National Maternity and Perinatal Audit

Bloodstream Infections in NHS Maternity and Perinatal Care for Women and their Babies

A Feasibility Report of Linking Maternity, Neonatal and Infection Datasets

Supplementary Information

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RCPCH Royal College of Paediatrics and Child Health Leading the way in Children's Health
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HQIP Healthcare Quality Improvement Partnership

The National Maternity and Perinatal Audit (NMPA) is led by the Royal College of Obstetricians and Gynaecologists (RCOG) in partnership with the Royal College of Midwives (RCM), the Royal College of Paediatrics and Child Health (RCPCH) and the London School of Hygiene and Tropical Medicine (LSHTM).

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Acknowledgments

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The NMPA Project Team and Board

* Since this feasibility study was carried out, NHS Digital has merged with NHS England. NHS England is now the single executive non-departmental government body with responsibility for digital technology, data and health service delivery in the NHS. Throughout this report we refer to NHS Digital, from 1 February 2023, NHS England has assumed responsibility for all activities previously undertaken by NHS Digital.

Abbreviations and glossary

Antimicrobial	Medicines that are used to treat bacterial, viral, fungal and parasitic infections.
Antimicrobial resistance	Occurs when bacteria, viruses, fungi and parasites change over time and no longer respond to antimicrobials making infections harder to treat and increasing the risk of disease spread, severe illness and death.
CAG	Clinical Advisory Group, made up of representatives from key clinical stakeholder groups.
CSF	Cerebrospinal Fluid, the fluid that flows in and around the brain and spinal cord.
Deterministic linkage	Matching records between databases by comparing one or more fields that uniquely identify an individual (e.g. an individual's study ID) between the records; a link is made if they all agree.
Early Onset Neonatal Sepsis	Infection affecting a newborn baby in the first 72 hours of life.
GBS	Group B Streptococcus is a type of bacteria which lives in the intestines, rectum and vagina of between 20% and 40% women in the UK.
GBS3	The GBS3 trial is investigating at whether testing pregnant women for Group B Streptococcus reduces the risk of infection in newborn babies compared to the current strategy in place in the UK, which is to offer antibiotics during labour to women who are considered at raised risk of their baby developing a group B Strep infection.
GBSS	Group B Strep Support (GBSS) is the world's leading charity working to eradicate group B Strep infection in babies.
HES	Hospital Episode Statistics, a dataset containing information about individuals admitted to NHS hospitals in England.
High dependency	An area or ward providing care to people who are seriously ill but do not require intensive care.
IAP	Intrapartum Antibiotic Prophylaxis, are antibiotics given to a pregnant woman or person whose baby is at risk of early onset neonatal infection.
ICCQIP	The Infection in Critical Care Quality Improvement Programme, a collaboration of professional organisations representing adult, paediatric and neonatal intensive care microbiology and infection control, supported by the UK Health Security Agency (UKHSA).
ICU	Intensive Care Unit, a specialist hospital ward providing treatment and monitoring for people who are critically ill.
LP	Lumbar puncture. The procedure where a small needle is used to extract a sample of cerebrospinal fluid (CSF) from around the lower region of the spinal cord.
MSDS	Maternity Services Data Set, managed by NHS England, which gathers data about pregnancy and birth from maternity healthcare providers in England.
Neonatal death	The death of a baby within the first 28 days of life.
NHS Digital	Formerly the national digital, data and technology delivery partner for the NHS and social care system. Merged with NHS England in February 2023.
NHS England	The single executive non-departmental government body with responsibility for digital technology, data and health service delivery in the NHS.
NMPA	National Maternity and Perinatal Audit.
NNAP	National Neonatal Audit Programme.
NNRD	National Neonatal Research Database.
PHE	Public Health England. Replaced in October 2021 by UK Health Security Agency (UKHSA) and Office for Health Improvement and Disparities (OHID).
Postnatal	The period immediately following birth, defined for the baby.
Postnatal ward	The ward or area where mothers and their babies are cared for following birth.

Postpartum	The period following childbirth, defined for the mother, and for the purposes of this report, the time period is six weeks.
Probabilistic linkage	Matching records between databases by comparing multiple fields that may not uniquely identify an individual (e.g. an individual's first and last name).
RCOG	Royal College of Obstetricians and Gynaecologists.
RCPCH	Royal College of Paediatrics and Child Health.
Sepsis	The life-threatening condition which may lead to tissue damage, organ failure and death, that can occur in response to an infection.
SGSS	Second Generation Surveillance System, the national laboratory reporting system used in England to capture routine laboratory data on mainly infectious diseases and antimicrobial resistance.
Stillbirth	The birth of a baby without signs of life at or after 24 weeks of gestation.
UKHSA	UK Health Security Agency. Previously known as Public Health England (PHE).
UK Sepsis Trust	The UK's leading sepsis charity, raising awareness & providing vital support to those affected.
WHO	World Health Organisation.

Throughout this document we use the terms 'mother', 'pregnant women and people' and 'women and birthing people'. It is important to acknowledge that it is not only women who access maternity, reproductive and gynaecology services.

Key findings, recommendations, report evidence and related national guidance

	Key finding (KF) **Recommendation (R)** *(Audience)*	**Report findings underlying this recommendation**	**Page**	**Related national guidance**
KF1	Linkage of maternity, neonatal and infection data has not been achieved, despite the existence of datasets and demand from clinicians, service users and stakeholder groups.	Methods	14-15	NHS England (2016) *Better Births, Improving outcomes of maternity services in England*,[1] NHS England (2019) *Saving Babies' Lives Version Two*,[2] National Institute for Health and Care Excellence (2017) *Intrapartum care for healthy women and babies*,[3] National Institute for Health and Care Excellence (2021) *Neonatal infection: antibiotics for prevention and treatment*,[4] Healthcare Safety Investigation Branch (2020) *National Learning Report. Severe brain injury, early neonatal death and intrapartum stillbirth associated with group B streptococcus infection*,[5] Department of Health (2017) *Safer Maternity Care, The National Maternity Safety Strategy – Progress and Next Steps*,[6] Royal College of Obstetricians and Gynaecologists (2017*) Prevention of Early-onset Group B Streptococcal Disease*,[7] WHO (2022) *Strategic Priorities on Antimicrobial Resistance. Preserving antimicrobials for today and tomorrow*,[8]
KF2	The barriers to obtaining linked data are largely due to timescales, resources and processes, as well as the capacity to collaborate in driving this forward. - Datasets are held within different organisations and it is necessary for some linkage operations to be performed by a third party (NHS Digital). - The process for information governance approvals and the capacity for NHS Digital (now NHS England) to perform the dataset linkage has not been feasible within the remaining NMPA contract period that ended on 31 December 2022.	Methods, Figure 1, Figure 2	14-15, 16-17	
R1	**Identify and explore the key reasons behind the significant delays in data provision and data linkage and propose an action plan to reduce these in the future.** *(NHS Digital)*			
KF3	Factors beyond the control of the NMPA, NNAP and stakeholder groups, and which affected the prioritisation of data and data linkage requests. These were the COVID-19 pandemic and the restructuring of Public Health England (now United Kingdom Health Security Agency (UKHSA)).	Figure 1	16	
R2	**Provide reasonable estimates of the anticipated date for receiving data and data linkage requests.** *(NHS Digital)*			

	Key finding (KF) **Recommendation (R)** *(Audience)*	**Report findings underlying this recommendation**	**Page**	**Related national guidance**
KF4	Ongoing routine data linkage of maternity, neonatal and infection data is required for infection and antimicrobial surveillance.	Background, Discussion	9-12, 18-19	UK Government (2019) *Tackling antimicrobial resistance 2019-2024. The UK's five-year national action plan*,[9] UK Government (2022) *Tackling antimicrobial resistance 2019 to 2024: addendum to the UK's 5-year national action plan*.[10]
R3	**Establish ongoing routine data linkage of maternity, neonatal and infection datasets for infection and antimicrobial surveillance in the population in order to describe rates of and variation in care and outcomes for:** - **Blood or CSF culture confirmed infection in mothers and babies** - **Intrapartum antibiotic administration** - **Empirical antibiotic administration** - **Number of mother-baby separation days attributable to infection** - **Number of baby days of antibiotic administration** *(NHS Digital, HQIP, UKHSA)*			
R4	**Review and optimise data items required for linking routinely collected data and ensure system compatibilities with futureproofing to guarantee ongoing linkage.** *(NHS Digital, HQIP, UKHSA, maternity services software developers)*			
KF5	Advisory group conversations highlighted a need for more information made available to families about the effects of infection during or after pregnancy on mothers and babies, and the impact on the whole family.	Advisory Group Meetings		
R5	**Prioritise further research into the consequences of maternal and neonatal infection, and into preventing infection and reducing antimicrobial resistance, utilising qualitative and quantitative methodologies.** *(National Institute for Health Research, UK Research and Innovation, Royal College of Obstetricians and Gynaecologists, Royal College of Paediatrics and Child Health, British Association of Perinatal Medicine, National Institute for Health and Care Excellence, policy makers, service planners/commissioners, service managers and healthcare professionals working for maternity services)*			

Introduction

Background on maternal and early onset neonatal infection

Infections during pregnancy can have adverse effects on both the mother and the fetus. Pregnant women and people may be colonised, meaning they are carrying pathogens but are not adversely affected by them, or they may become unwell themselves from an infection. Pathogens can be transmitted from the pregnant woman or person to the fetus during pregnancy, birth or the postnatal period. During pregnancy, organisms causing infections can be transmitted to the fetus via the placenta, or by ascending from the maternal genital tract. Transmission may also occur during birth due to direct contact with maternal secretions or blood. Infections in the newborn baby can be caused by direct contact with the mother or with other environmental sources in the postnatal period.

It is important to clarify that bloodstream infections and sepsis are not one and the same, although the terms are often used interchangeably in the literature and in clinical practice. A bloodstream infection is diagnosed by the presence of a pathogenic organism grown in a blood culture and this may lead to sepsis.[11] The World Health Organisation (WHO) defines maternal sepsis as: a life-threatening condition defined as organ dysfunction resulting from infection during pregnancy, childbirth, post-abortion, or postpartum period.[12] If not recognised and treated promptly, sepsis can be associated with tissue damage, multi-organ failure and death.

Despite being highly preventable, maternal and neonatal infection are significant causes of mortality and morbidity in women and birthing people, and their babies.[4,13,14] Globally, maternal mortality from sepsis varies greatly depending on healthcare provision. Worldwide, sepsis accounts for 10.68% of all maternal deaths, and for 4.73% and 10.70% in high- and low/middle-income countries respectively.[15] In contrast, the UK the mortality rate from sepsis for women and birthing people is 8 per 100 000 live births.[16]

Maternal sepsis is the second leading cause of direct maternal death during pregnancy, or in the six weeks following birth in the UK. Whilst the rates of sepsis are increasing yearly, the increase is not statistically significant.[17] Rates of neonatal deaths and stillbirths caused by sepsis remained static between 2015 and 2019.[18]

The Royal College of Obstetricians and Gynaecologists (RCOG) *Bacterial Sepsis in Pregnancy* and National Institute for Health and Care Excellence (NICE) *Sepsis: recognition, diagnosis and early management* guidelines outline those who are at risk of infection. Women and people who are pregnant, have given birth or had a termination of pregnancy or miscarriage in the past six weeks are considered to be a group who are at a higher risk of sepsis.[19,20] NICE guidance for early onset neonatal infection lists maternal risk factors along with clinical signs in the baby to identify those who may be at risk of, or showing signs of infection. Babies may be given empirical antibiotics when there is suspected or confirmed bacterial infection in the mother, and some mothers may be given antibiotics during labour to offer protection them and their baby.[4,7]

Adverse outcomes from infection during pregnancy may include pregnancy loss, congenital anomaly, fetal growth restriction, stillbirth, preterm birth, obstetric haemorrhage, maternal death, neonatal death, or long-term disability.[21,22] With prompt diagnosis and treatment, many women and birthing

people and babies recover without long lasting physiological effects,[14] however, there can be an ongoing psychological impact.

> *"[after discharge home] I didn't know the world that I was walking into. It had a lot of psychological effects. I was diagnosed with PTSD."*
> (NMPA advisory group member)

The most common organisms identified in pregnant women and people dying from sepsis are Group B streptococcus (GBS) and *Escherichia coli* (*E. coli*).[23] It is estimated that 20-40% of women in the UK carry GBS in their digestive system or vagina.[24] The pathogens that most commonly cause sepsis in the six weeks following birth are *Streptococcus pyogenes* (Group A streptococcus), *E. coli*, *Staphylococcus aureus*, *Streptococcus pneumoniae*, methicillin-resistant *S. aureus* (MRSA), *Clostridium septicum* and *Morganella morganii.*[23]

Early onset neonatal infection is defined as infection affecting the newborn baby within the first 72 hours of life.[4] Organisms involved are most often gram-positive bacteria, GBS, Staphylococci (predominantly *S. aureus*), Streptococci (other than GBS) and Listeria, followed by gram-negative bacteria, (*Escherichia coli* (*E. coli*), *Enterobacter* spp*., Klebsiella* spp.). GBS is the most common pathogen causing early onset neonatal infection in babies born at term, at or after 37 completed weeks gestation.[26] In England in 2020, early onset GBS infection was reported in 0.53 per 1000 live births across all gestations.[27] A retrospective cohort study of term admissions to English neonatal units found that concerns about infection were the second most common reason for admission from maternity services and the fifth most common reason for admission from home.[28] However, these results do not take into account those who are not admitted to a neonatal unit, for example, babies with suspected early onset neonatal infection who are admitted to a paediatric ward, or those who may be managed in transitional care.

If there is a concern or suspicion of a bacterial infection in a pregnant woman or person, those who have given birth, or a baby, a blood culture should be taken prior to antibiotics being given. It is not necessary to wait for the result before starting treatment, and ideally antibiotics should be given within one hour of the decision being made to treat. In babies with a strong clinical suspicion of early-onset neonatal infection, or signs and symptoms suggestive of meningitis, a lumbar puncture (LP) should be performed to obtain a sample of cerebrospinal fluid (CSF) for culture.[4] Babies with suspected sepsis, who are being treated with empirical antibiotics, but remain clinically well may remain on the maternity ward with their parents. This reduces separation, but the baby may still need to be taken to a treatment room for the insertion of a cannula or for an LP.

> *"I didn't even get to see her [my daughter], they whisked her off to give her antibiotics. Then they gave her to my husband, I got to see her face but then they said 'they've got to leave the room now…' [By the time] I managed to get the strength to hold her, it was about 72 hours later."*
> (NMPA advisory group member)

The decision to administer antibiotics to either mothers or babies must be carefully considered to ensure appropriate use of both testing and treatment. Cohort studies and a randomised trials have shown that both intrapartum antibiotic prophylaxis (IAP) and neonatal empirical antibiotics temporarily disrupt the developing gut microbiota of the newborn, although the longer-term effects are uncertain, and may contribute to antibiotic resistance.[29-31]

An increase in multidrug resistant microorganisms is a concern for global public health, with bacterial infections resistant to treatment accounting for just under 1.3 million deaths worldwide in 2019.[32] An estimated 2 596 deaths England in 2019 were attributed to resistant bacterial infection.[33] The WHO global strategy urges stakeholders to come together to address the growing threat of antimicrobial resistance, calling for surveillance of antimicrobial consumption, and highlighting "data is key to understand the [antimicrobial resistance] burden and evaluate the response".[8] The UK Government's 2019 action plan aimed to optimise the use of, and reduce unnecessary exposure to, antimicrobials with targets to reduce the number of drug-resistant infections by 10% by 2025.[9,10]

Previously, the linking of neonatal data with data on infections held in the Second Generation Surveillance System (SGSS) has been shown to be feasible using deterministic and probabilistic methods. However, babies with early onset neonatal infection were excluded and no maternal data was included in the linkage.[34] This previous data linkage also only included babies who had been admitted to a neonatal unit.

In this report, the National Maternity and Perinatal Audit (NMPA) have explored the feasibility of linking relevant datasets to report on characteristics, care and outcomes of women and birthing people and their babies diagnosed with bloodstream infections during pregnancy, childbirth or the postpartum period. It was not possible to obtain linked data within the timeframe of the current NMPA contract, which ended on 31 December 2022.

Because of this inability to obtain linked maternity, neonatal and infection data, we have been unable to answer the following important questions:

- What proportion of women and birthing people and babies had a positive blood culture, and of those, what proportion required admission to an adult Intensive Care Unit (ICU) or a neonatal unit?
- What proportion of pregnant women and people receiving IAP
    - had a blood culture sample taken?
    - received IAP because of risk factors or because of a positive blood culture?
    - had a confirmed infection?
- What proportion of babies born to women and birthing people who received IAP
    - had a blood or CSF culture samples taken?
    - received empirical antibiotics? And for how long?
    - had a confirmed bloodstream or CSF infection?

- What proportion of babies born to women and birthing people with a confirmed bloodstream infection
    - were admitted to a neonatal unit?
    - received empirical antibiotics? And for how long?
    - had a confirmed blood or CSF infection?
- What proportion of babies admitted to a neonatal unit with either suspected infection or confirmed bloodstream or CSF infection were born to women and birthing people
    - who had received IAP?
    - had risk factors or a confirmed bloodstream infection?
- What proportion of babies received empirical antibiotics for suspected infection irrespective of neonatal unit admission or remaining in a postnatal setting?
- What proportion of women and birthing people were readmitted to maternity services as "accompanying an unwell child" but remained well themselves?
- What proportion of babies were readmitted to maternity services as "well baby" when admitted alongside their mother or birthing person readmitted with an infection?

The purpose of this report is to illustrate how the NMPA has attempted to obtain linked data, to describe the importance of linking datasets containing information on English maternity and perinatal care, with laboratory confirmed bloodstream infections for women and birthing people, and bloodstream and/or CSF infections in the first 72 hours of life in their babies, and to demonstrate how, using routinely collected data, care and outcomes experienced by women and babies using NHS maternity services can be reported.

> *"This is one of those situations where the data are available, but we can't currently link it together. Also, the ideas around screening, treating and preventing GBS early onset neonatal infections are changing over time… and we want to know what is happening, does it make a difference?"*
> (NMPA advisory group member)

Aims and objectives

The aim of this report was to establish the feasibility of linking English NHS maternity and neonatal data with data on bloodstream infections confirmed in women and birthing people, and their babies, during pregnancy, the postpartum or postnatal period.

The objectives were to:

- determine the rate of bloodstream infections, confirmed with a positive blood culture, for women and birthing people during pregnancy or in the six weeks following birth.
- determine the rate of bloodstream infections confirmed with a positive blood culture, and/or confirmed CSF infection for babies in the first 72 hours of life.
- identify the proportion of women and birthing people with confirmed bloodstream infection whose baby also had confirmed early onset neonatal sepsis; or those who received intrapartum antibiotic prophylaxis and their baby received empirical antibiotics.
- identify the proportion of women and birthing people who received intrapartum antibiotic prophylaxis, or babies who received empirical antibiotics, for suspected infection but who did not have a positive blood or CSF culture.
- identify characteristics or risk factors for maternal and neonatal infection.
- report differences in care and outcomes for those diagnosed with a confirmed bloodstream or CSF infection.

By linking datasets and data items available we envisaged being able to describe the rates of women and birthing people and their babies affected by bloodstream infections. Firstly, by identifying the women and birthing people who had a blood culture sample taken (or the babies who had a CSF sample as well as blood culture sample) and whether there was a positive pathogen growth or not. Secondly, the rates of those with a positive blood or CSF culture where their linked mother or baby also had a positive blood or CSF culture; and thirdly, the rates of those with a positive blood or CSF culture where their linked mother or baby did not have positive pathogen growth.

Methods

This section describes the data sources and data items required by the NMPA to explore the feasibility of linking maternity, neonatal and infection datasets. As it was not possible to obtain linked data, this section also describes the options for data linkage explored and the difficulties encountered.

The NMPA, along with the United Kingdom Health Security Agency (UKHSA) and National Neonatal Audit Programme (NNAP), have met to discuss the importance and feasibility of linking datasets, a timeline is outlined in Figure 1. Figure 2 illustrates the various options explored and the barriers encountered.

Data sources

The NMPA uses data from the Maternity Services Dataset (MSDS) and Hospital Episode Statistics (HES), that are routinely collected during maternity and perinatal care. The NMPA methods and technical specification are available on the NMPA website.

Data that are routinely collected during care provided to babies admitted to a neonatal unit are reported by the NNAP.[35] The NNAP data flow diagram can be found on their website. Data with identifiers are captured by Clevermed Ltd, transferred to the Royal College of Paediatrics and Child Health (RCPCH) and de-identified for NNAP analysis.

UKHSA's SGSS captures routine laboratory surveillance data on infectious diseases and antimicrobial resistance from diagnostic laboratories across England.[36]

The type of data included in each dataset, along with the organisations acting as data controllers and data processors of each dataset can be found in table 1.

Table 1: Dataset description and availability to the NMPA.

Dataset	Data type	Data controller	Data Processor	NMPA data access
MSDS	Maternity episode	NHS Digital	NMPA	Established
HES	Hospital admissions	NHS Digital	NMPA	Established
NNAP	Neonatal unit admission data	HQIP	RCPCH (NNAP)	Additional approvals required
SGSS	Infection	UKHSA	UKHSA	Additional approvals required

There are ongoing programmes exploring data linkage of ICU and infection datasets. An existing collaboration of professional organisations representing adult, paediatric and neonatal intensive care, and adult, paediatric and neonatal audits, as well as microbiology and infection control, titled the Infection in Critical Care Quality Improvement Programme (ICCQIP), aims to obtain a national picture of bloodstream infection in English ICUs. [37,38] The programme relies on data being uploaded

by participating ICUs, the number of units providing data has risen from 19 in 2016 to over 75 across the UK in adult, paediatric and neonatal units.[39] Maternity data sources are not currently included.

> *"The ICCQIP and NNAP data linkage only captures babies who have been admitted to a neonatal unit. There is some information about the mum in the baby's record and likewise, in MSDS, there are some details for the baby. It's about making sure you've got the mum and baby dyad, together with infection data; that's really important because we're just missing out a big chunk of what's happening by not linking them together. There are going to be mums and babies who are missed because they don't fall into those two datasets."*
> (NMPA advisory group member)

Data items

The data items that are already captured in the datasets for linkage to explore the characteristics and outcomes of women and birthing people and their babies, who are diagnosed with a bloodstream infection can be found in appendix 2, along with a list of additional data fields that would be relevant for ongoing infection and antimicrobial surveillance.

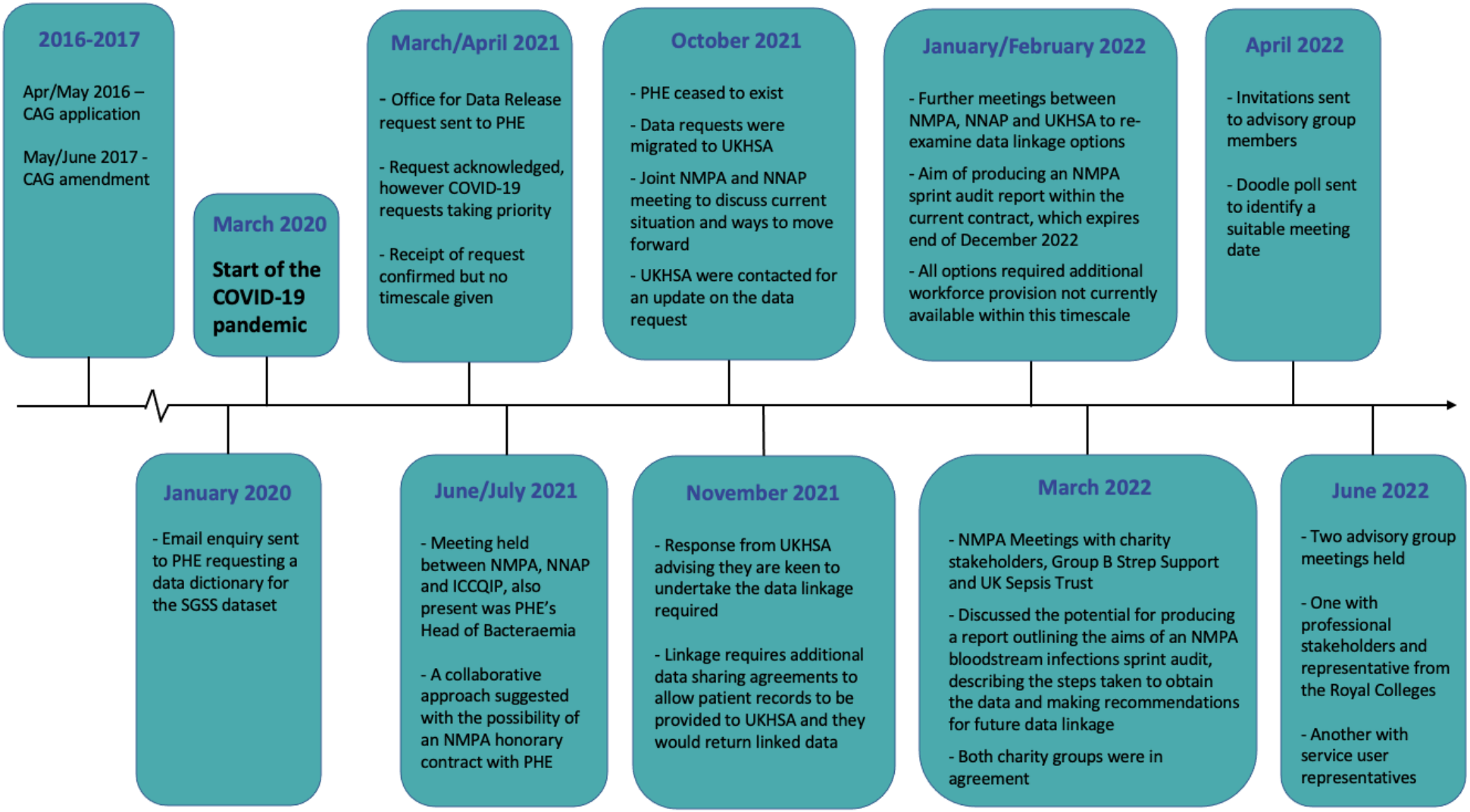
Patient and public involvement

The work was supported by an advisory group that comprised professionals from obstetric, midwifery and neonatal specialties, executive members from UK charities UK Sepsis Trust and Group B Strep Support, and women and families with lived experience of perinatal sepsis. The group shared their experiences and knowledge to help shape the report and recommendations.

> *"It wasn't until during my [emergency] c-section that I was put on the Sepsis Six pathway, which we only know from looking at my notes. [There was] no communication whatsoever. I wasn't told I had sepsis, just 'you've got an infection. You're on antibiotics, you can't go home because your blood levels aren't right."*
> (NMPA advisory group member)

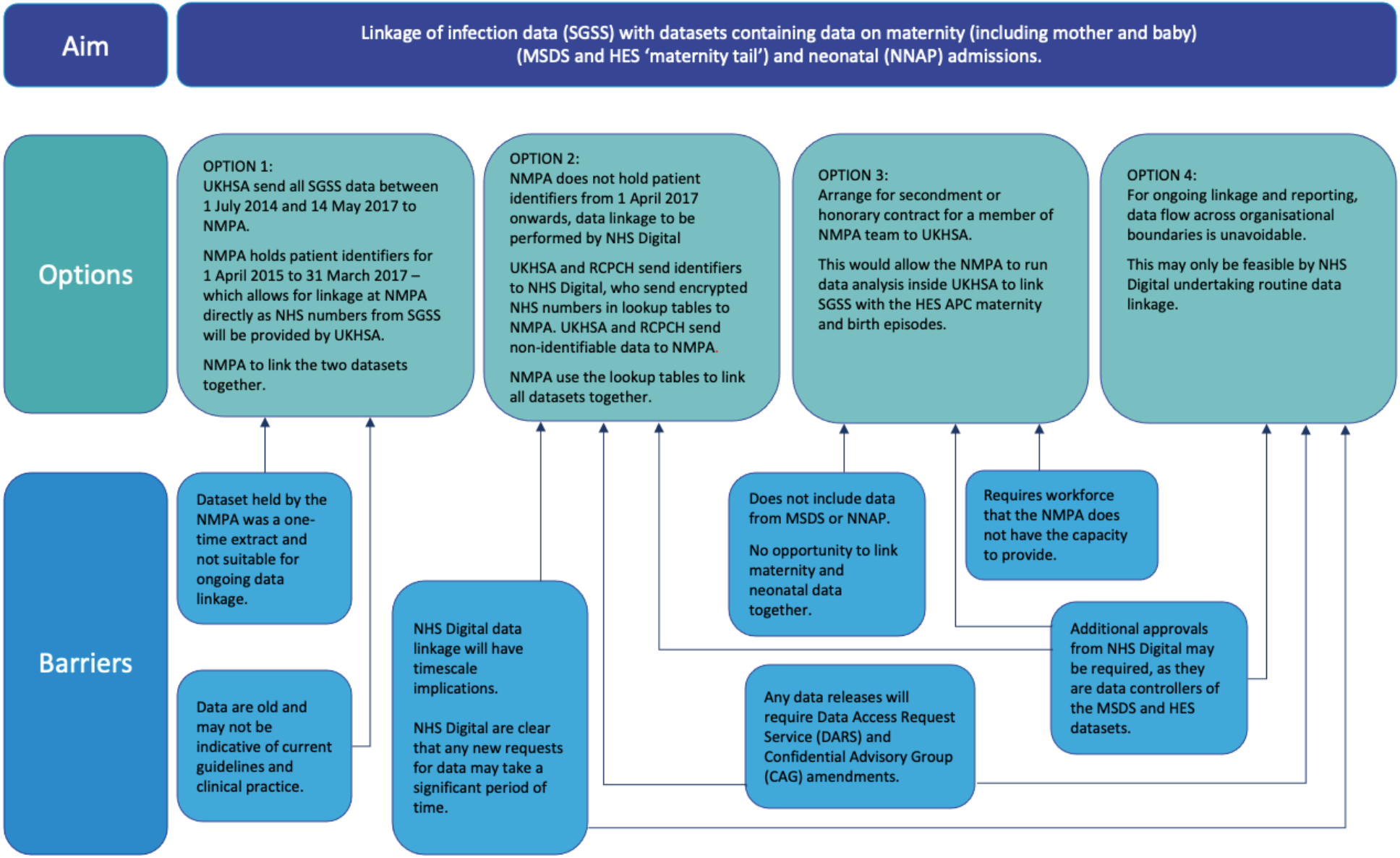
UK Sepsis Trust aims to save lives and improve outcomes through raising awareness of sepsis by educating both the public and healthcare professionals campaigning for political change and providing support for those affected by sepsis. The charity devised the Sepsis Six tool in 2005, it is now used in 30 countries worldwide.[40]

The Group B Strep Support charity is the world's leading charity working to eradicate GBS infection in babies. On average two babies per day develop GBS infection and of those who become unwell each week, one will die and one will be affected by long-term disability.[41] The charity works to raise awareness among parents and to educate healthcare professionals, as well as campaigning and making recommendations for routine GBS testing in pregnant women and people.



CAG = Confidential Advisory Group, PHE = Public Health England, SGSS = Second Generation Surveillance System, NMPA = National Maternity and Perinatal Audit, NNAP = National Neonatal Audit Programme, ICCQIP = Infection in Critical Care Quality Improvement Programme, UKHSA = United Kingdom Health Security Agency.

Figure 1 Timeline of NMPA actions to obtain linked datasets.



RCPCH = Royal College of Paediatrics and Child Health, HES = Hospital Episode Statistics, APC = Admitted Patient Care, MSDS = Maternity Services Data Set, UKHSA = United Kingdom Health Security Agency, SGSS = Second Generation Surveillance System, NMPA = National Maternity and Perinatal Audit.

Figure 2: Options for and barriers to data linkage.

Discussion

It was not possible to obtain linked data within the timeframe of the current NMPA contract, which ended on 31 December 2022. Therefore, our findings demonstrate how the NMPA explored different options for linking datasets to report on characteristics and measures of care and outcomes of women and birthing people and their babies with confirmed bloodstream or CSF infections during pregnancy, childbirth or the postpartum period.

Infection during pregnancy can affect both the mother/birthing person and the baby. Conversely, it may just affect one, resulting in either the mother/birthing person or baby becoming unwell and requiring treatment for infection whilst the other remains well. It is therefore important to analyse maternal and neonatal infection data in combination and report on the risk factors, impact and outcomes for both.

The aim of the ICCQIP programme is to obtain a national picture of bloodstream infections in English adult, paediatric and neonatal ICUs.[37,38] ICCQIP analyse intensive care data submitted via the Intensive Care Unit Data Capture Systems (ICUDCS), as mandated by the *Adult Critical Care Service Specification.*[42] ICCQIP produce three quarterly reports on adult, paediatric and neonatal data.[43] A list of mandatory and optional data items can be found in the programme's protocol.[38] Maternity data sources are not currently included, meaning if a woman or birthing person becomes unwell with an infection during pregnancy or the postpartum period, they will only be included in the overall results in ICCQIP's reports if they are admitted to an ICU. These reports do not disaggregate results to report on rates of perinatal infection. Women and birthing people will only be included if they are admitted to an ICU, and admission criteria may vary between trusts, with some providing high dependency care within the maternity unit. The neonatal dataset captures babies admitted to a neonatal unit. Babies who may have a blood or CSF culture sample taken but who remain clinically well may be managed in a transitional care or postnatal ward setting and will not have a neonatal unit admission and will therefore, not be captured in the ICCQIP. Therefore, additional data linkage of datasets containing specific maternity data for mothers and babies is required to provide an overall picture of bloodstream infections occurring during pregnancy or soon after birth.

Newborn infections are primarily bacterial in origin and manifestations include pneumonia, sepsis and meningitis.[44] The clinical guidelines in many neonatal units will call for a blood culture specimen and to begin empirical antibiotics for any baby of a woman or birthing person who has triggered the Sepsis Six protocol. Other units may use alternative guidelines and/or an assessment calculator such as the Kaiser Permanente, an interactive calculator that uses maternal risk factors and details about a baby's condition to provide clinicians with a probability of early onset neonatal sepsis, and aids decision-making when starting empirical antibiotics or not.[45] Uncertainties remain around the long-term effects of antibiotics (both IAP and neonatal) on the development of the newborn's gut microbiota.[29-31] These, along with reports of emerging global antimicrobial resistance, highlight the importance of routinely linking data for mothers and birthing people, and their babies, with infection datasets for ongoing antibiotic and infection surveillance.

The NNAP dataset only captures data for babies who have been admitted to a neonatal unit, thereby not including babies who remain in a postnatal ward or transitional care setting but who may have blood culture or CSF samples taken and receive empirical antibiotics, or have a confirmed infection but remain clinically well. Linking MSDS and HES to the SGSS will capture these babies who are not admitted to a neonatal unit, further adding to the landscape by identifying the babies of women and

birthing people with risk factors for infection or a confirmed bloodstream infection who do not go on to develop a bloodstream or CSF infection themselves. Likewise, linking these datasets will also identify incidents of a confirmed early onset neonatal infection in a baby when the mother or birthing person does not have an identified infection. Linking these datasets will also capture occurrences of maternal readmission to a maternity ward of a woman or birthing person with either suspected or confirmed infection themselves, or maternal readmission when accompanying a baby with suspected early onset neonatal infection.

The linkage of MSDS and HES datasets to the SGSS is of particular importance since the inception of NHS England's initiative to reduce admissions to a neonatal unit of babies born at term. Whilst the Avoiding Term Admissions into Neonatal Units (ATAIN) programme does not specifically include infection as one of its key clinical areas, it has led to an increased awareness of the impact of separating mothers and babies,[44] and in maternity and neonatal services reviewing their transitional care provision and remit. This may in turn lead to an increase in babies with confirmed infection but who are clinically well avoiding admission to a neonatal unit to remain with their mother in a postnatal or transitional care setting. Even if mothers and babies are not separated by being cared for in different settings, the care, equipment, and interventions required when there is a suspicion of, or confirmation of, infection may interfere with activities during the postnatal period, such as performing nappy changes, skin-to-skin and breastfeeding.

> *"…because I was so hooked up to lines and things like that, I couldn't breastfeed my daughter for the first 24 hours…"*
> (NMPA advisory group member)

NHS Digital are clear that any new requests for data and data linkage may take a significant period of time. A description of the data application and linkage process for a congenital heart disease study shows that data access, including all necessary permissions can take years before completion.[47] The NMPA have experienced this with other data requests (for example applying for MSDS) which took roughly 2 years from application to receipt. There are many valid reasons for these delays (including the impact of COVID-19) however the significant time required for requests is a clear reason to consider alternatives.

This report highlights the difficulties encountered by the NMPA in linking datasets that are needed for the ongoing routine linkage of mother and baby data with infection data for those admitted to ICU or a neonatal unit; but also, and perhaps more importantly, for those mothers and babies who are not admitted to an ICU or neonatal unit. This is essential not only for ongoing surveillance of those who have confirmed bloodstream or CSF infections, but also pregnant women and people who are treated with IAP, and babies who receive empirical antibiotics.

Increasing rates of antimicrobial resistance and changes to clinical guidelines and practice demonstrate an urgency in evaluating infection data for mothers and their babies, during pregnancy, labour and in the postpartum or postnatal period. Data linkage between neonatal and infection datasets have been tested and shown to be feasible.[34] There are ongoing programmes exploring data linkage of ICU and infection datasets, and investigating infection in babies admitted to a neonatal unit. Linking these data is essential to explore how characteristics, differences in care and outcomes, their impact upon each other, and how these differ between mothers and their babies. However, the missing link is combining maternity, neonatal and infection datasets.

> *"This data would assist the [UK] Government in meeting its national ambition for safer maternity care."*
> (NMPA advisory group member)

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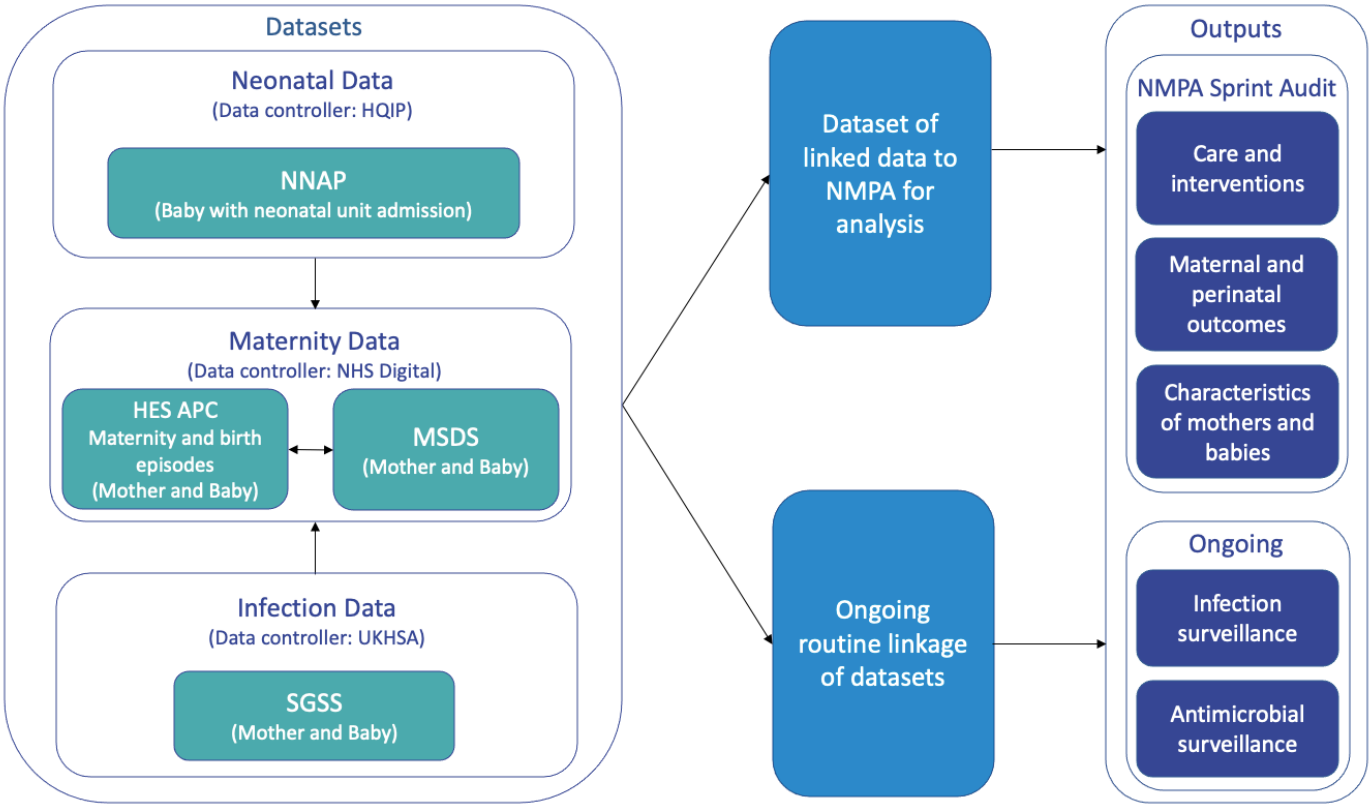
Appendix 1



HQIP = Healthcare Quality Improvement Partnership, NNAP = National Neonatal Audit Programme, HES = Hospital Episode Statistics, APC = Admitted Patient Care, MSDS = Maternity Services Data Set, UKHSA = United Kingdom Health Security Agency, SGSS = Second Generation Surveillance System, NMPA = National Maternity and Perinatal Audit.

Figure 2: Data linkage diagram showing datasets required for linkage.

Appendix 2

Table 2: Mapping of data items required for linking bloodstream infections data.

Variables	NMPA (MIS linked to NNRD for 2015-17)	HES	MSDS V2.0	NNAP NB: All recorded postnatally	UKHSA SGSS
NHS/CHI number MOTHER	YES	YES	YES	YES	YES
NHS/CHI number BABY	YES	YES	YES	YES	YES
Patient DOB	YES	YES	YES	YES	YES
Sex				YES	YES
Organism	NO	NO	NO	YES	YES
Date of onset	NO	NO	NO	NO	YES
Culture specimen type (source)	NO	NO	NO	YES	YES
Culture specimen date/time	NO	NO	NO	YES	YES
Postcode/IMD	YES	YES	YES	YES	YES
Ethnic group	YES	YES	YES (Mother and baby)	YES (Mother and baby)	YES
Parity	YES	YES	YES	YES	NO
Previous caesarean section	YES	YES	YES	NO	NO
Previous perinatal loss (stillbirth/neonatal death)	YES	YES	YES	NO	NO
Maternal diabetes (gestational & pre-existing)	YES	YES	YES	YES	NO
Pre-eclampsia (B/P ≥ 140/90, Proteinuria 2+ or more) /hypertension (pre-existing or PIH)	YES	YES	YES	YES	NO
Cardiac disease	YES	YES	YES	YES	NO
Pre-pregnancy height and weight, and BMI	YES	NO	YES	NO	NO
Maternal age	YES	YES	YES	YES	NO
Gestational age (weeks/days)	YES	YES	YES	YES	NO

Variables	NMPA (MIS linked to NNRD for 2015-17)	HES	MSDS V2.0	NNAP NB: All recorded postnatally	UKHSA SGSS
Onset (spontaneous, induced (prostaglandins or balloon or ARM/oxytocin), no labour).	YES-partially Labour augmentation Y/N* Onset of labour (options) * Oxytocin administered Y/N	YES	YES	YES	NO
Duration of ruptured membranes	YES-indirectly Extrapolate from Time of ruptured membranes and Time of delivery	NO	NO	YES Preterm ROM Prolonged ROM	NO
Presentation at onset of labour (cephalic, breech, other)	YES	NO	YES	NO	NO
Mode of birth: spontaneous, instrument (ventouse, forceps), vaginal breech, planned CS, emergency CS (and whether before or during labour).	YES	YES	YES	NO	NO
Meconium staining of the amniotic fluid (ideally whether intrapartum or at delivery and whether thin/old or thick/fresh)	Indirectly from baby diagnosis with ICD	Indirectly from baby diagnosis with ICD	Indirectly from baby diagnosis with ICD	NO	NO
Maternal Temperature in labour, ideally, maximum as a number. Otherwise – normal, ≥37^{o}C x 2, or ≥38^{o}C x 1.	Sepsis from ICD	Sepsis from ICD	Sepsis from ICD	NO	NO
Baby alive or dead at birth	YES	YES	YES	NO	NO
Apgar score at one and five minutes	YES	YES	YES- Apgar at 5	NO	NO
Time to first spontaneous breathing	NO	NO	NO	NO	NO
Resuscitation method (bag and mask, intubation)	YES	YES	YES	NO	NO
Transfer to neonatal unit	NO	YES	YES	YES	NO
GBS carrier - yes/no	NO	NO	NO	NO	NO
Antibiotics given in labour	YES	NO	NO	NO	NO
Maximum maternal heart rate	NO	NO	NO	NO	NO
Maternal length of stay	YES	YES	YES	NO	NO
Baby length of stay in maternity setting	YES	YES	YES	NO	NO

Variables	NMPA (MIS linked to NNRD for 2015-17)	HES	MSDS V2.0	NNAP NB: All recorded postnatally	UKHSA SGSS
Neonatal length of stay in NNU	NO	NO	NO	YES	NO
Drugs during labour	YES	NO	NO	NO	NO

Additional variables required:

Sepsis Six triggered
GBS carrier status
Blood culture sample taken
Indication for IAP
Indication for empirical antibiotics
Antibiotics given during pregnancy, labour or postpartum period
Type of antibiotic given in labour
Antibiotics given to baby in the postnatal setting
Duration of antibiotics
Infection confirmed in mother who remains in maternity services (maternity HDU etc.)
Infection confirmed in baby who remains in postnatal care, including transitional care
Mother transfer to ICU/HDU
Timing of drugs and fluid administration
Number of vaginal examinations
Well mother readmission with unwell baby
Well baby readmission with unwell mother