POTOCOL

Neonet: Providing a national demand/capacity model for neonatal care in England.

Summary of Research

The aim of this proposed research is to understand current and potential future national patterns of neonatal care by location of demand and care, acuity of care, and cost of care to service providers and parents. Modelling will allow us to investigate the trade-offs between different service configurations with varying degrees of centralisation (e.g. by changing the number of the highest level of unit). The planned research is a collaboration between the University of Exeter Medical School and the Neonatal Data Analysis Unit based at Imperial College, London, with the Neonatal Critical Care Clinical Reference Group acting as the steering body.

The NIHR-SDO programme has previously funded a project (ending May 2014) to develop a discrete event simulation model that would mimic the behaviour of a regional neonatal network. The key outputs of this model (which exceed the specification for the original project are):

- Predicted average and peak workloads in units (data segregated by care level)
- Predicted distances from parents home location using road distances (some public transport analysis has also been carried out)
- Predicted time spent above nominal BAPM guideline work level
- Predicted resource utilisation (nurse or cots)
- Predicted number and distances of transfers
- Predicted nursing costs
- Demand derived from 'Badger' neonatal data or nationally available GP profile data
- Model allows predictions of performance with different network configurations (e.g. closure or re-designation of units).

This model has been shown to have very good predictive ability. It was model trained with 24 months of data and tested against a separate 6 month dataset. R-square was >0.9 for all predicted vs actual comparisons; the model predicted an average distance from the point of care to the patient node of 19km against 21km in the training data set (both results exclude patients being cared for outside of the network); and the model predicted 373 transfers per year against actual transfers of 389 per year.

This model, while answering key questions at a regional level has raised further questions, especially at the national level.

What is the nature of the trade-off between unit throughput and parent travel distances?

Centralisation of services has potential benefits, for example: 1) increased throughput of infants leading to increased specialism and expertise, and 2) reduction in the 'spare capacity' needed to deal with peaks and troughs in workload (relative variation reduces as throughput increases). However, centralisation of services will increase average distances that parents must travel to the point of care. The effects of centralisation in neonatal care is complicated by the transition of the infant through different levels of care (each of which may have a different degree of centralisation), and by the organisation of units into networks of units. Modelling provides an excellent tool for understanding the behaviour of this complex system.

We intend to investigate this key trade-off at a national level by addressing the following specific questions:

1. What effect does network size (by population or by area) have on travel distances and times?
2. How would service reconfiguration (e.g. greater centralisation of services by having fewer of the highest level of care units) affect the trade-off between throughput and parent travel distances? How would the number and distance of transfers be affected?
3. What is the average and maximum planned distance and travel time from parents' home location to point of care? How does this vary across the country? How does this compare with actual distances and travel times (when infants travel further than to the closest unit of an appropriate level)?
4. What effect do network boundaries have on travel distances and times? What happens to travel distances if network boundaries are removed (infant goes to closest suitable and available cot, regardless of network affiliation)?
5. How may conflicting objectives be balanced against each other?
6. What is the relationship between the number of units and the expected travel times and throughputs? Given any fixed number of units which locations would minimise travel times?
7. What is the expected impact regionally and nationally of applying population projections?

How will costs per infant and outcome change with reconfiguration of services?

During our regional project we found that use of HRG reference costs had limited value as they assume a fixed infant cost regardless of size of unit. In the regional model we allowed for variation in nursing costs depending on configuration, but it is necessary to understand neonatal costs in significantly more detail so in order to predict better the likely relationship between service configuration and NHS costs. Having access to the individual responses to a recent BLISS survey on costs to parents we also seek to better model the relationship between network configuration and costs to parents.

Questions to be addressed are:

1. What components, and in what proportion, contribute to the costs of the different types of neonatal unit?
2. How would changes in the degree of centralisation of services affect the 'spare capacity' needed to deal with peaks and troughs in workload? How would total costs be affected?
3. How would changes in the degree of centralisation of services affect parent travel distances and costs?

4. How does the degree of centralisation affect the requirement for local accommodation for parents?

We plan to extend from this this successful regional model to a national model to help answer these questions that are key to the future organisation of neonatal services. We will do this in collaboration with Neonatal Data Analysis Unit (NDAU) based at Imperial College, London, who hold a database of all neonatal admissions (extracted from local 'Badger' data).

Patient recruitment

This project recruits no patients. There are no changes of care processes for any patient in this project. The project uses historic collated data alone.

Data

The project will used pseudo-anonymised data. The project team will not access information that can be used directly to identify the infant. No names, NHS# or address/postcodes will be accessed. The location of the mother will be accessed at the level of 'Lower Super Output Area', which locates people to a population of about 1,500 and an area of ~4km^2. Duration and location of length of stay at each care level (intensive care, high dependency care, special care, transitional care) will be reported for each infant.

Demand data will be based on data held by the Neonatal Data Analysis Unit (NDAU) based at Imperial College London[1]. NDAU will provide the project team with an extracted data set. The National Neonatal Research Database is approved by the National Research Ethics Service (Ref 10/HO803/151).

A detailed list of data fields and their use in the project is described in Appendix 1.

Data will be accessed for all neonatal units in England. The initial data extract for model building will be for a 2 year period. A later 6 month extract will be used for model validation.

The National Neonatal Research Database is approved by the National Research Ethics Service (Ref 10/HO803/151)."

Research methodology

The model is based on discrete event simulation. In this type of simulation each computer-generated infant exists as an independent object in the model and has associated details (such as gestational age at birth, entry level of care, home hospital, etc). The simulation runs through time and takes into account the variability experienced in the system (e.g. random occurrence of births with varying needs, fluctuating availability of staff). For each hospital the number of cots, the number of nurses, and the highest level of care each cot is capable of supporting will be specified. Care levels will be classified by Specialist Surgical/Cardiac Care, Intensive Care, High Dependency Care, Special Care and

[1]http://www1.imperial.ac.uk/departmentofmedicine/divisions/infectiousdiseases/paediatrics/neonatalmedicine/ndau/

Transitional Care. Care levels are defined as per BAPM 2011 guidelines[2]. Unit types, describing what level of care is offered and which infants may be cared for, will be defined as per NHS England Neonatal Service Level specifications[3]

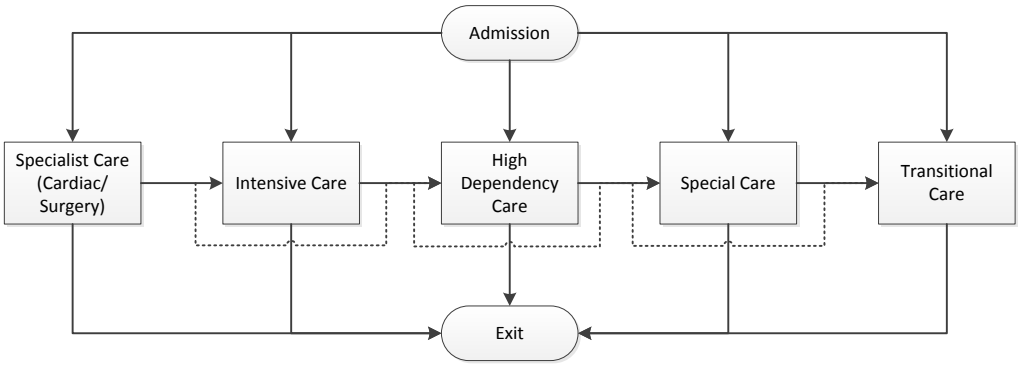

Fig 1. Flow of patients through care levels. Patients are cared for in the closest hospital to home that can meet the clinical needs of the patient, and that has spare capacity to accept new admissions.

The distribution of gestational age, and levels and duration of care initially required will be as observed in the NDAU historic data set. Geographic location of demand will be based on the home location of the mother (which may be located using either GP affiliation or Lower Super Output Area). Infants will be divided into categories based on gestation age. The probabilities of requiring particular levels of care and the duration of care will be assigned according to gestational age category. Lengths of stay will be sampled from distributions so that infant-to-infant variability (even at the same gestational age) is incorporated into the model.

Examples of data analysis and summary from a previous model are shown below:

Category	Gestational age @ birth	% of infants requiring care	% Infants who are twins	% of deliveries requiring care**	% deliveries that are twins
1	<24	0.15	25.0	0.14	14.29
2	24 to <27*	1.05	20.7	0.99	11.54
3	27 to <30	1.95	17.4	1.86	9.54
4	30 to <33	5.27	23.0	4.88	12.98
5	33 to <36	16.26	21.3	15.19	11.89
6	36+	72.64	4.4	74.26	2.25
7	Surg/Card	2.67	7.3	2.69	3.78

*Or multiples <28 weeks
** Delivery of twins = 1 delivery, 2 infants

Table 1. Categorisation of infants by gestational age or requirement for specialised surgical/cardiac care.

[2] http://www.bapm.org/publications/documents/guidelines/CatsofcarereportAug11.pdf
[3] http://www.england.nhs.uk/commissioning/wp-content/uploads/sites/12/2015/01/e08-serv-spec-neonatal-critical.pdf

Category	Entry point				Exit from ICU (or surgical/cardiac unit)					Exit from HDU			Exit from SCU	
	ICU	HDU	SCU	TC	ICU	HDU	SCU	TC	Exit	SCU	TC	Exit	TC	Exit
1	100.0	0.0	0.0	0.0	NA	11.1	0.0	0.0	88.9	100.0	0.0	0.0	0.0	100.0
2	100.0	0.0	0.0	0.0	NA	60.3	0.0	0.0	39.7	97.1	0.0	2.9	50.0	50.0
3	91.1	8.9	0.0	0.0	NA	93.5	0.0	0.0	6.5	100.0	0.0	0.0	74.7	25.3
4	47.4	35.8	16.8	0.0	NA	83.5	11.6	0.0	4.9	100.0	0.0	0.0	80.2	19.8
5	7.8	30.2	60.8	1.2	NA	76.6	23.4	0.0	0.0	99.3	0.5	0.2	79.5	20.5
6	5.9	11.0	72.4	10.7	NA	40.7	52.5	1.2	5.6	96.4	2.7	0.8	53.6	46.4
7	NA	NA	NA	NA	NA	33.3	13.3	0.0	53.3	71.4	0.0	28.6	18.5	81.5
7* (Surgical unit)	100.0	0.0	0.0	0.0	45.0	11.9	41.7	1.4	0.0					

Table 2. Entry points and transition between levels of care for each category.

Category	LoS (Mean Days)				% CV			
	ICU	HDU	SCU	TC	ICU	HDU	SCU	TC
1	5.4	76.7	17.9		119.7	90.0	43.0	
2	17.0	43.8	30.2	3.2	112.4	89.7	43.4	74.8
3	10.1	18.3	32.6	3.0	67.6	66.9	36.0	66.8
4	3.7	6.2	24.4	3.0	89.0	100.0	39.5	64.0
5	2.7	2.6	9.6	2.4	81.0	88.4	72.4	71.6
6	2.6	2.2	3.2	1.6	92.3	185.6	129.0	80.4
7*	9.5	16.0	10.5	2.0	99.0	126.0	320.4	62.7
7* (Surgical unit)	5.8				100.0			

7*: Surgical infants require time in surgical ICU (average 5.8 days) and then subsequent ICU care (average 9.5 days) which may be in a non-surgical unit

Table 3. Lengths of stay (mean and standard deviation) by gestational age and care level.

The model then seeks to find a suitable cot in the following order

- Cot in hospital closest to mother's home location.
- Closest available cot in mother's neonatal network.
- Closest cot outside of mother's neonatal network.

In order for a hospital in the model to accept an infant there must be an available cot capable of the level of care required and sufficient nursing staff (units close to new admissions when workload exceeds 150% BAPM guidelines). Infants stay at a defined level of care for a given time (sampled from a distribution based on their gestational age) before transitioning to another level of care or exiting the network. There are opportunities to move infants closer to their home hospital when space becomes available.

The standard types of hospital and admission acceptance criteria is shown below (these may be customised in the model):

Hospital Type		Surgical provision	Care for <24 weeks?	Care for <27 weeks?*	Care for <30 weeks?	Max permitted predicted ICU LoS (days)	Max permitted predicted HDU LoS (days)	ICU transfers in allowed
1	Special care unit	No	No	No	No	0	2	No
2	Local neonatal unit	No	No	No	Yes	2	No Limit	No
3	Local neonatal unit +	No	No	No	Yes	28	No Limit	Yes
4	Network neonatal unit	No	Yes	Yes	Yes	No Limit	No Limit	Yes
5	Surgical unit	Yes	Yes	Yes	Yes	No Limit	No Limit	Yes

* Or twins of <28 weeks

Table 4: Neonatal care unit types

Model outputs

The key outputs of the model are:

- Daily variation in workload at each hospital (for each care level). This includes number of infants and the nurse workload[4]
- The proportion of time units work above BAPM workload guidelines, and the proportion of time unit are closed to new admissions.
- The proportion of time infants are cared for away from the most appropriate hospital (that closest hospital to home that is able, if resources are available, to care for the infant).
- The distances from mother's home location to the location of care (including the number of infants cared for further away than 50km; assumed to be a maximum reasonable daily commuting distance).
- The number of infants that cannot be cared for within the mother's home neonatal network.
- The number and distances of transfers.

We are also developing costs of care in the model. At a minimum this is the nursing cost for any planned configuration if care, but we are seeking to include as many additional costs as possible.

The model will be run under different configurations (e.g. what if the number of intensive care units were reduced, or what if the number of total neonatal units were reduced). The effect of possible changes on both units and on parents will be forecast.

Project timescale and steering committee

The project will commence in September 2015 and will run for 18 months.

The Neonatal Critical Care Clinical Reference Group, chaired by Prof. Neil Marlow, will act as the steering group for the project.

[4] For nurse workload, one nurse by BAPM guidelines can care for 1 infant in intensive care, 2 in high dependency care and 4 in special care (we assume one nurse can care for 8 infants in transitional care, though no national guidelines exist).

Appendix 1: Required data from national data set

Category	Category detail	Item Name	Field ID	NHS Data Dictionary Item Name	Description	Purpose
NNUEpisodes	Demographics and Birth Information (Baby)	Unique system identification	AnonPatientID	BABY LOCAL PATIENT IDENTIFIER (NATIONAL NEONATAL DATA SET)	A unique ID that will only identify the baby if used by a user with permission to see the record of that baby.	Used to identify infant in locations of care for the purpose of communication where patient identifiers are not included.
NNUEpisodes	Demographics and Birth Information (Baby)	Month of birth	DateTimeofBirthMonth	YEAR AND MONTH OF BIRTH (BABY)	Calendar month derived from the date and time variable. Date and time variable is identified by prefix to month in the Field ID.	Used in instances where identifiable data is not sent.
NNUEpisodes	Demographics and Birth Information (Baby)	Year of birth	DateTimeofBirthYear	YEAR AND MONTH OF BIRTH (BABY)	Derived from the date and time variable. Date and time variable is identified by prefix to year in the Field ID.	Used in instances where identifiable data is not sent.
NNUEpisodes	Demographics and Birth Information (Baby)	Place of Birth NHS Code (Location of baby's birth)	PlaceofBirthNHSCode	SITE CODE (OF ACTUAL PLACE OF DELIVERY) or ORGANISATION CODE (OF ACTUAL PLACE OF DELIVERY)	Place at which the birth took place as recorded.	Used to conduct data analysis on the organisation.
NNUEpisodes	Demographics and Birth Information (Baby)	Birth weight (g)	Birthweight	BIRTH WEIGHT	Birth weight at the time of delivery in grams	Used to identify risk factor on admission to neonatal care.
NNUEpisodes	Demographics and Birth Information (Baby)	Gestation age in weeks	GestationWeeks	GESTATION LENGTH (AT DELIVERY)	The best obstetric estimate at the time of delivery in weeks. This will normally be based on the postmenstrual age but, if appropriate, may be modified on the basis of antenatal ultrasound. Where gestation at delivery is not known, this is based on the postnatal estimate of maturity	Used to identify risk factor on admission to neonatal care.
NNUEpisodes	Demographics and Birth Information (Baby)	Gestation age days	GestationDays	GESTATION LENGTH (REMAINING DAYS AT DELIVERY)	Specify, if known, the number of days between whole weeks in the gestation period.	Used to identify risk factor on admission to neonatal care.

NNUEpisodes	Demographics and Birth Information (Baby)	Sex of the baby (phenotypic)	SexPhenotype	PERSON PHENTOTYPIC SEX	The sex of the baby. 'Not known' is an option if information is missing or not recorded. 'Not specified' is an option for instances where the sex cannot be determined at birth. This option can be changed later if the chromosomal sex of the baby has been determined as follows: Male (XY) or Female (XX) or remain 'Not specified' if the genotypic sex is not defined as XX/XY or is still not known.	Used to aggregate by sex.
NNUEpisodes	Parents	Post code mother (LSOA)	PostCodeMotherLSOA	n/a (derived on receipt)	An LSOA equivalent of UK post code of the mother's residence at time of delivery.	Used to derive PCT and other geographical areas, including Sure Start areas, for aggregation to compare outcomes and plan services
NNUEpisodes	Parents	GPPractisecode	GPPractiseCode	GENERAL MEDICAL PRACTICE CODE (PATIENT REGISTRATION (MOTHER))	Please specify mother's General practitioner at time of delivery.	Required for aggregation by GP/Area
NNUEpisodes	Antenatal (Pregnancy Details)	Intended place of delivery NHS code	BookingNHSCode	SITE CODE (OF INTENDED PLACE OF DELIVERY) or ORGANISATION CODE (OF INTENDED PLACE OF DELIVERY)	Place at which mother was first booked for her confinement. The first intended place of delivery by the healthcare professional in consultation with the woman.	Used to aggregate by geographical area
NNUEpisodes	Labour & Delivery	Fetus total	FetusTotal	NUMBER OF FETUSES (NOTED DURING PREGNANCY EPISODE)	Total number of foetuses noted at any time in the pregnancy which resulted in delivery of a live or still born baby. This excludes foetus papyraceous and foetuses reabsorbed in utero and not delivered.	Used to monitor outcomes comparing singleton and multiple pregnancies
NNUEpisodes	Labour & Delivery	Mother's onset of labour	Onsetoflabour	LABOUR OR DELIVERY ONSET METHOD CODE (NATIONAL NEONATAL DATA SET)	Specify the status of mother's labour.	Used to monitor delays in delivery and outcomes for mothers and babies
NNUEpisodes	Labour & Delivery	Mode of delivery	ModeOfDelivery	MODE OF DELIVERY	Specify the mode of delivery.	Used to compare outcomes and variance in practice

NNUEpisodes	Admission details	Admission: date and time -anonymised	AdmitTimeAnon	NUMBER OF MINUTES (BIRTH TO EVENT)	The anonymised version of the data and time variable derived by calculating the time difference, in minutes, between this date and time and the date and time of birth.	
NNUEpisodes	Admission details	Admission: date and time - Month	AdmitTimeMonth	CRITICAL CARE START YEAR AND MONTH	Calendar month derived from the date and time variable. Date and time variable is identified by prefix to month in the Field ID.	Associate ad hoc events
NNUEpisodes	Admission details	Admission: date and time - Year	AdmitTimeYear	CRITICAL CARE START YEAR AND MONTH	Derived from the date and time variable. Date and time variable is identified by prefix to year in the Field ID.	Associate ad hoc events
NNUEpisodes	Admission details	Episode of care	CriticalCareIdentifier	EPISODE NUMBER (NEONATAL CRITICAL CARE SPELL)	The EPISODE NUMBER (NEONATAL CRITICAL CARE SPELL) is used to sequentially identify each CRITICAL CARE PERIOD within a Neonatal Critical Care Spell. The first CRITICAL CARE PERIOD identifier commences at 1; subsequent CRITICAL CARE PERIODS during the same period of care (within the same or different Health Care Providers) are then incremented by 1. For example, a Neonate is admitted to the Neonatal Intensive Care Unit at Trust A, starting a CRITICAL CARE PERIOD and generating EPISODE NUMBER (NEONATAL CRITICAL CARE SPELL) 1. The Neonate is then transferred to a different Health Care Provider, Trust B (ending the CRITICAL CARE PERIOD at Trust A), which generates EPISODE NUMBER (NEONATAL CRITICAL CARE SPELL) 2. The Neonate may then return to Trust A (ending the CRITICAL CARE PERIOD at Trust B), generating EPISODE NUMBER (NEONATAL CRITICAL CARE SPELL) 3.	Used to ascribe outcomes

NNUEpisodes	Admission details	Hospital baby admitted to	ProviderNHSCode	SITE CODE (OF ADMITTING NEONATAL UNIT) or ORGANISATION CODE (OF ADMITTING NEONATAL UNIT)	This is the code for the hospital recording information on this patient. It is a code which identifies an organisation uniquely. For NHS organisations it is a code that is managed by the Corporate Data Administration section of the Department of Health to identify most organisations that exchange information within the NHS or return information to the Centre. Examples of organisations that can be identified this way are NHS Trusts and Health Authorities.	Used to ascribe outcomes
NNUEpisodes	Admission details	Location baby admitted from	AdmitFromNHSCode	SITE CODE (ADMITTED FROM TO NEONATAL UNIT) or ORGANISATION CODE (ADMITTED FROM TO NEONATAL UNIT)	The place from which a baby was admitted from into this episode of care. If the baby is admitted to the neonatal unit from its own local labour ward or theatres, then the value entered is the NHS code of this hospital.	Used to analyse transfer of patients
NNUEpisodes	Admission details	Hospital baby admitted from location detail	AdmissionSource	LOCATION IN HOSPITAL TYPE (BABY ADMITTED FROM)	The exact location at the hospital from which a baby was admitted into this episode of care. SCBU- Specialist Care Baby Unit NNU-Neonatal Unit	Used to analyse transfer of patients
NNUEpisodes	Admission details	Admission: Reason for admit	ReasonForAdmit	PRIMARY CATEGORY OF CARE REQUIRED ON ADMISSION TO NEONATAL CRITICAL CARE	Specify the type of clinical service the infant is being admitted to receive including if the service is part of back transfer (returning to hospital from which an infant was transferred for care to location of the previous episode of care). Type of care is identified using British Association of Perinital Medicine (www.BAPM.org) classification.	Used to analyse transfer of patients

NNUEpisodes	Discharge details	Discharge date and time -anonymised	DischDateTimeAnonDate	NUMBER OF MINUTES (BIRTH TO EVENT)	The anonymised version of the data and time variable derived by calculating the time difference, in minutes, between this date and time and the date and time of birth.	Used to measure length of stay and to calculate the anonymised version of this field
NNUAdhoc	Discharge details	Discharge date and time - Month	DischDateTimeMonth	CRITICAL CARE DISCHARGE YEAR AND MONTH	Calendar month derived from the date and time variable. Date and time variable is identified by prefix to month in the Field ID.	Used to measure length of stay
NNUAdhoc	Discharge details	Discharge date and time - Year	DischDateTimeYear	CRITICAL CARE DISCHARGE YEAR AND MONTH	Derived from the date and time variable. Date and time variable is identified by prefix to year in the Field ID.	Used to measure length of stay
NNUEpisodes	Discharge details	Discharge destination	DischargeDestination	DESTINATION ON DISCHARGE FROM NEONATAL CRITICAL CARE	The destination of the baby at discharge from this episode of care.	Used to compare outcomes for babies
NNUEpisodes	Discharge details	Discharge reason	DischargeReason	TRANSFERRED FOR FURTHER CARE TYPE (NATIONAL NEONATAL DATA SET)	The destination of the baby at discharge from this episode of care. If the discharge destination is a transfer to another location then this item is required.	Used to compare outcomes for babies
NNUEpisodes	Discharge details	Discharge destination ward	DischargeWard	WARD TYPE DISCHARGED TO (NATIONAL NEONATAL DATA SET)	Specify the type or ward the baby will be discharge to.	Used to compare outcomes for babies, a National Neonatal Audit Programme filter
NNUEpisodes	Discharge details	Discharge hospital NHS code	DischargeHospitalNHSCode	SITE CODE (RECEIVING) or ORGANISATION CODE (RECEIVING)	The hospital to which a baby is being transferred to from this episode of care. Record if discharge reason is specified.	Used to compare outcomes for babies
NNUEpisodes	Discharge details	Date of death and time -anonymised	DateofDeathAnonDate	NUMBER OF MINUTES (BIRTH TO EVENT)	In minutes from birth and where discharge is marked as death..	"Derived (minutes)"

NNUEpisodes	Discharge details	Date of death and time - Month	DateofDeathMonth	PERSON DEATH YEAR AND MONTH	Calendar month derived from the date and time variable. Date and time variable is identified by prefix to month in the Field ID.	Used in survival analyses and calculate anonymised dates
NNUEpisodes	Discharge details	Date of death and time - Year	DateofDeathYear	PERSON DEATH YEAR AND MONTH (DURING NEONATAL CRITICAL CARE PERIOD)	Derived from the date and time variable. Date and time variable is identified by prefix to year in the Field ID.	Used in survival analyses and calculate anonymised dates
Daily	General information	General Information: Date of day of care anonymised	ActiveDateAnonDate	NUMBER OF MINUTES (BIRTH TO EVENT)	"Derived (minutes)"	"Derived (minutes)"
Daily	General information	General Information: Any surgical procedures	SurgicalProcedure	PROCEDURE (OPCS DURING NEONATAL CRITICAL CARE PERIOD) or PROCEDURE (SNOMED CT DURING NEONATAL CRITICAL CARE PERIOD)	Surgical procedure on the date and time specified	Used to monitor health status, outcomes and calculate anonymised versions
Daily	General information	General Information: Baby transported	TransportedDay	PERSON ACCOMPANYING TRANSPORTED PATIENT	If baby has been transported today Specify with whom the transport took place. ANNP is an Advanced Neonatal Nurse Practitioner.	Used in neonatal transport dataset
Daily	General information	General Information: Level of care (2011 definition)	LevelOfCare2011(derived)	Derived based on the BAPM categories of care 2011	Applying the BAPM 2011 categories of care definition.	Used in commissioning