

STUDY TITLE: Understanding the epidemiology in the transition from neonatal to paediatric care: a data linkage study

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1 BACKGROUND

1.1 BACKGROUND TO THE PROPOSED STUDY

Following birth, around one in seven babies are admitted for specialist neonatal care in the UK (1). Reasons for admissions to neonatal care vary according to gestational age and the clinical condition of the baby at birth but include extreme prematurity (e.g. babies born before 27 weeks of gestational age) requiring ventilation support; antenatally detected anomalies (e.g. cardiac anomalies requiring complex surgery); feeding difficulties; infections or jaundice. Admission rates to neonatal care have increased in recent years (1,2). This increase is partly due to improved survival of the most vulnerable babies (3-5). Intervention for, and survival of, these babies has become increasingly normalised by clinicians and families, but the impact of health problems and care received in the initial period after birth can be lifelong (6,7).

There has been a similar increase in admissions to paediatric intensive care units (PICU) (8) and other paediatric services including children's wards and A&E. There are children with very demanding needs who now survive, who in the past did not. The main reasons for PICU admission are respiratory problems (e.g. bronchiolitis, ~30% of PICU admissions) or cardiovascular conditions (~27% of PICU admissions). The length of stay of children who die in PICU is increasing, potentially indicating efforts to prolong life in children with life limiting conditions (9).

Research investigating the short to long-term outcomes of children who require neonatal care is limited and to date has mainly focused on particular subgroups, for example those who were born prematurely (6,10). However, less is known about the transition and care pathways between specialist neonatal and paediatric care and any additional healthcare resources these babies may need in early childhood. The care received in each of these settings provides a very different experience for families and babies/children. For example: a baby's length of stay in neonatal care can be very long (e.g. months for babies born very preterm (11)), whilst the length of stay of a child in paediatric care is much shorter (median on paediatric wards: one day (12), median in PICU: two to three days (13)).

Once a baby is discharged from neonatal care, if they need to come back to hospital, even within a short time frame, they will generally be admitted to paediatric care to reduce the

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risk of infection within the neonatal unit (14). This movement from neonatal to paediatric services represents a transition between two services - an 'interruption in the delivery of care' with implications for patient safety and care quality (15).

Whilst there is available data on neonatal care (National Neonatal Research Database, NNRD); paediatric intensive care (Paediatric Intensive Care Audit Network, PICANet) and other paediatric care (Hospital Episodes Statistics, HES and Patient Episode Database for Wales, PEDW) as well as outcomes (Office for National Statistics, ONS), these data sources have never all been linked to allow consideration of the entire care pathway from neonatal admission and beyond. Therefore, the scale and impact of admission to paediatric care of babies who received neonatal care is unknown in the UK.

1.2 LAY SUMMARY

What is this research about?

Following birth, around one in seven babies are admitted for specialist neonatal care in the UK. Admission rates to neonatal care have increased in the last few years, partly due to improved survival of the most vulnerable babies, particularly those born very prematurely or those with serious health problems. More and more of these babies now survive, but the impact of their health and the care received immediately after birth can be lifelong. There has also been an increase in admissions to paediatric intensive care units (PICU) in the last ten to fifteen years. We believe that many admissions relate to children who received neonatal care immediately after birth, although the exact number is not known.

Very little is known about what happens between neonatal and paediatric care including which children are likely to experience both types of care, and how clinical services, parents and professionals manage the transition.

What are the aims of this research?

The aim of this research is to understand which children who receive neonatal care also go on to need paediatric care and how we can best support them and their families.

How are parents and families involved in this work?

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Parents with experience of a child having received neonatal care helped to develop this research project, and will continue to be involved throughout. The idea for this project was conceived during a meeting where several parents commented that they thought discharge from neonatal care would be the last interaction with acute hospital care for their child. This was regularly not the case as many of their children were subsequently admitted to paediatric care.

Why is this important?

Currently we do not know how many children who receive neonatal care go on to need paediatric care. We need this information to help plan clinical services but also to advise parents about how likely it is that their child will need hospital care in the future. This information will aid the conversations between clinicians and parents.

How is this research being conducted?

Information about the medical care received in neonatal units, paediatric units and hospitals is collected for hospital information systems and national audits. This data will be provided for this research project and this is known as an analysis of 'routine data.' There is no need to collect any new information about babies or children for this study. We will ask permission of the people who provided the data (the hospitals) to use it for this study. It will not be possible for the research team to identify individual babies or children from the data (e.g. no names of children will be provided to the team).

How will this work be disseminated?

This work will be published in peer-reviewed academic journals. We will also produce magazine articles, short podcasts and infographics to provide information in an easily accessible format. We will use social media to promote our work, and ensure that it is promoted within the general public as well academic and clinical communities.

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1.3 RESEARCH AIMS

The aims of this research are:

- To describe and understand the epidemiology of children who receive neonatal and/or paediatric care
- To describe the resource use and clinical need of children who receive neonatal and/or paediatric care
- To explore if there are certain groups of children at higher risk of needing paediatric care in the first two years of life after discharge from neonatal care

2 PROPOSED RESEARCH STUDY

2.1 BACKGROUND

There is limited information about children admitted to paediatric care following discharge from neonatal care in the UK, as the data sources have not been linked together. Whilst many families are aware that their child may have lifelong concerns following discharge from neonatal care some parents have still never considered future hospitalisation or PICU care. Therefore, it is vital to understand the changing epidemiology of paediatric care and to identify those babies who are likely to require subsequent admission(s) to paediatric care following discharge from neonatal care, to inform healthcare services, clinicians and better prepare their families.

It is hypothesised that admissions to paediatric care will fall into one of four broad categories

1. Unexpected admissions in a short timeframe (e.g. 48 hours) due to an unforeseen deterioration in health e.g. jaundice, breathing difficulties.
2. Unexpected admissions in a longer time frame due to deterioration in health, e.g. bronchiolitis in the first winter after neonatal care.
3. Expected admissions in a short timeframe, e.g. after a brief planned break home or to a hospice for respite care (anticipated to be very rare in this population).
4. Expected admission in a longer timeframe, e.g. need for ongoing cardiac surgical procedures through early childhood and beyond.

This data linkage study will investigate whether at discharge from neonatal care there are certain groups of babies who are at a higher risk of hospital admission in the first two years of life. For example, groups of babies may include:

- Babies with cardiac defects requiring surgery
- Extremely premature babies who received prolonged ventilation (therefore at a high risk of respiratory viruses)
- Metabolic conditions

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Knowledge of whether a baby with certain characteristics is at risk of one of the admission scenarios (1) to (4) will help inform decisions about their discharge, and provide information for their families. We will specifically investigate if they are admitted to paediatric care in certain time frames including within:

- 48 hours of discharge from neonatal care
- a week after discharge from neonatal care
- up-to a year after discharge from neonatal care
- up-to two years after discharge from neonatal care

2.2 STUDY RECRUITMENT

This study makes use of routinely available data and as such, no active study recruitment is required. To access data available in the NNRD, all neonatal units will be written to with information about the study and offered the opportunity to opt-out. This is an established process. PICANet has approval to be used for research although all PICUs will receive information about this study. Information about the project will also be made available online.

3 DATA

3.1 DATA SOURCES AND DATA QUALITY

This study will only use routinely available data, it will not actively recruit any babies or children. No identifiable data will be provided to the study team at the University of Leicester. The dataset will be formed by linkage between the NNRD; PICANet; HES/PEDW and mortality data from the Office for National Statistics (ONS). NHS Digital/NHS Wales Informatics Service will undertake the linkage using personally identifiable data, and no identifiable data will be provided to the research team at the University of Leicester. NHS Digital will perform the linkage between the NNRD and PICANet. Further information about the data sources is as follows

1. **National Neonatal Research Database (NNRD):** The NNRD captures information about all babies admitted for neonatal care after birth. This study will make use of

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data related to demographics of the child; clinical diagnoses; treatment received in neonatal care and the outcomes at the time of neonatal discharge.

2. **Paediatric Intensive Care Audit Network (PICANet):** PICANet is commissioned by the Healthcare Quality Improvement Partnership and is based at the Universities of Leeds and Leicester. Data is collected by PICANet related to referrals, transports and admissions to PICU. This study will make use of the admission data which includes: demographics of the child; clinical diagnoses; treatment received whilst in PICU and outcomes at the time of PICU discharge.
3. **Hospital Episodes Statistics (HES):** Admissions to hospital and A&E attendances are routinely collected for England within the HES database. HES collects data related to patient demographics; diagnoses and clinical care.
4. **Patient Episode Database for Wales (PEDW):** As HES, but collects data within hospitals in Wales.
5. **Death registrations from the Office for National Statistics (ONS):** The Office for National Statistics collects data regarding date and cause of death in England and Wales.

3.2 DATA ITEMS FOR EXTRACTION

We will extract information related to, but not limited to, the following items from each dataset:

NNRD: We will receive information about the baby's demographics (e.g. gestational age at birth, sex, birthweight, ethnicity); clinical care (e.g. days on ventilation, medications received, length of stay); diagnoses (e.g. congenital anomalies, retinopathy of prematurity, bronchopulmonary dysplasia) and outcomes (e.g. survived neonatal care, discharged to a surgical unit).

PICANet: We will receive information about the child's demographics (e.g. age, sex, ethnicity, deprivation); clinical care (e.g. days on ventilation, medications received, length of stay); diagnoses (e.g. respiratory infection, cardiac defect, cancer) and outcomes (e.g. survived PICU, died in PICU). We will focus on care received in the first two years of life but for those children who were also subsequently admitted in later years we will also receive the information related to later admission(s).

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HES: We will receive information about the child's demographics (e.g. age, sex, ethnicity, deprivation); clinical care (e.g. where care was received, medications received, length of stay) and diagnoses (e.g. respiratory infection, appendicitis).

PEDW: We will receive information about the child's demographics (e.g. age, sex, ethnicity, deprivation); clinical care (e.g. where care was received, medications received, length of stay) and diagnoses (e.g. respiratory infection, appendicitis).

ONS: We will receive information about any death registration, including date of death and cause of death.

Detailed data dictionaries and information about the extraction will be developed before data is provided to the team at the University of Leicester. Data which is potentially identifiable (e.g. date of birth) will be anonymised.

3.3 DATA LINKAGE (NHS DIGITAL)

The data linkage proposed in this study is required to understand the experience of children as they transfer between different healthcare services. Each data source provides detailed information on the care provided to babies and children, but to date no research has investigated which graduates from neonatal care go on to require care in paediatric settings.

Linkage will be undertaken by NHS Digital using personally identifiable data including NHS number; sex; date of birth; name and postcode and the data flow can be found in Appendix 1. All records transferred to NHS Digital will include a pseudo-anonymised identifier to allow linkage back to the clinical data by the team at the University of Leicester. No clinical data will be transferred from the NNRD or PICANet to NHS Digital.

Personal data will be securely transferred to NHS Digital on all eligible babies born and admitted to neonatal units captured by the NNRD on the first day of life. Similar personal data will be transferred by PICANet related to admission(s) to PICU of children aged less than two years. An individual baby's record in the NNRD may match to multiple PICU admissions or there may be no PICU admission records. Similarly, a PICU record may have no match in the NNRD. NHS Digital will compare the datasets and provide information about those only in the NNRD, those only in PICANet, and those common to both datasets.

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NHS Digital will add in information from HES and mortality information from ONS that have occurred in the two years following birth and remove the personally identifiable information (whilst retaining the pseudo-anonymised link). This will be transferred to the team at the University of Leicester who will receive additional data related to demographic, care, treatment and outcomes directly from the NNRD and PICANet. This data can be added to the data from NHS Digital via use of the pseudo-anonymised identifier.

Due to the need to access personal data to perform the linkage we will apply for Confidentiality Advisory Group (CAG) approval for this aspect of the study, the proposed data flow for this section can be found in Appendix 1.

3.4 DATA LINKAGE (NHS WALES INFORMATICS SERVICE)

The equivalent of HES data for Wales (PEDW) will be provided by the NHS Wales Informatics Service. This service only provides linkage undertaken on NHS number. Data on babies born and admitted to neonatal units and children admitted to PICU will be sent securely by the NNRD and PICANet respectively. The NHS Wales Informatics Service will add in information about hospital care received in Wales whilst the children were aged less than two years.

There is no need for the linkage between the NNRD and PICANet undertaken by NHS Digital to be repeated by the NHS Wales Informatics Service.

Due to the need to access personal data to perform the linkage we will apply for CAG approval for this aspect of the study, the proposed data flow for this section can be found in Appendix 2.

3.5 DATA SECURITY

The University of Leicester will only receive pseudo-anonymised data for this project and the link back to the personally identifiable data will only be accessible by the providers of the data (NNRD and PICANet) and NHS Digital/NHS Wales Informatics Service.

All data and documentation related to the study will be stored on the university server system known as the R Drive. The relevant area of the R Drive is only accessible to the PI and other nominated research team staff. Access to this area is via a request to IT Services by the PI (Sarah E Seaton) in order to control access.

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Data access is strictly restricted to the study University R drive. No data can be moved or copied to any other area of the R Drive, or any other location, and no data can be taken off the physical University premises. If working away from normal office location is deemed essential (such as in the event of a University shut down) then access to the data will be available via secure Virtual Private Network (VPN), via a University managed laptop.

All offices are locked when vacant and computers have screen lock applied when leaving the desk. There will be no personal data stored on paper.

All data will be transferred securely via approved systems (e.g. Bizcom used by the University of Leeds and FileDrop used by the University of Leicester). All files will be password protected and passwords will be provided verbally over the phone.

4 ANALYSIS

4.1 SAMPLE SIZE

All babies admitted for neonatal care in England and Wales from 1/1/2013 to 31/12/2018 will be included. This will allow all babies to be followed up for two years identifying any PICU/hospital admissions occurring over this period (we anticipate having all approvals to access data in place by early 2021). Babies who were admitted within specific time points after discharge from neonatal care will be compared with those who are not admitted for paediatric care at any time in the first two years of life.

Approximately 80,000 babies receive neonatal care in England and Wales each year. This will provide an approximate sample size of 480,000 (2013-2018) to link with PICANet, HES, PEDW and ONS. It is hypothesised that the many of these children will not have a linked record as discharge from neonatal care will represent the last interaction these children had with healthcare services in their early life.

All children aged <2 years on their admission to PICU will be considered for potential linkage with the neonatal data. There are approximately 10,000 admissions to PICU of children aged <2 years each year, providing a total of ~80,000 PICU admissions (2013 to 2020). Some of these children will have received care in a neonatal unit, but it is not possible to quantify this at this stage.

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We will retain information related to children irrespective of whether it was possible to link them between the two datasets, i.e. we will have data of all children admitted to neonatal care from 2013 to 2018 and all children aged <2 years admitted to PICU from 2013 to 2020.

4.2 STATISTICAL ANALYSIS

A formal statistical analysis plan will be developed before receipt of data, and this will be approved by the multidisciplinary study team. The proposed analysis of the linked dataset is planned to be initially descriptive, not relying on formal statistical testing or when testing is employed, emphasis will be on clinical rather than statistical significance. Important consideration will be given to data quality and completeness, which are always potential issues within routine data analysis such as this.

Summary statistics will be produced of all babies admitted to neonatal units; all children admitted to PICU aged <2 years and those who receive care in both settings. Similar results will be explored for A&E and hospital admission following discharge from neonatal care.

Risk of admission to paediatric care

We will investigate the risk of admission to paediatric care for clinically meaningful groups of children (e.g. preterm born babies) identified through discussion with our multidisciplinary team. Alongside this an analysis will then be conducted to identify subgroups of children discharged from neonatal care who at risk of admission to paediatric care: PICU, A&E and hospital ward care. These subgroups will be identified using Latent Class Analysis (LCA) (16,17). LCA is a subset of structural equation modelling which is used to find groups or subgroups, known as latent classes, within data. Groups of babies will be identified who are similar to each other across a potentially large number of risk factors (e.g. diagnosis, morbidities on discharge, ventilated whilst in neonatal care). These identified groups can be given descriptive names e.g. “babies ventilated for >7 days”. This will inform clinical identification of babies likely to need admission to PICU or hospital following discharge from neonatal care.

Alongside identification of subgroups of children at risk of admission to paediatric care, we will also use logistic regression to investigate risk factors for admission. We will initially decide the selection of risk factors via discussion with clinical colleagues rather than using

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statistical approaches such as stepwise regression. Model fit will be assessed via use of appropriate tests including: Area Under the Curve (AUC); Briers score(18) and the Hosmer Lemeshow test(19).

Time to admission to paediatric care

Children will be admitted to paediatric care within different time frames. To explore this further, and investigate if there is a correlation with diagnoses or demographics, survival analysis approaches such as Cox regression or flexible parametric modelling will be used where the outcome is admission to paediatric care. Model assumptions will be carefully considered, for example the assumption of proportional hazards when using the Cox model.

We will also investigate the characteristics of the admission to paediatric care, for example considering the length of stay; intervention requirements; resource use and level of care.

4.3 MISSING DATA AND DATA QUALITY

Data quality and completeness of the PICANet data is high. Validated data entry via a customised system is undertaken alongside validation visits to each PICU approximately every 18 months to inspect data quality of entries in the preceding months. Ascertainment rates of PICANet data are high, with many variables >99%. Data completeness of the NNRD is subject to similar scrutiny, with feedback loops provided for key variables. However, data checks on all data will still be completed to investigate for missing or implausible data values.

If levels of missing data are high (>10%) for key variables, reasons for this will be investigated and methods to account for this may be used. For example, if we believe that missing PIM2 (20) scores (Paediatric Index of Mortality 2 score: a measure of morbidity in critically ill children) are those of the sickest children, we may propose to undertake a sensitivity analysis to impute poor scores and rerun the initial analyses to assess the impact on the results. Conversely, if we believe data are missing at random we will investigate whether multiple imputation may be appropriate. At this stage we are unaware of the level of missing data which will be encountered. We will develop robust proposals for handling each variable as we become aware of the level of missingness and consider them amongst the study team for approval before analysis is conducted.

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4.4 IMPACT OF THIS WORK

This study will inform:

- Understanding how neonatal care impacts on the need for paediatric care, investigate the entire early life care pathway of children - an area of epidemiology currently not understood or explored
- Information for clinicians and commissioners about the impact of babies admitted for neonatal care on their other services
- Information to inform parents about the risk that their baby may be admitted for paediatric care

5 PATIENT AND PUBLIC INVOLVEMENT (PPI)

This project has been designed with parents and families at the heart of it. The initial idea for this project was conceived during a PPI meeting of a previous research study. Parents of sick babies explained to me that they often viewed discharge from neonatal care as representing the 'end' of their child's interaction with the acute healthcare service (i.e. intensive care units and specialist care) and for many this was not the reality.

I developed the idea for this research project with parents who had children who experienced neonatal care, and all suggestions and ideas were discussed with a diverse group. A parent advisory group will be established for the purposes of this study. The parents and families will continue to be involved throughout, including the co-production of materials for parents and healthcare professionals at the end of this project (see Dissemination).

6 DISSEMINATION, OUTPUTS AND IMPACT

All publications from this work will be written on behalf of the UK Neonatal Collaborative, and the Paediatric Intensive Care Audit Network to reflect their contributions to this work.

The impact of this work will be in the following ways:

Working with clinicians and healthcare professionals to inform the information and support provided to parents and families: This work will allow identification of those children at increased risk of admission to paediatric care, and therefore clinicians will be able to tailor the information they provide to parents.

Informing the information for policy makers and managers: This work will explore the care needs of children throughout their early life. This has never been investigated before and so this will provide information for healthcare services to understand how to plan and commission their services. I will work with Bliss (baby charity in this area) and other stakeholders to develop guidance including NICE guidelines or appropriate paediatric standards, to improve the care and support for families around the time of neonatal discharge and subsequent support for these parents in the PICU.

Informing the public debate around sick babies and children: Awareness and knowledge of this population of sick children is limited, but is beginning to increase in recent years. This largely relates to a number of high profile PICU/neonatal care cases (e.g. Charlie Gard). However, broadly the general public do not have awareness of these issues. As part of this project I will promote public engagement and knowledge within this area.

I will achieve this impact via dissemination and output in the following ways:

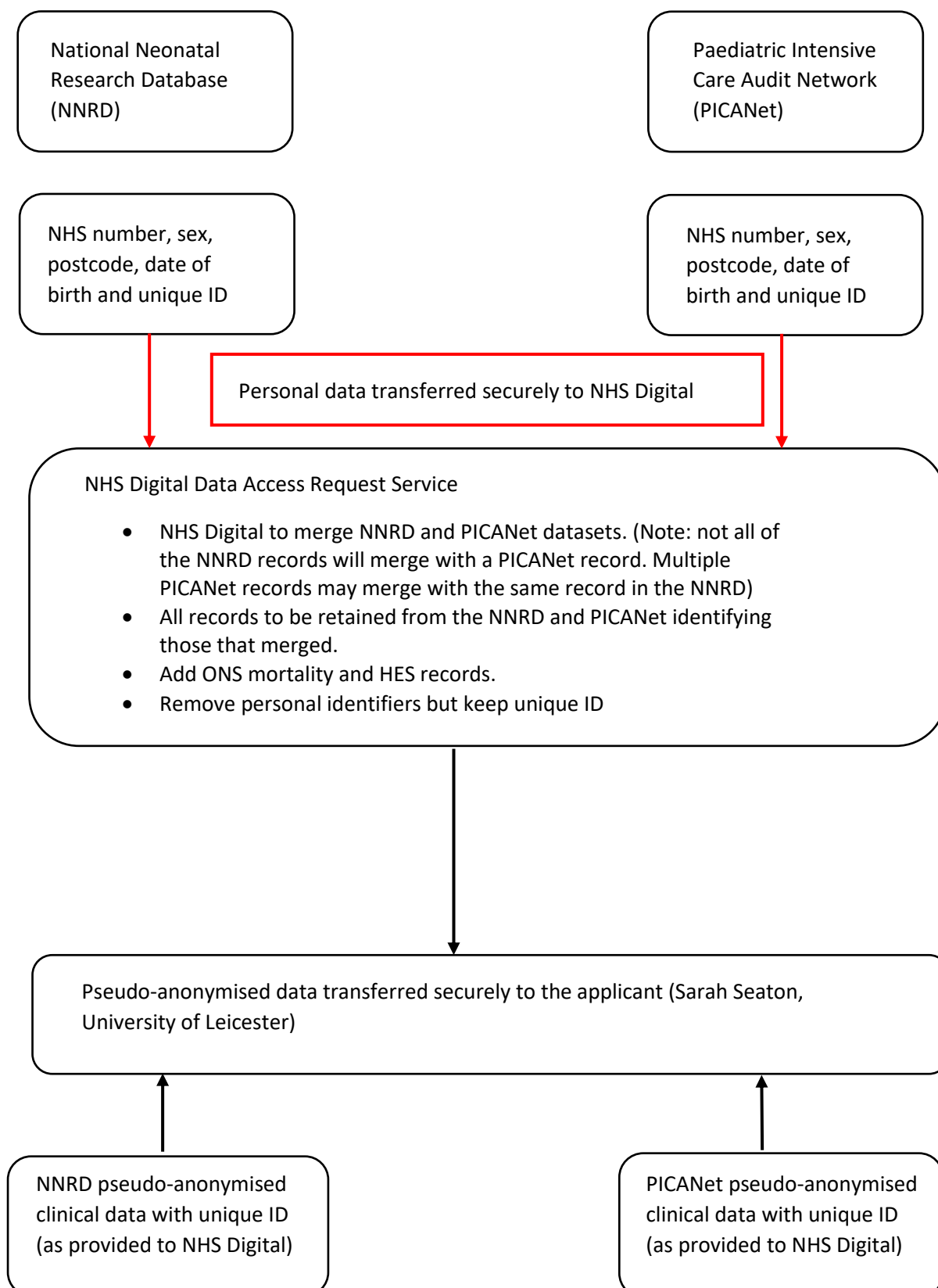
- **Academic articles:** at least two peer reviewed papers will be published from this study. These will be targeted at different audiences (a clinical journal, e.g. Pediatrics, and a more general journal, e.g. BMJ Quality and Safety). These articles will be made open access. Alongside this, for each article I will produce one short podcast and several infographics to highlight the key points. I will also produce short magazine articles for healthcare professionals magazines (e.g. Infant, a popular magazine for those who work in the area of neonatal care).

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- **Online resources or training:** If appropriate I will produce online training or resources for healthcare professionals. These will be co-produced with families and the content will be led by them.
- **Information for parents and families:** I will produce useful information for parents and families to receive, potentially on discharge from neonatal care. This information will be co-produced with families. The medium and format that this will take will be decided in conjunction with the parents and families involved in this work. This is likely to be a leaflet or an online resource provided on discharge from neonatal care. However, I have no fixed views on the form this information should take and will allow parents and families to influence this work. We will work to ensure reach across a diverse range of patient groups.
- **Ensuring uptake within the NHS:** I have previous success with the uptake of my research within the NHS. To encourage and facilitate implementation into practice, I will offer to attend journal clubs on neonatal/paediatric units and actively encourage them to discuss my papers. When attendance is not possible, I will actively promote podcasts/videos and short overviews of my work. I will attend clinical meetings and present my findings in simple to understand formats.
- **Promoting the awareness of sick babies and children with the general public:** I am passionate about increasing public awareness of all research, especially my research in perinatal and paediatric care. To facilitate this, I give public lectures at the local library. I will also offer to give talks to local social groups (e.g. University of the Third Age, Secular Society) and on the local radio. All dissemination will be promoted via social media and will be developed to be accessible to the general public.

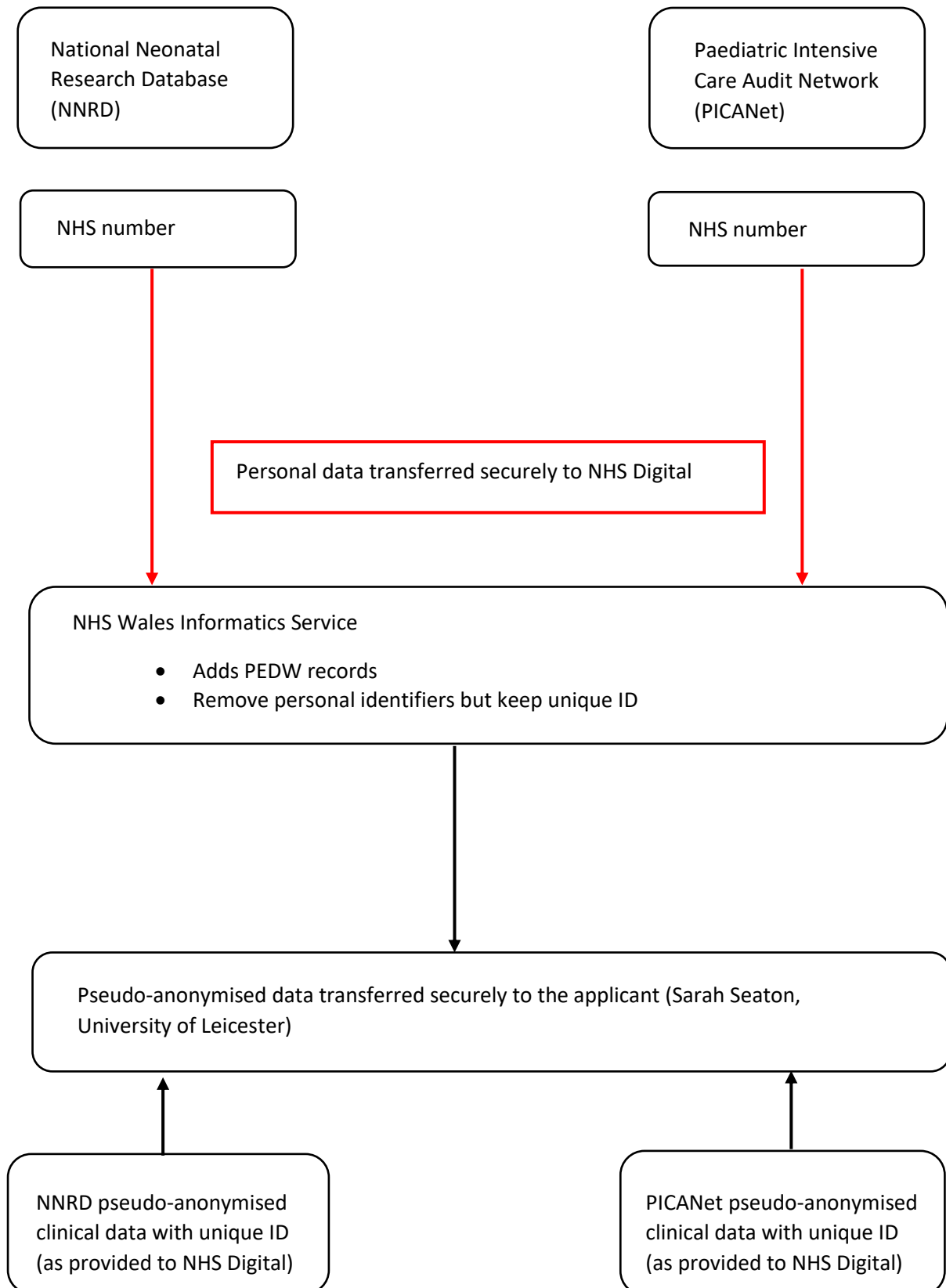
7 APPENDICES

APPENDIX 1: Data flow for data linkage by NHS Digital (note: red denotes the transfer of personal data)



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APPENDIX 2: Data flow for data linkage by NHS Wales Informatics Service (note: red denotes the transfer of personal data)



8 REFERENCES

- (1) NNAP. National Neonatal Audit Programme Annual Report 2018 - on 2017 data. Online at: <https://www.rcpch.ac.uk/resources/national-neonatal-audit-programme-annual-report-2018-2017-data> [Last accessed: 16/4/2020].
- (2) NNAP. National Neonatal Audit Programme Annual Report 2015 on 2014 data. Online at: https://www.rcpch.ac.uk/sites/default/files/NNAP_2015_Annual_Report_on_2014_data.pdf [Last accessed: 16/4/2020].
- (3) Field DJ, Dorling JS, Manktelow BN, Draper ES. Survival of extremely premature babies in a geographically defined population: prospective cohort study of 1994-9 compared with 2000-5. *BMJ* 2008;336(7655):1221-1223.
- (4) Manktelow BN, Seaton SE, Field DJ, Draper ES. Population-based estimates of in-unit survival for very preterm infants. *Pediatrics* 2013 Feb;131(2):425.
- (5) Santhakumaran S, Statnikov Y, Gray D, Battersby C, Ashby D, Modi N. Survival of very preterm infants admitted to neonatal care in England 2008–2014: time trends and regional variation. *Archives of Disease in Childhood - Fetal and Neonatal Edition* 2018 May;103(3):F208-F215.
- (6) Moore T, Hennessy EM, Myles J, Johnson SJ, Draper ES, Costeloe KL, et al. Neurological and developmental outcome in extremely preterm children born in England in 1995 and 2006: the EPICure studies. *BMJ* 2012;345:e7961.
- (7) Pollack MM, Holubkov R, Funai T, Clark A, Berger JT, Meert K, et al. Pediatric intensive care outcomes: development of new morbidities during pediatric critical care. *Pediatr Crit Care Med* 2014 Nov;15(9):821-827.
- (8) Davis P, Stutchfield C, Evans TA, Draper E. Increasing admissions to paediatric intensive care units in England and Wales: more than just rising a birth rate. *Arch Dis Child* 2018;103(4):341.
- (9) Plunkett A, Parslow RC. Is it taking longer to die in paediatric intensive care in England and Wales? *Arch Dis Child* 2016;101(9):798.
- (10) Johnson S, Evans TA, Draper ES, Field DJ, Manktelow BN, Marlow N, et al. Neurodevelopmental outcomes following late and moderate prematurity: a population-based cohort study. *Archives of Disease in Childhood - Fetal and Neonatal Edition* 2015 Jul;100(4):F301-F308.
- (11) Seaton SE, Barker L, Draper ES, Abrams KR, Modi N, Manktelow BN. Estimating neonatal length of stay for babies born very preterm. *Archives of Disease in Childhood - Fetal and Neonatal Edition* 2019 Mar;104(2):F182-F186.
- (12) Heys M, Rajan M, Blair M. Length of paediatric inpatient stay, socio-economic status and hospital configuration: a retrospective cohort study. *BMC health services research* 2017 Apr 17;;17(1):274.
- (13) PICANet. Annual Report 2018. Online at: <https://www.picanet.org.uk/annual-reporting-and-publications/> [Last accessed: 20/6/2019].

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(14) London ODN, Readmission of babies to hospital post discharge. <https://bit.ly/2VSNE1M> [accessed: 24/01/2019].

(15) Cook RI, Render M, Woods DD. Gaps in the continuity of care and progress on patient safety. *BMJ* 2000;320(7237):791-794.

(16) Lanza ST, Rhoades BL, Greenberg MT, Cox M. Modeling multiple risks during infancy to predict quality of the caregiving environment: Contributions of a person-centered approach. *Infant Behavior and Development* 2011;34(3):390-406.

(17) Kaufman L, Rousseeuw PJ. Finding groups in data. New York: WILEY; 2009.

(18) Brier GW. Verification of forecasts expressed in terms of probability. *Monthly Weather Review* 1950;78(1):1-3.

(19) Hosmer DW, Lemeshow S. Applied logistic regression. 3rd ed. New York: John Wiley & Sons; 2013.

(20) Slater A, Shann F, Pearson G. PIM2: a revised version of the Paediatric Index of Mortality. *Intensive Care Medicine* 2003 Feb;29(2):278-285.