeping the initial trainers and superusers involved throughout the process will lead to them being champions and optimization agents, in the future.

The MN-CMS has allowed clinical decisions support systems and educational links to be built into the system. These, for example, include visual color clues for abnormal values, the Irish Maternity Early Warning System, a sepsis alert algorithm, and reference text from national guidelines. There is also education-oriented documentation including that for shoulder dystocia (Figure 3) and sepsis. The increased functionality of the EHR allows staff to fully engage with it and be assisted in the care they provide through built-in clinical decision support systems. Key lessons from the optimization phase are outlined in Textbox 3.

Figure 3. Example of educational documentation in MN-CMS—shoulder dystocia. MN-CMS: Maternal & Newborn Clinical Management System.

Textbox 3. Optimization phase lessons learned.

Optimization phase lessons

- Enhanced assessment of medication errors is essential towards adequate patient safety
- Ongoing staff training required to fully assist documentation efficiency
- Data Quality personnel need to be resourced early in the project and in post before go-live. A data strategy and framework need to be developed
- For relevant reports, data entry requirements need to be planned and configured in advance. Ensure staff understand their responsibility is data accuracy and completeness
- Engage with patient representatives through the go-live and informing them of potential disruptions
- All trainers and superusers should be kept involved and fully utilized
- Decision Support tools in the electronic health record assist staff in the care they provide

Discussion

Digital technologies have transformed private industries such as banking, finance, transportation, navigation, internet search, retail, and now EHRs may bring the same revolutionary change to health care [18]. Globally, however, the overall implementation of EHRs has not been as successful as anticipated, and the benefits of EHRs have been slow to be realized [2]. It has been recognized that health information systems are needed, but key events in recent years have highlighted the need for this even further [21]. First, the global COVID-19 pandemic has accelerated the need for sharing of health data in the interest of public health [21], and, second, in Ireland the cyber security breach on the Irish Health Service Executive in May 2021 underlined the need for trust in data information security and the protection of health data [21]. The data generated from a national EHR have the potential to save lives around the world [22]. The Goldacre Review in the United Kingdom's National Health Service has identified that data stored on tens of millions of people could have a huge potential on improving patient outcomes and saving lives if it is used and analyzed appropriately [22].

This paper has outlined the lesson learned in the Irish context for the development of the maternal and newborn EHR. The MN-CMS is an example of a clinician-led, patient-focused, change management project from its inception to implementation. The National Project team maintained patient care at the core of the development and implementation of this EHR and has provided valuable lessons for future EHR implementations. The importance of clinical leadership was integral throughout the process from planning, implementation, and optimization. Additionally, having the right people involved at the right stages of the project was essential. Challenges arose in terms of resourcing and often the same person was involved across multiple work streams such as testing, training, and change management [14]. The National Project team has since expanded and increased its resourcing since phase one. The key to ongoing support and optimization has been highlighted as essential to maintain the data quality and data input into the system. Regular data quality checks and ongoing training are essential post go-live. The key recommendations are summarized in Textbox 4.

Textbox 4. Key summary of recommendations.

Summary of recommendations

- Clinical leadership is essential throughout the project
- Involving the right people at the right stages of the project; for example, clinical staff needed for workflow development and information and communication technology staff needed for hardware setup
- Adequately resourced team for various stages; for example, clinical, medications, testing, training, and support
- Strong governance structure and strict change control process
- Ongoing support, training, and optimization required
- Data quality surveillance and development of a data strategy and framework
- Always keep the patient at the center of the project

Following the phase one implementation, the MN-CMS now encompasses 40% of all births in the Republic of Ireland [10] and provides the foundation of a national EHR [14]. The MN-CMS generates approximately 50 reports per day, which guides both planning of care and epidemiological research and audit reporting. Reports generated include daily delivery lists, admission and discharge reports, and reports for the General Register Office to name but a few. The ongoing deployment of the MN-CMS is dependent on future funding and resources from the Irish Department of Health. Phase 2 has gained approval and will progress over the next 2 years incorporating all the tertiary centers in Irelands and 70% of births. Devin et al assessed the impact of the introduction of MN-CMS in 1 tertiary site by measuring task distribution of neonatal intensive care staff [23]. This assessment concluded that the EHR introduction did not redirect time away from direct patient care

as other studies have reported [23]. Some EHR implementations have negatively redistributed time toward documentation and medication management and away from direct patient care [23]. The Irish Health Information Quality Authority proposes that effective engagement (professional and public), technical and operational, legislative frameworks, and governance structures are the cornerstone of informing policy on the collection, uses, and sharing of health data [21]. The MN-CMS has demonstrated these pillars in the EHR implementation.

The future of EHRs has an exciting future with new technologies such as vital signs to be automatically recorded into the chart, direct dictation to the record and even automated assistants that listen to the interactions between doctor and patient, and from verbal cues record the information in the examination room [18]. Interactive patient portals will allow patients not only to review their data (ensuring accuracy) but also to input information prior to consultations and assist self-care as part of chronic disease management [2]. Following a public engagement in the Republic of Ireland, 82% of people want access to their own health information [24].

The volume of data contained in an EHR has significant potential to positively influence all of our lives if used correctly and adhering to all data protection and legislation [2,22]. The potential to use data may be the greatest effect on health care and will come from data science using the information available in the EHR [2]. Data are the core of improvements in health care, and with the correct and appropriate analysis improvements can be realized in quality, safety, and cost-effectiveness of care across the entire health service [22]. The governance of data, however, is key to the continued success of the development of the EHR. Patients need to be informed of how their data are used, why they are used in a particular way, and how that can improve care and conditions for themselves and others [2]. They also need to know their data are respected and entered correctly based on European General Data Protection Guidelines [17]. Academic institutions have realized the importance of health informatics and the importance of data retrieval, and they are now providing modules at the undergraduate level to prepare medical professionals [25]. The Goldacre review recommends the introduction of trusted shared data platforms to rapidly capitalize on skills and data usage [22]. The introduction of new analysts, academics, and innovators can provide well-curated data and accessible technical documentation to improve patient outcomes [22]. The potential value of data science is well recognized in the ICT world; tech guru, Vinod Khosla, has suggested that "*In the next 10 years data science will do more for medicine than all the biological sciences combined*" [26]. It is likely that big data will assist us answer questions about the best care that would not be possible if we await randomized trial approaches [2]. Getting to this latter point in development requires significant work in the planning and development of the EHR, the change management to move from a paper environment, and the need for ongoing training and optimization to assist staff interaction with the system thereby enhancing the data quality that will allow big data output to assist care. The change management process in moving to an EHR environment needs to be patient centered, clinician led, and ICT supported. Our experience shows some of the lessons we have learned.

Conclusions

This paper has outlined the implementation of a national EHR for mothers and babies in Ireland. The experiences and lessons learned from the national project team have been explored and summarized. Key recommendations are that clinical leadership and strong governance are essential as well as having an adequately resourced team. Ongoing training and optimization are necessary, and data quality surveillance can lead to more accurate reporting from the system. The potential of accurate cumulative data from EHRs can have a positive influence on population health through appropriate analysis. Keeping the patient at the center of the project was always paramount. The MN-CMS has been successfully implemented into 4 maternity units in Ireland and encompasses 40% of births with a plan to expand further in the future.

Conflicts of Interest

None declared.

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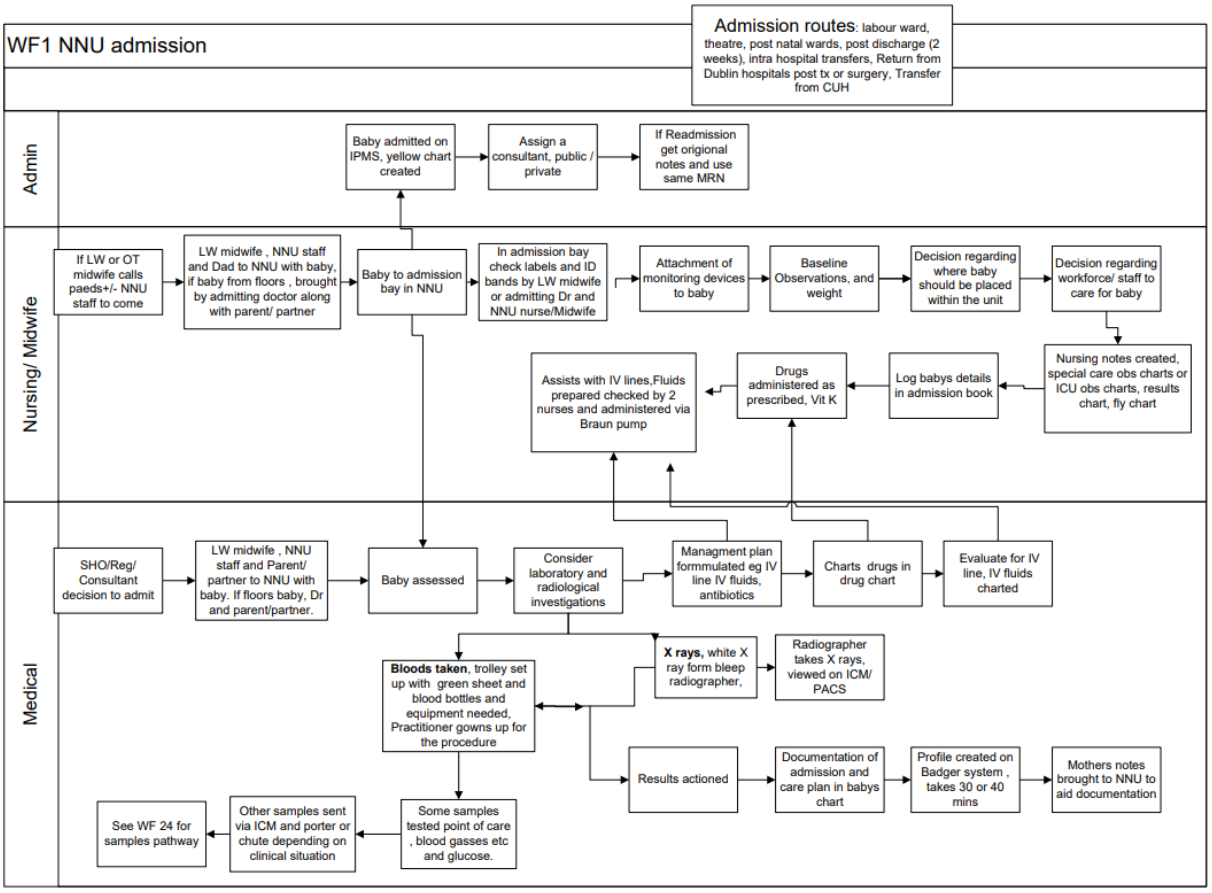
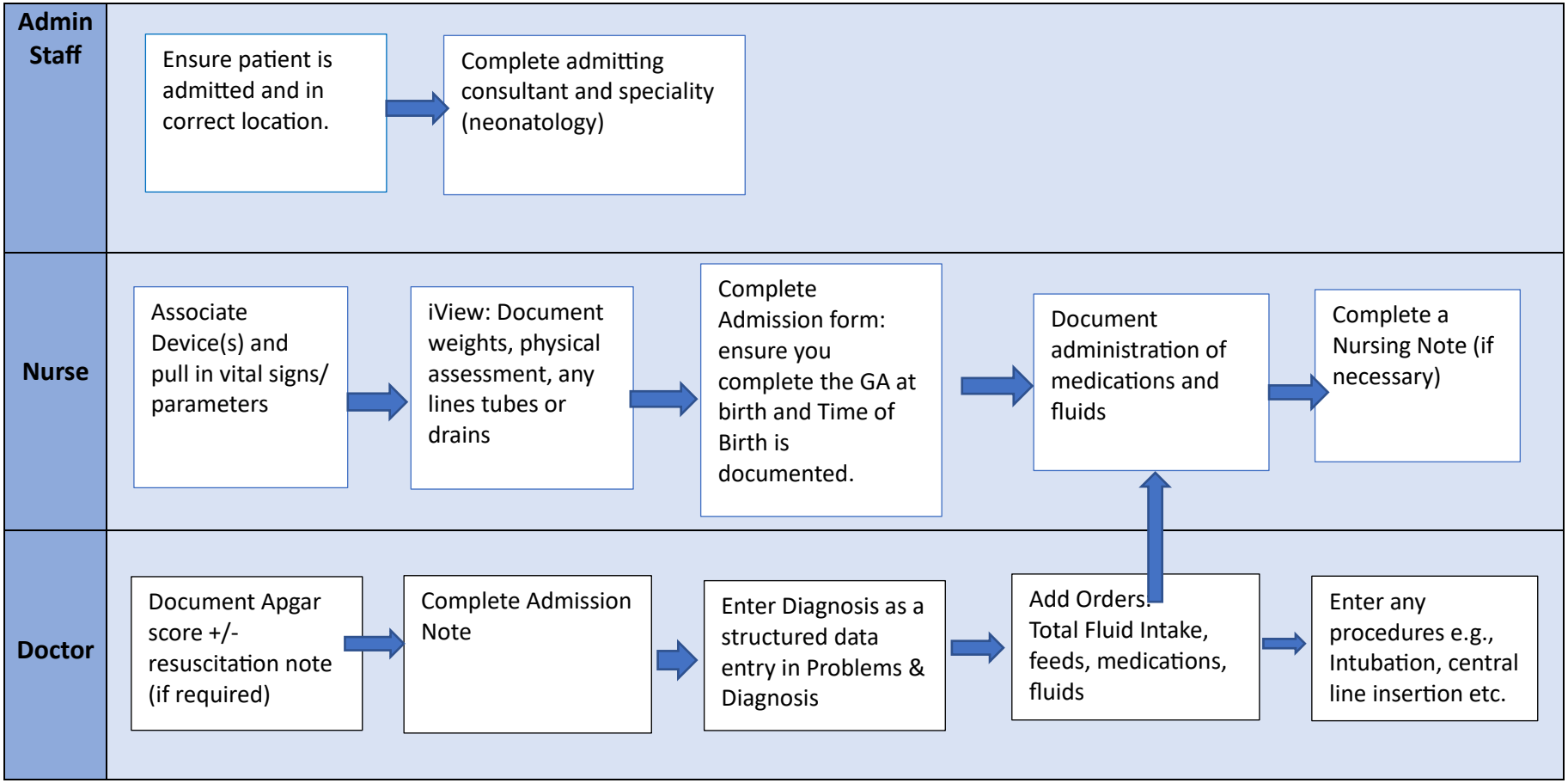
Abbreviations

EHR: electronic health record
ICT: information and communication technology
MN-CMS: Maternal & Newborn Clinical Management System
NICU: neonatal intensive care unit

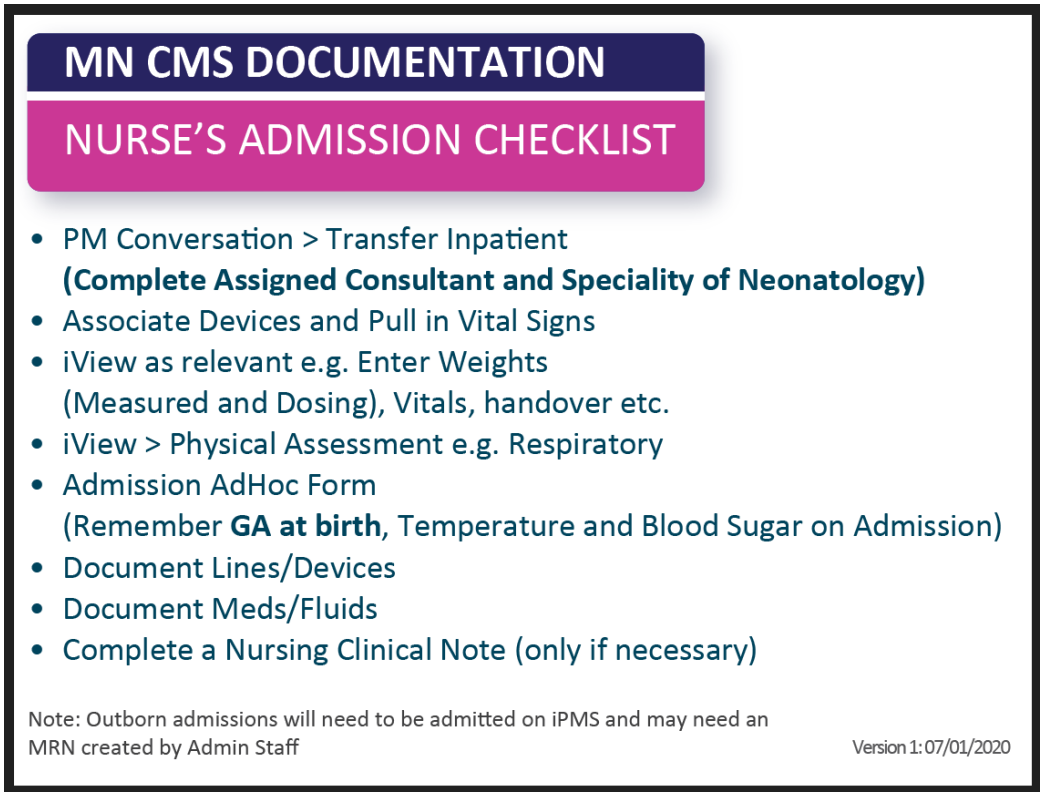
Appendix 6: Workflow mapping describing the paper-based admission of newborn to Neonatal Unit



Appendix 7: Future State Workflow process for admission to NICU for administration staff, nurses, and doctors.



Appendix 8: Nursing Workflow Checklist



MN CMS DOCUMENTATION

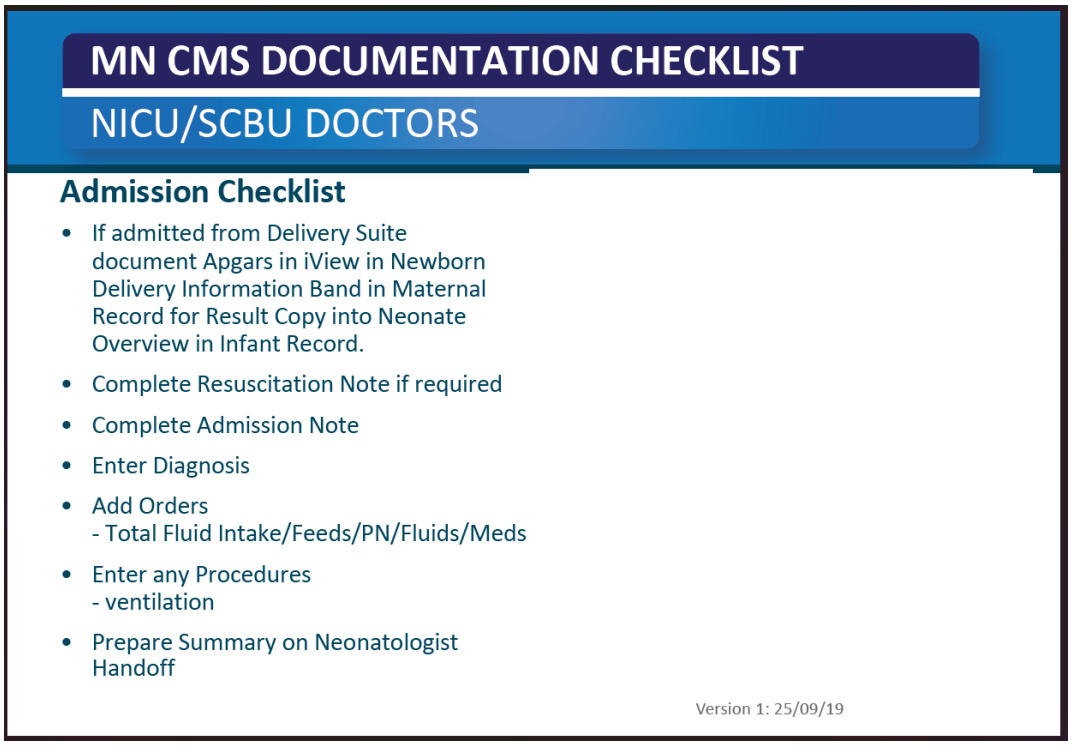
NURSE'S ADMISSION CHECKLIST

- PM Conversation > Transfer Inpatient
  (Complete Assigned Consultant and Speciality of Neonatology)
- Associate Devices and Pull in Vital Signs
- iView as relevant e.g. Enter Weights
  (Measured and Dosing), Vitals, handover etc.
- iView > Physical Assessment e.g. Respiratory
- Admission AdHoc Form
  (Remember **GA at birth**, Temperature and Blood Sugar on Admission)
- Document Lines/Devices
- Document Meds/Fluids
- Complete a Nursing Clinical Note (only if necessary)

Note: Outborn admissions will need to be admitted on iPMS and may need an MRN created by Admin Staff

Version 1: 07/01/2020

Appendix 9: Medical Documentation Checklist



MN CMS DOCUMENTATION CHECKLIST

NICU/SCBU DOCTORS

Admission Checklist

- If admitted from Delivery Suite document Apgars in iView in Newborn Delivery Information Band in Maternal Record for Result Copy into Neonate Overview in Infant Record.
- Complete Resuscitation Note if required
- Complete Admission Note
- Enter Diagnosis
- Add Orders
  - Total Fluid Intake/Feeds/PN/Fluids/Meds
- Enter any Procedures
  - ventilation
- Prepare Summary on Neonatologist Handoff

Version 1: 25/09/19

Appendix 10: Memo following go-live of the workflow change needs for Apgar data entry focusing on the Actor and the Context

Feidhmeannacht na Seirbhíse Sláinte
Health Service Executive

Cork University Maternity Hospital,
Health Service Executive,
Wilton
Cork.

MEMO

From: Executive LIT
Date: 24/08/2017

Documenting the Apgars

There are 3 different types of scenarios

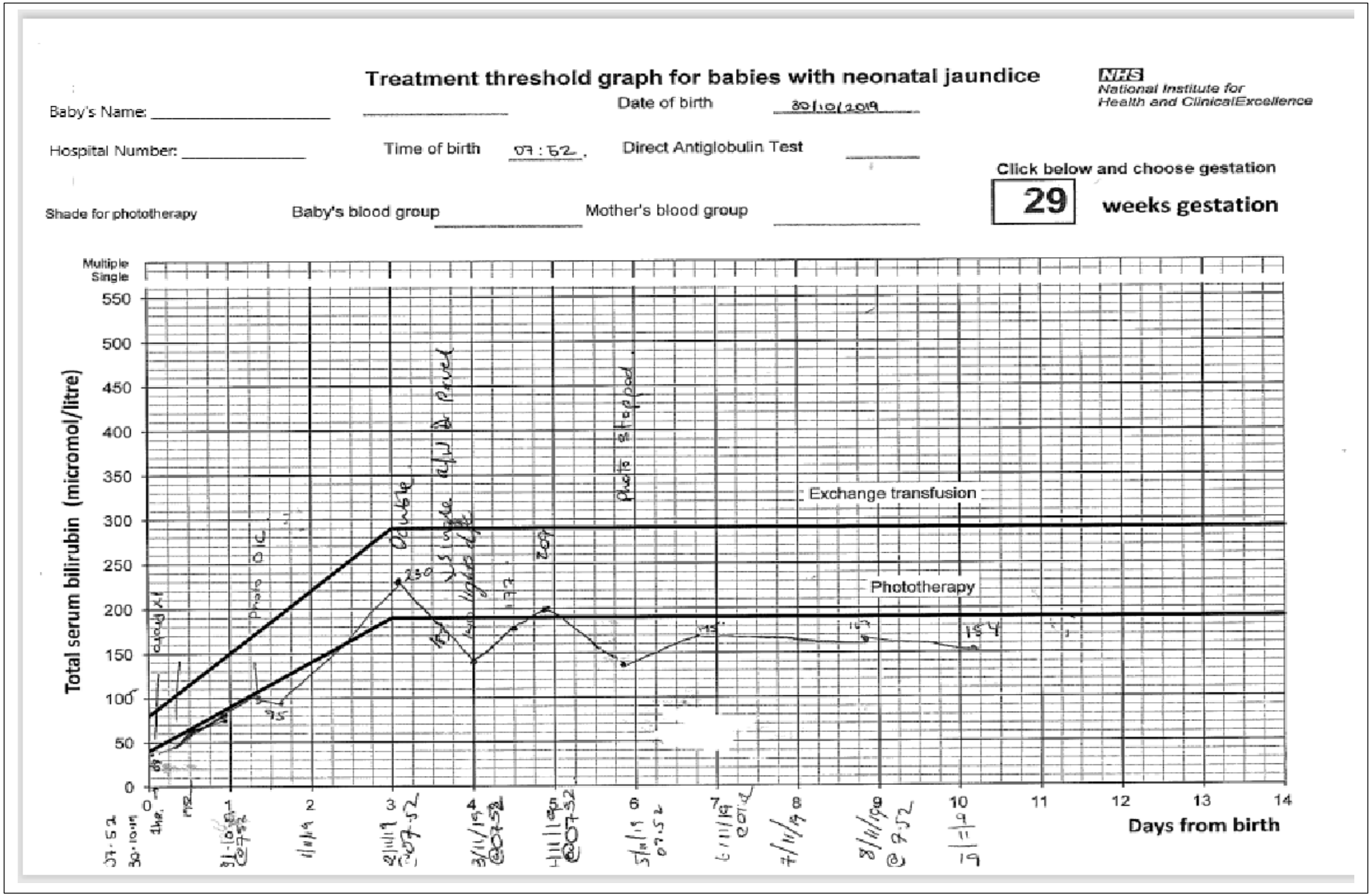
1. Well Healthy Baby: Midwife documents in mother's chart and result copy across to baby chart

2. Baby who needs initial Resus: by either Midwifery /Paeds and not admitted to NNU

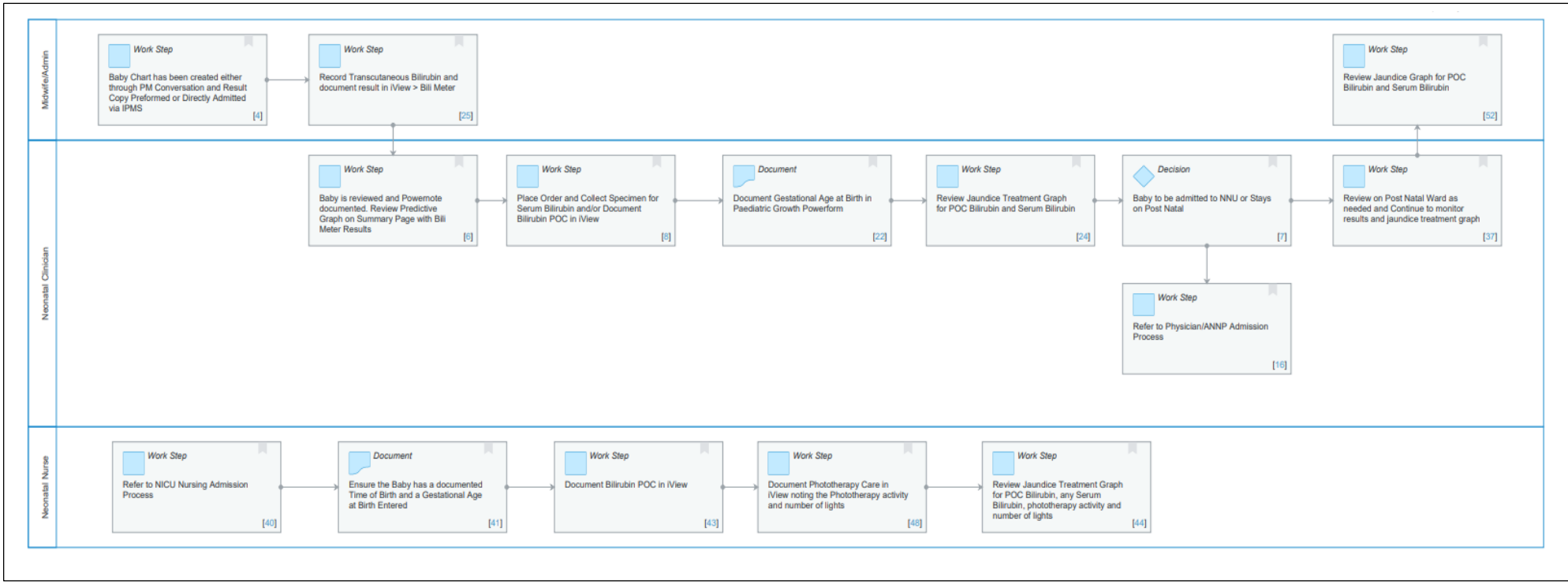
    a. Apgars are agreed by both Paeds and Midwife
    b. Entered into iView by Midwife in iView in Maternal Chart
    c. Paeds name is entered in the "Assigned by" field by Midwife

3. Sick Baby: Needing transfer to NNU. Apgars entered by Paeds in mother's chart and result copied across

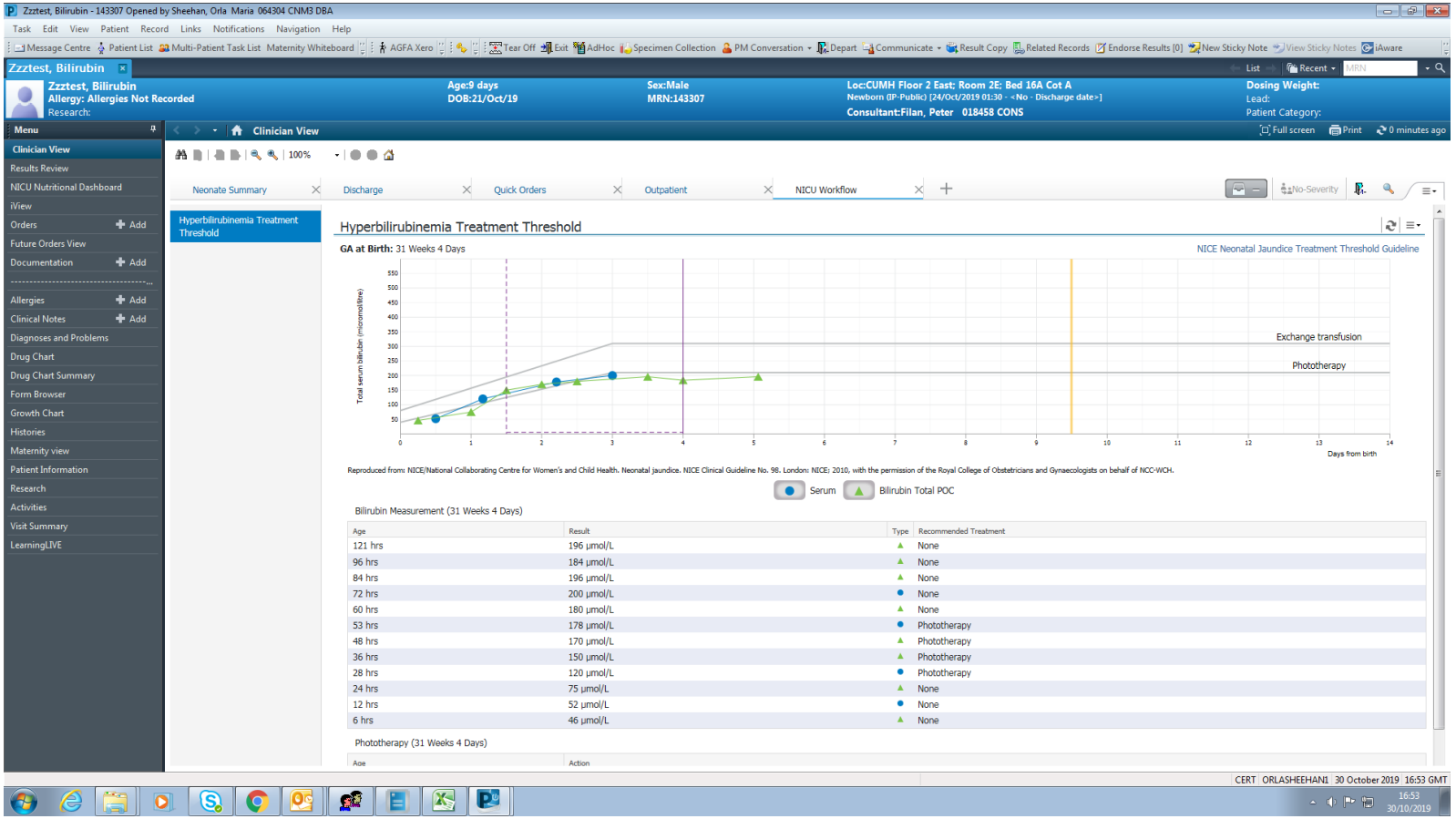
Appendix 11: Example of paper jaundice treatment graph



Appendix 12: Workflow design for the new jaundice treatment graph detailing the necessary steps to be performed by particular staff.



Appendix 13: The NICE Jaudice Treatment Graph from the MN-CMS EHR (using test patient) displaying treatment threshold lines, point of care and serum bilirubin plotting and phototherapy activity.



Appendix 14: Impact of an Upgraded Patient Summary Page: Measuring Workflow Compliance in a Neonatal Electronic Health Record (Peer-reviewed publication in the Journal of Informatics Nursing)

Impact of an Upgraded Patient Summary Page: Measuring Workflow Compliance in a Neonatal Electronic Health Record

Orla Sheehan, Richard A. Greene, Paul Corcoran, Joye McKernan, and Brendan Murphy

This quantitative study measured workflow compliance following an upgraded electronic health record summary page. Data were collected using audit log files and analyzed. Some positive improvements were demonstrated for key workflow tasks; significant time savings and more structured data entry were observed.

Key Words: electronic health record, EHR, workflow, optimization, neonatal

Health care can generate huge volumes of data daily (Health Information and Quality Authority [HIQA], 2017). The delivery of safe and effective health care can depend on the availability of accurate and up-to-date data in a legible, reliable, and timely manner (HIQA, 2017; Ireland Department of Health, 2013). The entry of structured data using discrete data fields not only standardizes data entry for direct patient care but also has potential advantages for secondary analysis and epidemiology research (Bush et al., 2017). However, direct data acquisition from clinicians remains one of the largest obstacles to optimizing the electronic health record (EHR) (Bush et al., 2017). This article describes a quantitative study that measured workflow compliance following an upgraded patient summary page in a national neonatal EHR using pre- and post-measurements of key users of the neonatal EHR.

Workflows

EHR implementation in the hospital setting can be complex (Boonstra et al., 2014; Maguire et al., 2018). However, it is a necessary part of modernizing health care, enhancing the availability of patient data for healthcare providers, and promoting health equity (Acholonu & Raphael, 2022). The inability of an EHR system to meet the workflows of end-users and organizations is often cited as negatively impacting its success (Ross et al., 2016; Sligo et al., 2017).

A clinical workflow is a series of steps enacted to perform a certain clinical activity, such as inpatient admissions to a healthcare facility (Zheng et al., 2020). In the clinical setting, workflows can be complex and multifaceted with numerous interdependencies of various healthcare teams (Zheng et al., 2020). Creating and adapting both the technology and work practices in workflow development are key factors in implementing an EHR (Boonstra et al., 2014), and there is a need for flexibility in digital change transformation (Maguire et al., 2018). Suboptimal workflows will eventually promote users working around the EHR (Zheng et al., 2020) and drive EHR dissatisfaction due to usability issues (Howe et al., 2018; Zheng et al., 2020).

Workflow measurement is essential in assessing compliance. Zheng and colleagues (2020) recommend measuring workflows by breaking them down to various tasks and using time-in-motion studies or audit logs. Time-in-motion studies can be labor-intensive and subject to individual bias (Zheng et al., 2020). Whereas EHR system audit logs are useful for measuring various workflow activities objectively (Zheng et al., 2020) and have been successfully validated and used in previous studies (Karp et al., 2019; Overhage & McCallie, 2020; Wu et al., 2018).

Background

The Maternal and Newborn Clinical Management System (MN-CMS) is a national EHR for mothers and newborns in the Republic of Ireland. Recently, the neonatal EHR updated the patient summary page to upgrade the software and optimize the clinical information available to users. Software upgrades are necessary as they allow for new and improved functionality and/or fix any known bugs within the software (Goodman & Miller, 2021). The old and new patient summary views appear in Figures 1a and 1b.

The new page was designed to view structured patient data in a summary format. Digital healthcare transformation to EHRs has been slow in the Republic of Ireland compared to the United States. There is typically an overreliance on free-text clinical notes rather than structured data entry, such as problems, diagnoses, procedures, and orders from medical staff primarily. Furthermore, this impacts the nursing workflow with an overreliance on reviewing the medical free-text notes for plans of care.

The new summary page was designed using an iterative action research approach described by Murphy and colleagues (2020) to encourage a revised review, communication, and recording workflow. The purpose of this new patient summary page was to bring clinical information together and improve the reviewing and communication across disciplines without going further into silos of information to access data for care decisions. The purpose of this study was to measure workflow compliance using key workflow tasks based on these steps: *Review* (charts open, review times, endorsing results); *Communicate* (orders placed, problems, diagnoses and procedures entered); and *Record* (documentation type and times, number of documents signed).

Aim

This quantitative, descriptive study measured workflow compliance using pre- and post-measurements within a national EHR.

Method

The study population was neonatal users from one large tertiary hospital (approximately 7,000 births/year) with a level III Neonatal Intensive Care Unit (NICU) included: NICU nurses (n=76) and neonatal Non-Consultant Hospital Doctors (NCHDs) (n=29). Due to the routine NCHD rotation and

change-over of personnel, NCHD data were collated from two independent samples of NCHDs, one before and one after the upgrade. Data were gathered 1 month prior to the implemented change and 1 month after the change.

This study extracted data from software audit log files. These files included timing data related to keystrokes and mouse movements from all EHR users. This data report captured a user's activity based on category structures, such as chart review times, documentation times, orders, problems and diagnosis, medication administration, and general timing in the EHR. Categories are defined in Table 1. An example of the audit log files for 1 month of a single user for both the pre- and post-phase are displayed in Figures 2 and 3, where the distribution of EHR time is displayed in percentages.

Data Analysis

All data with participant identifiers were removed and imported to IBM SPSS 27 for analysis (IBM, 2022). For both groups, each metric was described using means and standard deviations. Mean differences and their 95% confidence intervals were calculated, and their statistical significance was assessed based on *p*-values derived from paired t-tests for the NICU nurse data and independent t-tests for the NCHD data. Independent t-test were used for the NCHD group because they were two independent samples before and after rotation changeover. The significant *p*-value was set at 0.05 (5%), meaning a *p*-value <0.05 was a statistically significant result.

Some specific metrics such as entry of procedures, problems, diagnoses, and orders also were reviewed in total numbers and directly compared to hospital activity such as birth rates and neonatal unit occupancy. The workflows being examined were the routine daily medical patient review tasks (such as documentation, placing orders) and the daily nursing care workflows. Data points varied by discipline due to the difference in end-user workflow practices. Nursing workflows focus on documentation, medication administration. and some specific orders. Medical team workflows focus on entering problems, diagnoses, procedures, placing orders, and documenting medical notes. Workflows were subdivided into reviewing, communication, and recording for each group.

Figure 1a.
Former Patient Summary Page

Figure 1b.
New Patient Summary Page

- *Review* data points being measured for this study consisted of documentation and flowsheet review, charts opened, and endorsing results.
- *Communicate* data points were identified as those structured entries that would enhance communication across the multidisciplinary team, such as orders placed, problems, diagnoses and procedures entered.
- *Recording* data points consisted of documentation methods, structured and free-text documentation.

These data points are listed in Figure 4. Some data points were gathered by running specific reports against the database, such as procedures entry and results endorsement. A pre- and post-comparison was conducted between each value for each user.

Results

The NCHD group had a reduction in the number of charts opened (mean reduction of 301 charts) and the number of documents signed (mean reduction of 101 documents). However, this group did display an increase in problems created (+317%) and problems reviewed (+250%), albeit from low baseline levels. There also was a large increase in the number of diagnoses created (+47%). The total orders placed showed a mean reduction of 21.7 orders (36.8% reduction); this was a larger reduction than the activity reduction and so does not support an improvement in

Table 1.
Definition of EHR Functions and Categories as Described by the Log Files

Chart Review	Review clinical results, observations, and notes in the EHR broken down by using different areas of the chart (e.g., Mpage, document viewer, flowsheets)
Documentation	Recording documentation and creating notes
iView	Interactive view – contains various data points related to patient care, observations in a structured and organized way
PowerForm	Structured form of data entry at patient level (e.g., admission form)
PowerNote	Structured form of medical note with paragraphs containing history, physical examination, plan of care
Clinical Note	Free-text note
Macro	Predefined entry selection for PowerNote at paragraph level (e.g., well baby physical exam)
Orders	Writing orders includes various categories (e.g., patient care, diet, consults, referrals)
PowerPlan	Group of patient orders (e.g., care orders, medications, laboratory, etc.)
Problems and Diagnoses	Reviewing and updating the patient's problem list
Other	Non-categorized EHR times from specific activities or categories of activities that are too small to uniquely represent
Care Compass	Multi-patient organizer with patient summary and tasks
Medication Administration	Documentation of medications administered

Note: The above provides explanations of the log file outputs for each user.
Adapted from Overhage & McCallie (2020)

this data entry. Endorsing laboratory results from either an inbox or pool was consistently well managed in the pre- and post-phase. The NCHD results are presented in Table 2.

The NICU nursing group spent most of their time in the EHR documenting, with little variance in the pre- and post-measurements (see results in Table 3). Documentation methods had some reportable changes in the post-phase with more structured (iView) documentation (p=0.024) and less free-text clinical notes use (p=0.003), which would be consistent with the workflow compliance for this group. NICU nurses spent 18% of their time in the chart review measurement category, which had minimal variance in the pre- and post-measurements. However, they had 17 fewer clicks per patient. There was no change in nurses placing orders, and this data point remained consistent, displaying no improvement. A secondary analysis found statistically significant time reductions for nursing time in the EHR with a time saving of 1 minute and 14 seconds per patient (p=0.037).

Discussion

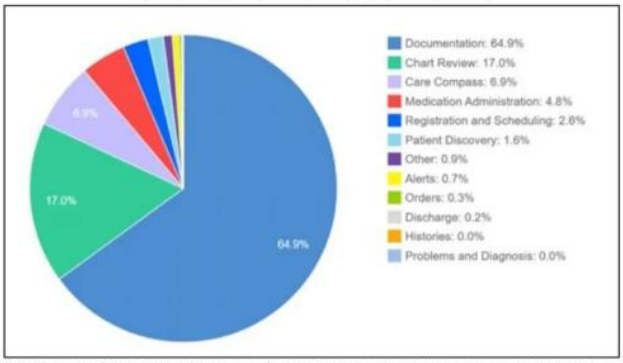
Few studies from the literature have examined nursing and medical workflows together (Lopez et al., 2021). This study examined both, and findings indicate that workflows of the nursing and medical groups were inextricably linked together. The workflow measurement following this EHR upgrade showed a notable increase in problems and diagnoses entry by senior NCHDs, but this was not displayed consistently throughout this group as senior registrars entered these data more than junior doctors, so they were not statistically significant.

It has been suggested the use of diagnoses entry should require specialized physician training (Quinn et al., 2019). Furthermore, a lack of face-to-face clinical discussion of the patient's diagnoses can lead to more fragmented data entry in the EHR (Quinn et al., 2019). Documenting such relevant data points in the patient's EHR can ensure an overall review would be easier and more consistent for all multidisciplinary users to gain an updated status on a patient's condition. The reduced documentation by doctors may be due to an overall reduced activity in the post-measurement phase with birth rates reduced by 45 births (7.2%) and neonatal unit occupancy reduced by 19.6%. The pre phase had a neonatal unit average occupancy of 35.8 inpatient babies per day and the post phase had 28.8 inpatient babies per day which is a reduction of 7 inpatients babies on average per day in the post phase. With less patients, there can be less documentation notes to enter into the EHR. The reduced post-period order entry was not consistent with the facility's reduced activity, however. The ordering process, such as fluid and diet orders, are still not entered in a structured format and could be reflective of the different health systems between Ireland and the United States-based EHR vendor. The benefits of using orders and order sets creates an opportunity for enhancing awareness for the unique healthcare needs of an individualized patient and can provide an opportunity for greater collaboration between different healthcare providers across the multidisciplinary team (Schor, 2016).

Nursing documentation in the post phase improved with statistically significant increase in structured documentation and reduction in free text note writing. The nursing group also had a significant reduction of time in the EHR per patient. This reduced time in the EHR was measured per patient and so was independent of the reduced activity and occupancy in the facility. Reduced nursing documentation time using EHRs possibly may be associated with more time being directed to clinical care (McCarthy et al., 2019) and thus highlights the significant benefit of this nursing time saving following the introduction of this upgrade.

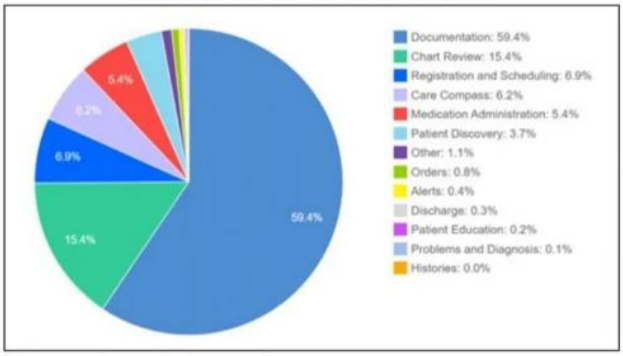
Nursing data entry into EHR systems is essential in planning care (Atak et al., 2023) and therefore, the usability of EHR systems is a key factor for nurses (Kutney-Lee et al., 2021; Lopez et al., 2021; Melnick et al., 2021). Poor EHR usability has been associated with adverse nursing outcomes such as burnout (Kutney-Lee et al., 2021; Melnick et al., 2021) and poor patient outcomes such as mortality and readmission (Kutney-Lee et al., 2021). Furthermore, excess EHR screen time can lead to emotional distress, physician burnout, and reduced patient contact, and may contribute to increased medical errors (Khairat et al., 2020; Tawfik et al., 2018). It is essential

Figure 2.
Time in EHR Allocation (Pre-Measurement Phase)



Note: Example of the audit log for one user for 1 month during the pre-measurement phase; displaying a breakdown of time distribution in the EHR described in percentages.

Figure 3.
Time in EHR Allocation (Post-Measurement Phase)



Note: Example of the audit log for one user for 1 month during the post-measurement phase; displaying a breakdown of time distribution in the EHR described in percentages.

that EHR design aims to maximize the clinician's time spent interacting with and providing care to their patients (Alami et al., 2022).

Implications for Practice, Policy, and Research

Practice

Increasing the usability of EHR systems can have a positive impact on data entry, reducing workload burdens and increasing the reliability of records (Atak et al., 2023). The use of audit logs for clinical practice potentially could provide some excellent opportunities for optimization and improving usability of systems. It could be used to identify issues and offer users further training and optimization in workflows.

Policy

Although, there are European directives on accurate data recording (The European Parliament and The Council of the European Union, 2016), Ireland would benefit from local and national policy guidance in EHR data entry to improve the reliability of records for both nurses and doctors who interact with an EHR.

Research

Although this study contributed greatly to the quantitative measurement of workflow analysis, additional research would be beneficial to contribute further to this topic. Further research using log files from a European perspective would be beneficial rather than a U.S. comparison based on significantly different healthcare structures. Additionally, more nursing data variables are needed to describe EHR usage across different health services and countries, such as documentation times, chart review times, and medication administration times. In this way, different nursing specialties can be directly compared, and optimization plans can be introduced. Further qualitative studies around attitudes and perceptions of users to software changes would be beneficial.

Limitations

Unfortunately, due to the prolonged restrictions in health care from the COVID-19 pandemic, the training plans for implementation were dramatically altered to facilitate learning in a socially distanced way. Users were provided with a video of the new summary page's functionality rather than via in-person classroom sessions. Although

Figure 4.
Evaluation Points to Quantify Workflow Compliance

Note: Data points were categorized to quantifiably measure the workflow.

Table 2.
Pre- and Post-Description of NCHD Groups Using the Review, Communicate, and Record Workflow

					95% Confidence Interval of the Difference		
	Pre Mean	Post Mean	Mean Change	(% Change)	Lower	Upper	*p* value
Review							
Charts Open	965.5	663.8	-301.7	-31.3	-552.4	-51.1	0.019
Communicate							
Total Orders Placed	58.9	37.2	-21.7	-36.8	-48.9	5.6	0.117
PowerPlans Selected	15.5	10.2	-5.3	-34.2	-12.2	1.7	0.132
Orders – Consults	4.3	2.8	-1.5	-35.8	-3.8	0.8	0.182
Orders – Referrals	6.8	3.3	-3.4	-50.8	-7.3	0.4	0.080
Orders – Diet	0	0.2	0.2		-0.1	0.4	0.161
Orders – Patient Care	5.4	2.8	-2.5	-46.9	-4.7	-0.3	0.025
Procedures Documented	0.3	0.3	0.0	-6.7	-0.5	0.5	0.936
Problems Created	1.7	6.9	5.2	317	-7.9	18.4	0.426
Diagnoses Created	18.7	27.5	8.8	47	-17.9	35.4	0.510
Problems Reviewed	2.0	6.8	4.9	250.8	-9.1	18.9	0.484
Record							
Documents Signed	302.3	201.0	-101.3	-33.5	-192.6	-10.0	0.031
Clinical Notes Signed	5.4	3.5	-1.9	-34.8	-5.5	1.8	0.305
PowerNotes Signed	237.8	142.9	-94.9	-39.9	-167.3	-22.5	0.011
Macros Used	46.7	29.2	-17.5	-37.5	-41.7	6.8	0.151
Average Documentation Time (seconds)	359.0	435.2	76.2	21.2	-23.9	176.2	0.131
Total Clicks per Note	963.4	1029.3	65.9	6.8	-132.6	264.5	0.505

Note: The data are described in mean values both pre- and post-implementation with the change identified in percentage.

Table 3.
Comparison of NICU Nurses' Utilization of the New Workflow (Before and After)

				95% Confidence Interval of the Difference		
	Pre Mean	Post Mean	Mean Change	Lower	Upper	*p* value
Review						
Chart Review	18.1%	18.4%	0.3%	-1.1%	1.7%	0.648
Chart Review Mpage	54.9%	55.3%	0.4%	-2.4%	3.1%	0.785
Chart Review Documents	35.2%	32.9%	-2.3%	-5.5%	0.9%	0.155
Chart Review Flowsheets	6.7%	6.5%	-0.2%	-1.4%	1.1%	0.811
Chart Review Clinical Notes	1.3%	1.3%	-0.1%	-0.6%	0.5%	0.850
Chart Review Other	1.8%	2.3%	0.5%	-0.1%	1.1%	0.131
Care Compass	4.1%	4.5%	0.4%	-0.2%	1.0%	0.195
Communicate						
Consults	0.2	0.2	0.0	-0.2	0.2	0.885
Diet Orders	0.2	0.2	-0.1	-0.1	0.0	0.208
Patient Care Orders	0.3	0.2	-0.1	-0.1	0.0	0.251
Record						
Documentation	63.2%	61.6%	-1.6%	-3.5%	0.3%	0.095
Documentation – iView	96.3%	97.3%	1.1%	0.1%	2.0%	0.024
Documentation – Clinical Notes	1.5%	0.8%	-0.7%	-1.2%	-0.3%	0.003
Documentation – PowerForms	2.1%	1.8%	-0.4%	-1.1%	0.4%	0.299
Documentation – Other	0.1%	0.1%	0.0%	-0.1%	0.2%	0.722
Medication Administration	6.4%	6.7%	0.3%	-0.5%	1.0%	0.490
Secondary Analysis						
Time in EHR per Patient (mins/secs)	13:22	12:08	-01:14	-02:24	-00:04	0.037
Time in EHR per Shift (hour/mins/secs)	01:19:05	01:03:53	-00:15:11	-00:18:25	-00:11:57	<0.001
Clicks per Patient	266.3	249.2	-17.0	-34.9	0.8	0.061

Note: Data are described in mean values both pre- and post-implementation with the mean change calculated.

training completion was reported to be 80% by the facility, a reasonable recommendation following this review is that further training and optimization would be beneficial to both groups. Users' knowledge and ability to use health information technology was not assessed in this study.

Conclusion

The introduction of the upgraded summary page has demonstrated some positive changes and adoption to utilizing the EHR optimally. Post-workflow change analysis has demonstrated more structured data entry for the NICU nursing group and a notable increase in problem and diagnosis entry by the NCHD group. Significant time savings were demonstrated in the nursing group, which can have positive impacts on patient care delivery. This study has demonstrated the useful benefits of EHR workflow measurement by quantifiably measuring tasks associated with the workflow. ◆

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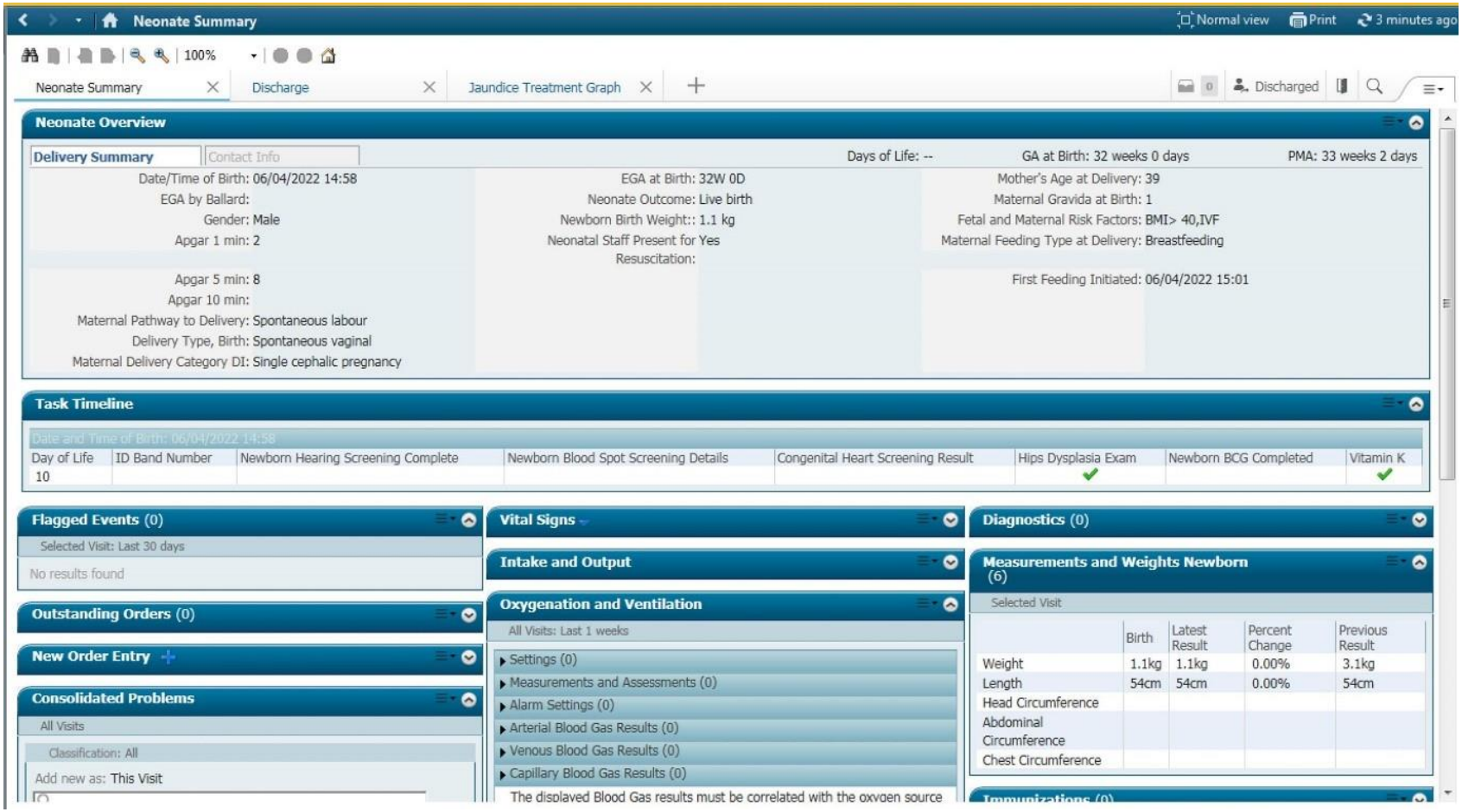
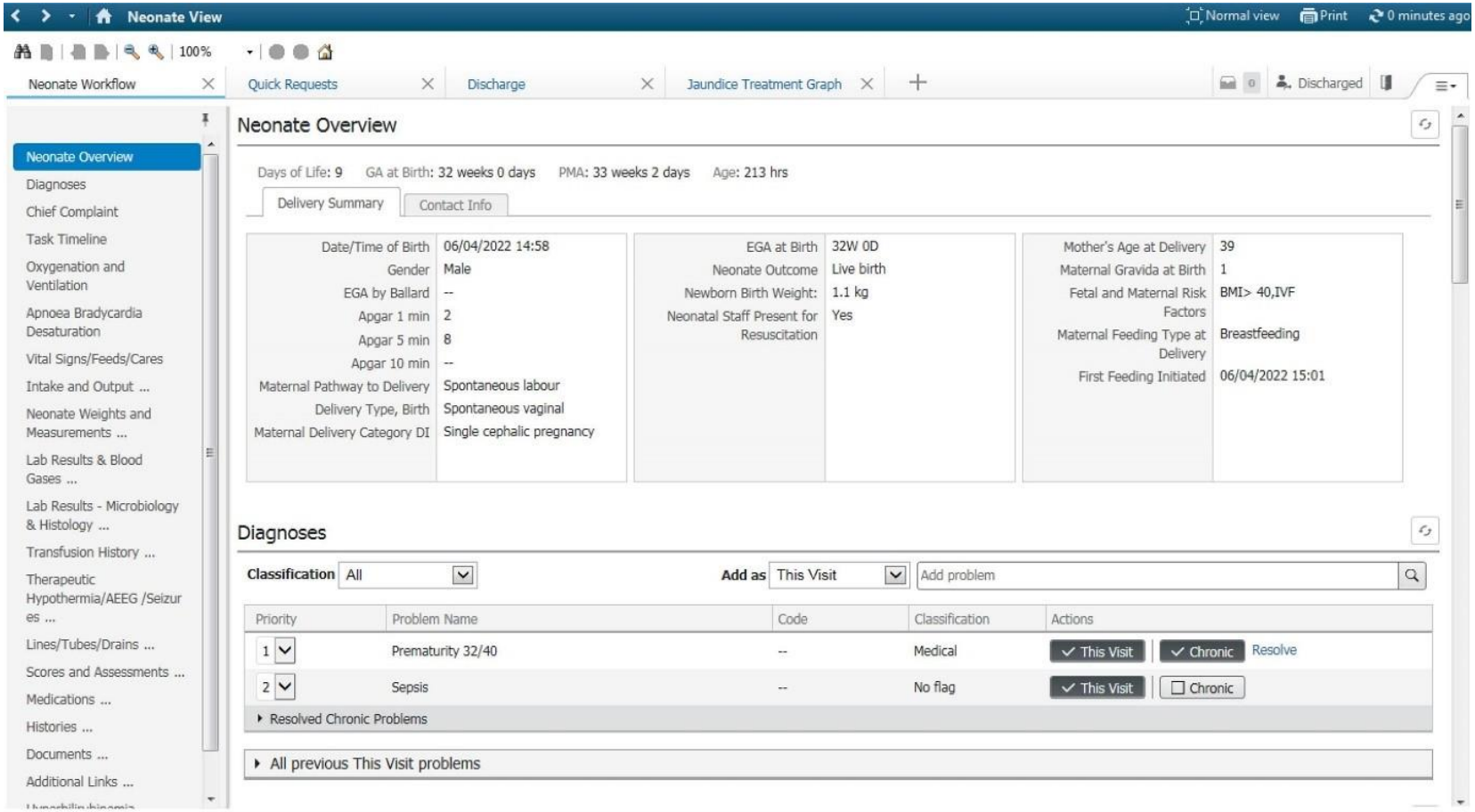
Appendix 15: Old View of the Neonatal Patient Summary Page



Appendix 16: New View of the Neonatal Patient Summary Page



Appendix 17: Peer- Reviewed Publication: Improving the quality of newborn feeding documentation in an EHR using a mixed methods approach

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Improving the quality of newborn feeding documentation in an EHR using a mixed methods approach

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ABSTRACT

Introduction: Newborn feeding is key to infant growth and survival. Accurate feeding documentation can inform care decisions and planning of care. A nutritional dashboard is available within the Electronic Health Record (EHR) which accumulates feeding data in a graphical display.

Purpose: To improve the quality of newborn feeding documentation for post-natal ward babies and babies in the Neonatal Intensive Care Unit (NICU).

Design: and Methods: A multidisciplinary end user expert group (n = 38) was established. Qualitative thematic analyses from this group were used to design new feeding data entry and review elements. Quantitative pre-post design was used to assess feeding documentation for both post-natal ward baby charts (n = 134) and NICU baby charts (n = 188). Descriptive statistics and Pearson's chi-square were used to assess pre-post differences and statistical significance. The use of a nutritional dashboard was assessed using system audit logs and analysed using Poisson regression testing.

Results: Post-natal ward babies had improvements in structured feeding documentation by 91.6% (from 17.9% to 34.3%) (p = 0.031). NICU data feeding documentation improved by 25% (from 72.3% to 90.4%) (p = 0.001). Use of the nutritional dashboard however reduced in the post period.

Conclusion: This study has positively demonstrated improvements in the quality of newborn feeding documentation within the patient's EHR can be achieved through a collaborative multidisciplinary approach optimising EHR design.

Practice implications: The benefit of a multidisciplinary approach to EHR design is paramount to promoting superior quality data entry compliant with individual workflows.

Infant nutrition has a key role to play in growth and development, and can have a profound impact on society in terms of reducing obesity and chronic disease prevention (Food Safety Authority of Ireland., 2012). The first year of life is a period of rapid growth and development (Food Safety Authority of Ireland., 2012). Infants born prematurely face numerous challenges including being vulnerable to suboptimal nutrition (Brennan et al., 2018). Premature infants are born at a critical time of brain development which can involve some complex and precisely programmed neurodevelopmental events (Aarnoudse-Moens et al., 2009; Sammallahti et al., 2017). This in turn poses a risk to the preterm brain being vulnerable to numerous insults and consequently leading to a high incidence of lifelong neurodevelopmental, cognitive, behavioral, and motor impairments (Aarnoudse-Moens et al., 2009; Sammallahti et al., 2017). Nutrition support can play an important role in the neurodevelopment of the preterm infant (Nava et al., 2024). Early nutrition is one of the interventions that can act to modify the development of the preterm brain and perhaps mitigate any long term neurodevelopmental outcomes (Nava et al., 2024). As the postnatal nutritional support may

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not optimally match the third trimester intrauterine growth, this can lead to high rates of faltering growth for preterm infants (Franz et al., 2009) and it is for this reason that postnatal nutritional support should be optimized (Franz et al., 2009; Keunen et al., 2015; Ottolini et al., 2020; Schneider and Garcia-Rodenas, 2017). To assist clinicians in making decisions around nutritional optimisation; having accurate and timely information can assist in care planning and nutritional progression (Cardin et al., 2023a). Within an Electronic Health Record (EHR), the use of data to extract information and develop into knowledge to support clinical decision making, is described as a critical success factor for an organization (Oliveira et al., 2005). Some elements of clinical data are routinely used to guide clinical care such as measurable attributes of blood pressure, heart rate and temperature. Nutrition and growth also need to be closely monitored to overcome any nutritional deficits during this critical growth phase particularly transitioning from parenteral nutritional to enteral nutrition (Brennan et al., 2018). Real life challenges have been identified around data quality in clinical organizations attempting to extract data in relation to newborn feeding (Garcia-de-León-Chocano et al., 2015) and highlight the need for the EHR to show an accurate view of the real clinical situation of patients (Garcia-de-León-Chocano et al., 2015; Liaw et al., 2013). Systematic errors associated with the information systems structure can hinder accurate data quality (Weng et al., 2012). The dimensions of data quality vary and include accuracy and reliability, timeliness, coherence, accessibility, and relevance (Health Information and Quality Authority, 2018). The quality of data input can strongly influence the quality of the results (Oliveira et al., 2005; Sattler and Box, 2001) and interpretation of data into knowledge. Since the beginning of modern nursing, nursing data have been the most potent source of data for planning and improving the quality of care (Atak et al., 2023). The importance of documenting newborn feeds can contribute to the plan of care and promotes consistency and safety of the infant (Cardin et al., 2023b). The benefits of careful documentation regarding the quality of the feed can communicate the infant's progress to the wider interdisciplinary team and has been identified as a crucial aspect of care (Cardin et al., 2023a).

1. Background

The Maternal and Newborn - Clinical Management System (MN-CMS) is a national project implementing a single national EHR for maternity and neonatal services in Ireland (eHealth Information and Quality Authority, 2018). With a national birth rate of 57,540 in 2022 (Central Stastistics Office, 2023), MN-CMS currently supports 40% of the births in Ireland, in 4 maternity hospitals/units, with a plan to implement to all 19 maternity units in the country (eHealth Ireland, 2018). The MN-CMS newborn EHR contains various data points on newborn feeding for both well babies on post-natal wards and babies admitted to the Neonatal Intensive Care Unit (NICU), completed by the midwife and NICU nurse. The MN-CMS project was instrumental during the EHR design in developing a nutritional dashboard for infants which provides a graphical display of daily intakes consisting of nutritious and non-nutritious parenteral fluids and enteral feeds. The enteral graph of the nutritional dashboard is populated by the feeding data entries in the EHR (See Fig. 1). The nutritional dashboard displays enteral feeds based on feed type (breastmilk or formula) and by method the milk was received (teat or tube). This graphical display of feeding progress has the potential to enhance feeding and nutrition review for the entire multidisciplinary team and contribute to the knowledge to support clinical decisions, however due to data quality issues based on feeding input, the graphical display is sometimes unreliable. The well post-natal ward infants also have inconsistent feeding documented in their EHR as a dual paper process is maintained. This causes difficulties in reviewing feeding progress particularly if care is transitioned when transferred from post-natal ward to the NICU due to numerous duplicated data fields. This mixed methods research study aimed to review the current workflows to change the systematic format of feeding data entry within the EHR for post-natal ward and NICU babies, to enhance compliance with the data completeness and correctness. A consistent data entry format was developed for all users to input all infant feeds. All changes to the national MN-CMS system were carried out in accordance with the strict change control pathways in place.

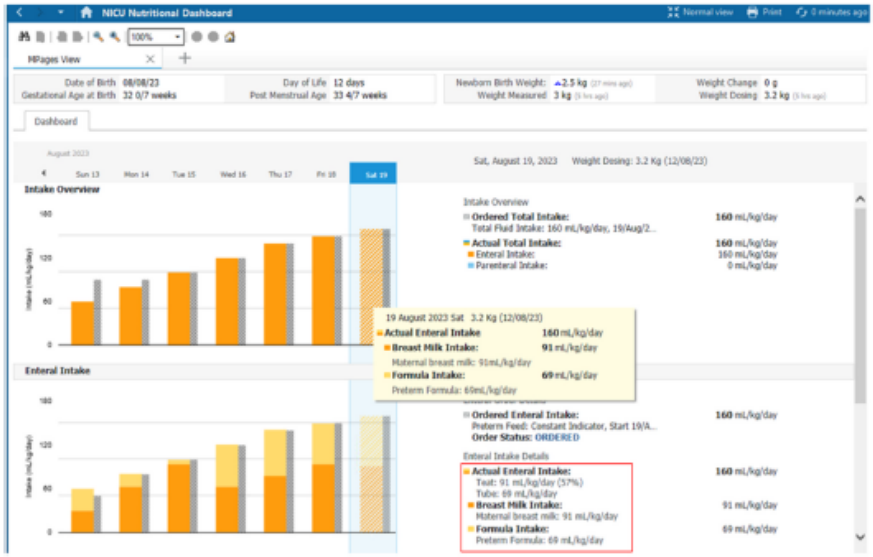

Fig. 1. NICU Nutritional Dashboard view display enteral intake with breakdown of Feed type and feeding method.

2. Purpose

This study proposed to 1) improve the data quality in relation to newborn feeding for well healthy newborns on post-natal wards and those admitted to the NICU and 2) improve the utilization of the NICU Nutritional Dashboard.

3. Design and Methods

Ethical approval was granted for the inclusion of all four hospitals in this study who utilize the EHR and from the project's information governance group. Separate ethical approval was granted for Site A and B (ECM 4 (c)), Site C (REC-2022-007) and Site D (EC17.2022). Three hospitals were tertiary referral sites with Level III NICUs (Neonatal Intensive Care Units), and one site was a local maternity unit. Qualitative and quantitative assessment evaluations before and after the development and implementation of the changes in EHR data were used to evaluate the revised data entry format for all users to input all infant feeds.

3.1. qualitative

For the qualitative assessment, a purposive sample of subject matter experts were included and therefore established the multidisciplinary expert group, with representation from all relevant disciplines who use the EHR daily and members of the national project team. Forty-one participants were invited to take part. In total 38 participants engaged in the group and signed a voluntary consent to participate in the study. The sample representation (n = 38) is displayed by discipline in Table 1. There was a larger number of nurses and midwives than there were medical, dietetic, lactation consultants for example but this mirrors the staff mix in the clinical care. The expert group was coordinated by the first author who is the NICU workstream lead for the MN-CMS project and has an in-depth knowledge of the EHR.

This expert group was used to identify the current issues and "sticky points" around poor data entry for all infants both on post-natal wards and NICU. They were instrumental in deciding the EHR changes to improve the data capture. Due to COVID19 restrictions in healthcare facilities, the group met via teleconference on five occasions lasting for 1 h each. Sessions were recorded and a transcript generated from the teleconference application. These transcripts were verified by the lead author, who was the coordinator of the group sessions. The first session, which had a wide representation of all disciplines across all 4 sites, was used to understand the current workflows and issues identified from various perspectives. The subsequent sessions had various members at different times who contributed to the final design of the EHR feeding entry and review changes. Not all members were present for all sessions but there was always good multidisciplinary representation. The questions explored with the group for the initial meeting were as follows.

1. What works well for infant feeding input and reviewing?
2. What does not work well for infant feeding input and review?
3. What would make data entry easier?
4. Do you use the NICU Nutritional Dashboard?
   a. If so, what do you like about it?
   b. If not, why do you not use it as a review tool?
5. What would help with the review of infant feeding?

Table 1
Expert group participants represented by discipline.

NICU Nurses	5
Midwives	13
Neonatology Consultants	2
Neonatal Non-Consultant Hospital Doctors (NCHD) and Advanced Nurse Practitioners (ANP)	2
Dietitians	3
Lactation Consultants	6
National Project Team	7
Total	**38**

3.2. (ii) quantitative

The data quality and completeness were quantitatively assessed by reviewing newborn EHR data for inpatient newborns in the four hospitals included in this study. Data were collected for a 24-48-h period looking at the feeding entry of newborn inpatients, receiving nutritive milk feeds (>40 mls/kg/day), on a selected date to obtain pre and post measurements. The sample size was calculated to detect a 20% improvement in data entry for both NICU babies (n = 188) and the post-natal ward babies (n = 134). The sampling method was convenience sampling of newborn inpatients in the NICU or post-natal ward. There was a separate pre and post sample cohort for both groups, the NICU group had 94 pre and 94 post and the post-natal ward group had 67 pre and 67 post. The post data was collected approximately two months after the changes were implemented. Key data entry for accurate population of the nutritional dashboard were identified using the dimensions of quality based on the Health Information and Quality Authority (HIQA) framework (Health Information and Quality Authority, 2018) as the primary measure of completeness. The dimensions of data quality are accuracy and reliability, timeliness, coherence, accessibility, and relevance (Health Information and Quality Authority, 2018). When each of these dimensions were met-the data quality was considered complete and accurate to populate the nutritional dashboard. These are displayed in Table 2 with an example of the EHR data entry to achieve the dimensions of data quality.

Additional data points were also captured and compared in the pre and post phase. Data were analyzed using SPSS 28 using descriptive statistics of cross tabulation and Pearson's chi-square test assessed the pre-post difference and statistical significance. Significance was set at 5% (0.05) meaning that a p valve of < 0.05 was significant. The use of the nutritional dashboard was evaluated by extracting data log files from the EHR database to evaluate the number of times a user launched the nutritional dashboard page to open the graphical display. The statistical software program, Stata, was used to assess the launches per day and the cumulative launches over the 7-day period. Poisson regression tests were used to assess the pre-post change.

4. Results

4.1. Qualitative

The qualitative data analysis was based on the Braun and Clarke (2006) 6-step process of familiarization of the data, generating initial codes (descriptive codes), searching for themes, reviewing themes, defining and naming themes and finally producing the report (Braun and Clarke, 2006). Using this thematic analysis, the researchers identified three overarching themes of 1) Complex data entry 2) difficulty in reviewing the data and 3) an unreliable nutritional dashboard. The outputs from the expert group consultations varied by each of the disciplines based on their different work practices and their need to either enter or review the information.

Table 2
Dimensions of Data Quality and EHR entry examples.

Dimensions of Data Quality	EHR Data Entry
Accuracy and reliability	Appropriate feed data entered e.g., feed type, feed method, feed volume etc.,
Timeliness	Correct time column entry
Coherence	Clearly entered using discrete data entry
Accessibility	Completed in the correct feeding section
Relevance	Entry completed per feed

4.1.1. Complex data entry

NICU Nurses and post-natal ward midwives, in particular spoke about how complex the feeding documentation was and how it was time consuming. They commented on how there were often too many options for various feeds, and they often don't separate different feed types on data entry as this is too cumbersome. The NICU nursing group felt the data entry was too complex (particularly with multiple feed types) with too many options and difficultly in seeing the total volumes per kilogram per day (mls/kg/day). NICU nurses also referenced multiple data entry points duplicated when newborns were moved from post-natal ward care to NICU care.

> "When a baby is moved from the wards to the neo there is a feeding method newborn and feeding method NICU to complete but I'm only feeding the baby once!"
>
> NICU Nurse, Site A

Nurses felt the data entry was complex and frustrating to enter correctly in separate time columns as designed. Nurses also commented that for some documentation-they had no structured data entry space to add this information such as "a reason formula was given".

Midwifery staff on the post-natal wards either did not enter structured data in the EHR or maintained a dual system of paper feeding charts which were either scanned into the EHR or transcribed in. They mentioned that it was too time consuming to do and they would enter data often at the end of a shift

> "We get the mums to write down the feeds for the day and then we put them in the chart (EHR) at the end of the shift".
>
> Post-natal ward Midwife, Site D

4.1.2. Difficulty in reviewing the data

Dietitians, Lactation Consultants and Medical staff in particular found reviewing information was difficult. Complex feeds with additives were difficult to review and users often clicked through 24–48 h of feeding data rather than seeing an overall summary picture.

> "The review of feeding is problematic to look at it at a glance and see 24–48hrs – you need to click through iView just to get an idea of what's happened."
>
> Neonatologist, Site D

The dietitians also noted difficulty finding the first feed and that there was a lack of information around the first breastmilk or buccal breastmilk administration. Neonatologists, NCHDs (Non-Consultant Hospital Doctors) and ANPs cited difficulty in reviewing the information and inability briefly to see the "key firsts" e.g., first feed, first breastmilk. Lactation consultants voiced concerns around key national reports and the difficulty in gathering information for these reports due to the poor data completeness of newborn feeding and often newborn charts didn't even have scanned feeding charts.

> "Sometimes you'd find a feeding chart scanned in (to the EHR) and sometimes not."
>
> Lactation Consultant, Site A

4.1.3. An unreliable nutritional dashboard

Dietitians and medical staff cited rarely reviewing the Nutritional Dashboard due to perceived inaccuracies of the display. They did acknowledge the Nutritional Dashboard had potential for reviewing the intake and tracking feeding progress, however due to inaccuracies it was unreliable, and they lacked trust in it.

> "The dashboard really has great potential to review the intake and track the progress but again there's too many entry options for all the different feeds and combined feed are problematic and this makes the dashboard too inaccurate to rely on …."
>
> Dietitian, Site C

Dietitians noted that the complex and combined feeds were difficult to order and to review, the complex feed entry was often inaccurate leading to inaccuracies in the nutritional dashboard which could have immense potential if accurate. The medical group found that the nutritional dashboard was "just not right or correct" for use on ward rounds or presenting patients as the data entry was probably not correct in the first place.

Following the group review and in efforts to redesign the current feeding entry, work began as outlined below and followed a similar format as described by Sutton et al. (2020). The EHR provided two views – one for midwives for the post-natal ward baby and one for the NICU staff and the sick neonatal baby with often duplicated data entry points.

1. A side-by-side analysis was made of both views and a comparison was made to determine which data elements were consistent and which were duplicated.
2. Common and essential data points were identified, aligned, and eliminated if deemed not essential to capture.
3. Responses to the duplicates were aligned to provide consistency.
4. More conditional logic was built into responses i.e., based on the selection of responses, additional relevant responses would open. These would remain hidden if not selected.
5. New data capture was agreed for inclusion e.g., reason for formula feeding, type of breastmilk and administering buccal breastmilk and an ability to record the mls/kg/day per feed.
6. Commonality of the design was decided and agreed by the stakeholders.
7. A new flowsheet was built for the purpose of reviewing all the feeding data in one place.
8. The agreed design was built in the pre-production (test) environment and demonstrated to the group.

Following a detailed demonstration to the group, some minor design adjustments were made, and the group identified some key encouragement points in promoting this to the end users. An implementation plan was developed with the group for each of their sites. The strategies identified for implementation were training, identifying champions and communication via newsletters and memos. Two short information training videos were developed for the data entry for midwives (5.5 min) and for the NICU nurses (6.5 min) and distributed to nominees on each site to disseminate along with a quick reference guide. Each group member was identified as champions for this change and provided support and encouragement to end users. The final design was built into the live environment at an agreed time once training was complete and memos were distributed to the users.

Once the design was complete and agreed, the expert group were asked what could encourage adoption of the new changes. The group mentioned that users had been asking for changes and these should represent their requests for change and make it easier to enter feeds and capture all the required information. A member of the national project team highlighted that every patient has a right to accurate data being recorded in their EHR.

> "Every patient has a right to data accuracy ….and they should have correct information around care being recorded."
>
> Member of the National Project Team of MN-CMS

A doctor noted that we need to stress the why we are doing this:

> " …. the *key is almost to start with the why, why are we making this change at all? It's to try and make it better and, and bring our care more centered around one of the key things that as all health care providers …. [that] we do for babies, which is to nourish them and to do it in a way that doesn't matter where the baby is ….the mother and baby and wherever they are in their feeding journey and in their care journey in the hospital"*
>
> Neonatologist, Site A

4.2. Quantitative

4.2.1. Post-natal ward newborns

For the postnatal ward newborns, the overall completed structured data entry across the 4 sites increased from 17.9% to 34.3% showing a statistically significant increase of 91.6% ($p = 0.031$). The cumulative results for the post-natal ward data entry are displayed in Table 3. There was also a notable increase in key structured data points of feed type and oral volume with increases of 80.4% and 123.8% respectively. Although the aim of this study was to improve the structured data entry, some post-natal ward staff documented newborn feeding in an unstructured way by free text notes or handwritten feeding charts scanned into the EHR. As these captured newborn feeding, they were accounted for in the data collection as *other* documented feeding records for newborns. Overall, across four sites, the other feeding documentation increased by 63.4%–68.7% of the sample having some feeding documented in their EHR. The new data changes included the reason for formula feeding and this was completed in 85% of applicable cases for post-natal ward newborns having previously not been captured.

The structured data completeness for each site is displayed in Table 4. Only one individual site (D) showed a significant improvement which was not, however, demonstrated across all four sites.

4.2.2. NICU newborns

The NICU chart review across the 4 hospital sites showed a data completeness to populate the nutritional dashboard significantly increase of 25%% from 72.3% to 90.4% ($p = 0.001$). The NICU data points collected following the chart review are displayed in Table 5 and display the cumulative results of data completion across all 4 hospital sites.

The individual sites are displayed in Table 6. Three sites (A, C and D) showed an increase in completeness and one site (B) remained static.

The *Feed Type* data entry point is especially important to capture as it allows the categorization of feed types such as breastmilk, term formula, preterm formula etc. in the reviewing process of nutritional intake. Overall, across the four NICUs this data point improved, increasing by 19.7% with statistical significance ($p = 0.007$). The individual sites are displayed in Table 7. Site A showed an increase in this feed type data point from 70% to 93.3% in the post phase, an increase of 33% completeness ($p=<0.02$). This data point was noted as being problematic in cases of complex feeds or with more than one feed type being administered such as combinations of breastmilk and formula.

The *feeding method* (e.g., via bottle teat or tube) data entry was often duplicated in the pre phase however accuracy and completeness increased by 32.8% over 4 sites ($p= <0.001$) with the new design. New data entry captured in the post phase such as, the reason for formula feeding, was recorded accurately across all 4 sites in 66% of relevant cases having not been recorded previously in a structured event set. The type of breastmilk (fresh or refrigerated or previously frozen) can now be captured for newborn feeding and was done so in 56% of relevant cases.

4.3. Nutritional Dashboard

There was a 5.7% reduction in launches of the nutritional dashboard overall across the four hospitals in the post period which was not statistically significant ($p = 0.115$) and may account for some usual variation. Reviewing each hospital separately, hospital A had a significant reduction in launching the page with a 23.7% reduction ($p=<0.001$). Hospital B, albeit with small numbers had a 45% increase in usage ($p = 0.339$), hospital C had a 5.5% increase ($p = 0.272$), and hospital D had a 12.6% reduction ($p = 0.178$). This is displayed in Fig. 2 below.

The launching of the page by position showed an increase by NICU Nurses of 8.2% ($p = 0.119$) and dietitians by 15.2% ($p = 0.247$) and significant reduction by medical staff by 24% ($p=<0.001$). Other positions are represented in Table 8 and graphically displayed in Fig. 3.

Table 3
Cumulative data completeness results of the four hospitals and the individual data points collected for the post-natal wards.

	Pre (%)	Post (%)	Change (%)	P Valve
Feed Type	19.4	35	+80.4	0.047
Oral Volume	16.4	36.7	+123.8	0.014
Feeding Method	29.9	43.3	+44.8	0.106
Formula Type	16.4	53.8	+228	<0.001
Feed Tolerance	47.8	80.6	+68.6	<0.001
Structured Data Complete	17.9	34.3	+91.6	0.031
Other Documentation	41.8	68.7	+63.4	0.002

Table 4
Individual site data quality compliance for completed structured data entry for newborn feeding on post-natal wards.

Site	Pre (%)	Post (%)	Change (%)	P Value
A	0	5	N/A	0.311
B	40	60	+50	0.371
C	10.5	15.8	+50.5	0.631
D	31.6	68.4	+116.5	0.023

Table 5
Cumulative data completeness results of the four hospitals and the individual data points collected for NICU.

	Pre (%)	Post (%)	Change (%)	P Valve
Feed Type	75.5	90.4	+19.7	0.007
Oral Volume	93.8	100	+6.6	0.048
Tube Volume	91	100	+9.9	0.016
Feeding Method	64.9	86.2	+32.8	<0.001
Formula Type	74.5	94.1	+26.3	0.006
Additives	83.3	89.7	+7.6	0.415
Feed Tolerance	48.9	73.4	+50	<0.001
Feed Order	42.6	26.6	−37.5	0.021
Fluid Order	63.8	52.1	−18.3	0.104
ND[a] Complete	72.3	90.4	+25	0.001

Note.
[a] ND refers to the Nutritional Dashboard and all data inputted into the EHR accurately populated the dashboard.

Table 6
Individual site data quality compliance to populate the nutritional dashboard.

Site	Pre (%)	Post (%)	Change (%)	P Value
A	70	93.3	+33.2	<0.02
B	75	75	0	1.00
C	76.7	90	+17.3	0.166
D	70	90	+28.6	0.053

Table 7
Individual sites to populate the Feed Type hierarchy accurately.

Site	Pre (%)	Post (%)	Change (%)	P Value
A	70	93.3	+33.3	<0.02
B	75	75	0	1.00
C	83.3	90	+8	0.448
D	73.3	90	+22.8	0.095

5. Discussion

This study aimed to improve newborn feeding documentation within an EHR and began by exploring the redesign of newborn feeding data entry using a multidisciplinary approach. Our study identified that users found the newborn feeding data entry complex and time consuming to complete, with some duplication and having too many options to complete. Likewise, the review of information was problematic due to the

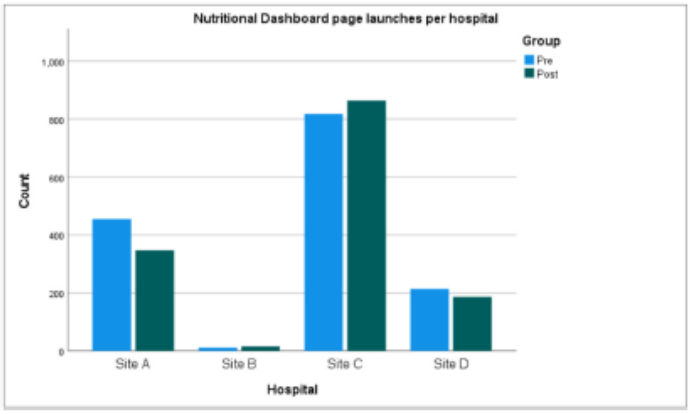

Fig. 2. NICU Nutritional Dashboard page launches by hospital site showing both pre and post.
Note: Site B is a smaller unit and has the lowest number of births per year however Sites A, B and C are comparable tertiary sites.

Table 8
The use of the nutritional dashboard by user positions displaying pre and post launches, % difference, Confidence Intervals (CI), and p value.

Position	Pre	Post	% Change	95% CI		P Value
NICU Nurse	758	820	+8.2	0.98	1.19	0.119
Medical	520	392	−24	0.66	0.86	<0.001
Dietitian	125	144	+15.2	0.91	1.46	0.247
Lactation Consultant	18	12	−33.3	0.32	1.38	0.277
Pharmacist	61	44	−27.9	0.49	1.06	0.099

complex data entry and gathering national reports was difficult as the information often could not be found or was not entered in a structured format. We used the key contributions of the multidisciplinary team to redesign the newborn feeding; to reduce the complexity and duplication for users and ultimately improve the data quality of the newborn feeding. The improvement of data quality was observed across the NICU and the post-natal wards. The second aim was to improve the use of the nutritional dashboard by all users and although the use did not show a general improvement, NICU nurses' use of the dashboard did show an improvement. This functionality may need more education and champions to promote its use. The continuing improvement of data completeness of the feeding data entry will ensure more accuracy of the dashboard and may improve users overall trust of the dashboard for clinical use. Changes to documentation within an EHR have implications for accuracy, efficiency, user satisfaction, and workflow (Wilbanks et al., 2018) which were positively demonstrated in this study. The key data points of feed type and feed method improved in accuracy due to alignment and reduced duplication of the data entry. Accurate data entry through thoughtful and detailed documentation can provide information that promotes continuity of care for newborn feeding (Cardin et al., 2023a). Some studies identify poor data quality in feeding documentation as a limitation of their study (Cardin et al., 2023b; Healy et al., 2023). This study has streamlined feeding data entry, reduced duplication, and improved data completeness which will be beneficial for clinical review, quality improvement, audit and research. The potential of using structured data from EHRs is the core of improvements in healthcare (Goldacre and Morley, 2022) and nurses are seen as an integral part of the team in improving data quality and data obtained by nurses in EHRs have become the most crucial source in planning care

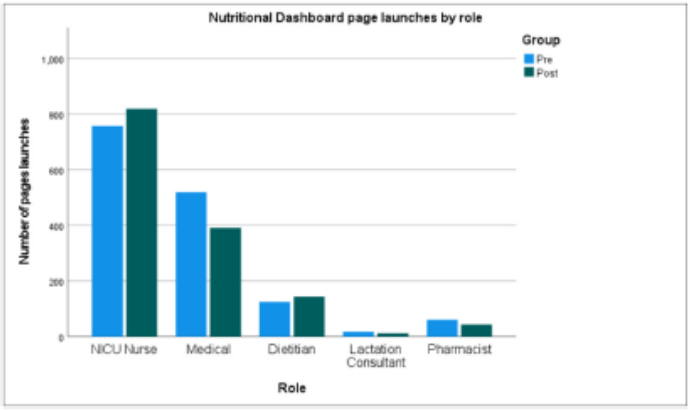

Fig. 3. NICU Nutritional Dashboard page launches by user roles across all four hospital sites.

(Atak et al., 2023). With the correct and proper analysis, as undertaken in this study, improvements can be realized in quality, safety, and cost-effectiveness of care across the entire health service (Goldacre and Morley, 2022).

6. Limitations

Limitations of this study included a convenient sample from the four hospitals using the national newborn EHR. This project was interrupted by a criminal cyber-attack on the Irish health service data infrastructure and delayed the overall implementation of the changes from the initial multidisciplinary group meeting.

7. Implications for practice

This study has contributed positively to improving data completeness around newborn feeding. The benefit of a multidisciplinary approach to EHR design is paramount to promoting superior quality data entry compliant with individual workflows. Further education, training, and awareness of the benefits of the nutritional dashboard is needed.

8. Implications for research

The establishment of an expert multidisciplinary group is essential in the design of the EHR as each member has a unique viewpoint based on their individual workflows and uses of the EHR, be it data entry or data review. Qualitative research makes an important contribution for EHR design and optimisation.

9. Implications for policy

Although the Irish Medical Council (IMC) gives some guidance to medical staff on recording accurate, timely, and up-to-date medical records in either paper or electronic form, the Nursing and Midwifery Board of Ireland (NMBI) give guidance only pertaining to paper records. The NMBI, who provide professional guidance to nurses and midwives, advise regular documentation of narrative notes to document patient care and progress (NMBI, 2015). These guidelines are relevant to paper records but do not support nurses recording clinical structured data in EHRs. A key recommendation from this study is that the nursing and midwifery professions need professional guidance for recording clinical care in a structured electronic format as health services embark on digital transformation.

10. Conclusion

Data completeness significantly improved across all four hospitals for newborn feeding in a national newborn EHR. Accurate recording of feeding can communicate the newborn's progress across the multidisciplinary team. This study has positively demonstrated that a collaborative multidisciplinary approach can improve EHR design and data quality through more accurate and complete data in the patient's EHR.

Author roles

OS, BM, RG, and JMK conceptualized the research. OS collected data. OS and PC formally analyzed the data. OS created the original draft of the paper. RG, BM, PC, JMK reviewed and edited the paper. OS was supervised by RG, BM, and PC.

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Declaration of competing interest

The authors have nothing to declare and have no conflicts of interest to highlight.

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Appendix 18: Consent and Participant Information Leaflet for Site A and B

ucc
Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

Information Sheet and Consent Form

Thank you for considering participating in this research project.

The aim of this study is to improve the EHR data quality in relation to newborn feeding for both well healthy newborns and those admitted to the NICU and to improve the utilisation of the NICU Nutritional Dashboard within the EHR. Should you choose to participate, you will be asked to join an expert group. Participation in this study is completely voluntary. All of the information you provide will be kept confidential and anonymous by the researcher in any subsequent publication or dissemination.

This expert group will be coordinated over Microsoft Teams and will be recorded. The data will then be transcribed by the researcher, and all identifying information will be removed. Once this is done, the audio-recording will also be deleted and only the anonymized transcript will remain. It is expected to take at least 3-6 call for 60 mins each.

This study has obtained ethical approval from the relevant Ethics boards associated with each Hospital/Hospital Group.

If you have any queries about this research, you can contact me at orla.sheehan1@hse.ie or Brendan.murphy@ucc.ie

If you agree to take part in this study, please sign the consent form overleaf.

Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

Consent Form

I……agree to participate in Orla Sheehan's research study.

The purpose and nature of the study has been explained to me in writing.

I am participating voluntarily.

I give permission for my expert group with Orla Sheehan to be audio-recorded.

I understand that I can withdraw from the study, without repercussions, at any time, whether before it starts or while I am participating.

I understand that anonymity will be ensured in the write-up by disguising my identity. I also undertake to maintain the confidentiality of the group.

I understand that disguised extracts from the expert group may be quoted in the thesis and any subsequent publications if I give permission below:

(Please mark one box:)

I agree to quotation/publication of extracts from the expert group ☐

I do not agree to quotation/publication of extracts from the expert group ☐

Signed: …….. Date: ……..

PRINT NAME: ……

Appendix 19: Consent and Participant Information Leaflet for Site C

ucc
Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

Information Sheet

For an Expert Group participation in a study entitled
Improving Data Quality of Newborn Feeding in a maternity hospital EHR

Thank you for considering participating in this research project.

The aim of this study is to improve the Electronic Health Record (EHR) data quality in relation to newborn feeding for both well healthy newborns and those admitted to the NICU and to improve the utilisation of the NICU Nutritional Dashboard within the EHR. Should you choose to participate, you will be asked to join an expert group. Participation in this study is completely voluntary. All of the information you provide will be kept confidential and anonymous by the researcher in any subsequent publication or dissemination.

This expert group will be coordinated over Microsoft Teams and will be recorded. The data will then be transcribed by the researcher, and all identifying information will be removed. Once this is done, the audio-recording will also be deleted and only the anonymised transcript will remain. It is expected to take at least 3-6 call for 60 mins each.

This study has obtained ethical approval from the relevant Ethics boards associated with each Hospital/Hospital Group.

If you have any queries about this research, you can contact me at orla.sheehan1@hse.ie or Brendan.murphy@ucc.ie

If you agree to take part in this study, please sign the consent form.

PARTICIPANT CONSENT FORM

Study title: Improving data quality of newborn feeding within a maternity hospital EHR

Researcher: Orla Sheehan and Dr Brendan Murphy

E-mail: orla.sheehan1@hse.ie and Brendan.murphy@ucc.ie

I have read and understood the Information Leaflet about this research project. The information has been fully explained to me.	Yes ☐	No ☐
I understand that I am participating voluntarily in this study and that I can opt out at any time. I understand that I don't have to give a reason for opting out.	Yes ☐	No ☐
I give permission for my expert group to be audio-recorded.	Yes ☐	No ☐
I understand that anonymity will be ensured in the write-up by disguising my identity. I also undertake to maintain the confidentiality of the group.	Yes ☐	No ☐
I understand that disguised extracts from the expert group may be quoted in the thesis and any subsequent publications	Yes ☐	No ☐

Participant Name (Block Capitals)	Participant Signature	Date

To be completed by the Principal Investigator or nominee.

I, the undersigned, have taken the time to fully explain this study to the above participant. I have invited them to ask questions on any aspect of the study that concerned them.

Name (Block Capitals)	Qualifications	Signature	Date

Appendix 20: Consent and Participant Information Leaflet for Site D

Information Sheet

For an Expert Group participation in a study entitled

Improving Data Quality of Newborn Feeding in a maternity hospital

EHR

Thank you for considering participating in this research project.

The aim of this study is to improve the Electronic Health Record (EHR) data quality in relation to newborn feeding for both well healthy newborns and those admitted to the NICU and to improve the utilisation of the NICU Nutritional Dashboard within the EHR. Should you choose to participate, you will be asked to join an expert group. Participation in this study is completely voluntary. All of the information you provide will be kept confidential and anonymous by the researcher in any subsequent publication or dissemination.

This expert group will be coordinated over Microsoft Teams and will be recorded. The data will then be transcribed by the researcher, and all identifying information will be removed. Once this is done, the audio-recording will also be deleted and only the anonymised transcript will remain. It is expected to take at least 3-6 call for 60 mins each.

This study has obtained ethical approval from the relevant Ethics boards associated with each Hospital/Hospital Group.

If you have any queries about this research, you can contact me at orla.sheehan1@hse.ie or Brendan.murphy@ucc.ie

If you agree to take part in this study, please sign the consent form.

Explicit Consent Form

Reference Number:	**Protocol Number:**
Title of Study: Improving Data Quality of Newborn Feeding in a maternity hospital EHR	
Patient / Respondent Identification Number for this research	
Name of Researcher: Orla Sheehan and Dr Brendan Murphy	

1. I confirm that I have read and understood the information leaflet for the above research study and received an explanation of the nature, purpose and duration of the study. YES☐ NO☐

2. I understand that my participation is voluntary (my choice) and that I am free to withdraw at any time without legal rights being affected. YES ☐ NO☐

3. I am willing to participate in the expert group for this study and I understand the expert group will be audio-recorded. YES ☐ NO☐

4. I understand that anonymity will be ensured in the write-up by disguising my Identity YES ☐ NO☐

5. I understand that disguised extracts from the expert group may be quoted in the thesis and any subsequent publications YES ☐ NO☐

I agree to take part in the study.

....

Name (in block letters) Date Signature

Appendix 21: Consent and Participant Information Leaflet for Site A; Qualitative Post Analysis Focus Group

Information Sheet and Consent Form

Study Title: Improving the quality of newborn feeding documentation in an EHR- a post change qualitative review using a focus group

Thank you for considering participating in this research project.

The aim of this study is to undertake a post-review of the implemented changes in relation to newborn feeding for both well healthy newborns and those admitted to the NICU and to understand the use of the NICU Nutritional Dashboard within the EHR. Should you choose to participate, you will be asked to join an expert focus group. Participation in this study is completely voluntary. All of the information you provide will be kept confidential and anonymous by the researcher in any subsequent publication or dissemination.

This expert focus group will be coordinated over Microsoft Teams and will be recorded. The data will then be transcribed by the researcher, and all identifying information will be removed. Once this is done, the audio-recording will also be deleted and only the anonymized transcript will remain. While anonymity within the group is not possible, what is discussed within the group and who is present must remain confidential. It is expected to take one call for approx. 45- 60 mins.

If you have any queries about this research, you can contact me at orla.sheehan1@hse.ie or Brendan.murphy@ucc.ie

If you agree to take part in this study, please sign the consent form overleaf.

Consent Form

I……agree to participate in Orla Sheehan's research study.

The purpose and nature of the study has been explained to me in writing.

I am participating voluntarily.

I give permission for my focus group with Orla Sheehan to be audio-recorded.

I understand that I can withdraw from the study, without repercussions, at any time, whether before it starts or while I am participating.

I understand that who is present in the group and what is discussed in the group must remain confidential.

I understand that anonymity will be ensured in the write-up by disguising my identity. I also undertake to maintain the confidentiality of the group.

I understand that disguised extracts from the focus group may be quoted in the thesis and any subsequent publications if I give permission below:

(Please mark one box:)

I agree to quotation/publication of extracts from the focus group ☐

I do not agree to quotation/publication of extracts from the focus group ☐

Signed: ……. Date: ……..

PRINT NAME: …….

Appendix 22: Topic Guides

Pre- Implementation Topic Guide

1. What works well for infant feeding input and reviewing?
2. What does not work well for infant feeding input and review?
3. What would make data entry easier?
4. Do you use the NICU Nutritional Dashboard?
5. If so, what do you like about it?
6. If not, why do you not use it as a review tool?
7. What would help with the review of infant feeding?

Post- Implementation Topic Guide

- Introduction:
    - Introduction to the study
    - Signed consent forms
    - Background to study and update on results/outcome from initial group meetings
    - Scope of this meeting- to review current status and be clear not to implement further changes (just to focus on the current state)
- Data Entry
    - Since we made the changes to the Newborn Feeding- how do you find the data entry now?
    - Before we made changes it was thought the entry was to complex and took too much time. Is this still the case?
    - Are complex feeds easier to enter?

- Data Review
    - Since we the changes to data entry and created new flowsheets for data review- how do you find the reviewing of feeding information now?
    - Are complex feeds easier to review?

- Nutritional Dashboard
    - Previously the dashboard was described as being unreliable but with great potential. How do you find the dashboard now since the data entry changes?
    - Is the dashboard more reliable?
    - Do you use the dashboard any more frequently now?

- Implementation:
    - Was the implementation successful?
    - Were the training /videos provided helpful?
- Conclusion
    - Is there anything else to address?
    - Thank participants

Appendix 23: Researcher's Personal Account

With my background as a NICU Nurse, I have always loved to learn and stay up to date of new technologies and research that may influence patient care for the better. And I am incredibly grateful for all the opportunities I have had along my career path and my education thus far. My career somehow pivoted to electronic health records from clinical care and clinical teaching when the MN-CMS was in the planning stage. From this point, I have been involved in MN-CMS in key roles from the design, implementation, and optimisation of the project specifically focused on the neonatal electronic chart.

My journey to PhD studies has started with why. Much like Simon Sinek's "Start with Why", I wanted to identify the purpose of our actions and how it can help inspire others and achieve success. The key recommendation from MN-CMS is keeping the patient at the centre of the journey and that has always been the case for our tiniest newborn patients. The creation of their EHR at birth provides the first digital footprint and the potential of an EHR to grow with them for the remainder of their lives. The learnings from the practical, hands-on implementation of MN-CMS have been immense and other hospitals, health networks and countries can learn so much from our journey.

Starting my PhD, I was guided to explore scientific frameworks for my work which would provide a scientific basis for implementation of changes to policy or practice in healthcare. This led me to the emerging scientific field of implementation science. Following application, I was accepted onto the Implementation Science Training Institute (ISTI) 2022 course, and I was funded to participate on this course by the National Perinatal Epidemiology Centre (NPEC). This was directly relevant to my learning needs around the healthcare implementation process including theories, models, and frameworks, implementation strategies and measuring outcomes from the implementation process. This learning contributed greatly to my overall PhD thesis and underpinning my work in a scientific framework. This training course facilitated by the Health Implementation Research Hub at the

School of Public Health, UCC and was facilitated by some of the most renowned implementation scientists.

The goal of using available information and data to improve patient outcomes is the ultimate benefit of EHRs worldwide. The biggest challenge faced during this time was around the criminal cyber-attack on the Health Service Executive's technology infrastructure in May 2021. The immediate and catastrophic loss of patient data was profound and something I never thought I would experience. For maternity hospitals relying primarily on the MN-CMS EHR to lose all types of patient data from scheduling, imaging results, laboratory results, plans of care, volumes, and times of last feeds, it left clinicians blind and highlighted the critical importance of up-to-date, accurate and timely data being available. The biggest technology challenges facing healthcare are managing the enormous growth in (healthcare) big data and the security threats facing health institutions and their infrastructure. Likewise, the COVID19 Pandemic highlighted the importance of data, data security and data sharing to improve public health and benefits to patients and the public.

On a personal level, my learning throughout these past 3 years has been immense and has included planning, organising, academic writing, journal submissions and publishing. In terms of the continued roll out of MN-CMS, I feel have a solid grounding now to bring new skills and learning to the future hospital sites for a successful EHR implementation based on my work and studies during this PhD journey. EHR implementation is a huge area and I hope I have contributed in some small way to the overall learning.

In conclusion, I feel that I have developed new skills and enhanced my overall development throughout this PhD journey. Having identified areas that needed improvement I sought to find the relevant learning that would improve my knowledge in various areas as highlighted throughout this reflective essay. Through the ISTI implementation science course, and through my research for this thesis, I have developed new knowledge in an emerging field of science, and I have used

this knowledge in practical implementation. I have learned how industry and healthcare together can improve patient outcomes through appropriate use and analysis of data. Implementation and optimisation of the EHR through workflow analysis and end user involvement will ultimately improve data quality and completeness and enhance the output from EHRs to generate data which can be used for audit, informing healthcare policy, and improving patient outcomes.