Modelling protocol - Computer Simulation of a neonatal network

Overview of the model

The aim of the simulation model is to mimic the performance of a network of neonatal units in a virtual computer simulation environment. The units in the model may be equipped with varying number of cots (ICU, HDU & SCU*) and nurses (ICU-qualified and other). Infants are "born" in the model requiring different levels and durations of care based on their gestational age. The location of the parents is assigned according to the current distribution of births. The model then identifies the closest unit with sufficient capacity (cot, nurses, specialist ability) to admit the infant. There are opportunities to relocate the infant to a unit closer to home if and when appropriate.

The model will allow the investigation of alternative allocation of resources (either more, less or relocated resources). These different test scenarios may be examined for their expected impact on demand and activity in units, the time units spend working above BAPM* guidelines for infant:nurse ratios and the distances that infants are cared for away from the parent's home address.

We will access data on infants from the CleverMed Badger system. These data include the gestational age of the infant and how long the infant spent in three levels of care (ICU, HDU & SCU).

The model will use pseudo-anonymised data (the patient ID will be replaced by another unique identifier before the data is handled by the modelling team). Location data will be restricted to postcode sector (postcode without the last two letters) of the parent's home address.

*ICU= Intensive care; HDU = High dependency care' SCU = Special care

*BAPM = British Association of Perinatal Medicine. Guidelines for infant:nurse ratios are 1:1 for ICU, 2:2 for HDU and 4:1 for SCU.

Background

In 2006-07, 62,471 babies, or roughly one in ten of all births, were admitted to neonatal units. This was up from 59,711 in 2005-06. In England there are 180 neonatal units structured into 23 regional networks. Each unit has a designation of either level 1, 2 or 3 which indicates the type and intensity of the care it provides. There has been significant strain on this service. In 2007 BLISS (Are We Failing Special Care Babies in the UK? Bliss – The Premature Baby Charity. 2007) reported the following problems and needs in this area:

- Neonatal units are, on average, understaffed by over a third.
- Over six months, neonatal units were shut to new admissions for an average of 24 days.
- One in ten units exceeded its capacity for intensive care for more than 50 days during a six month period.
- 65% of neonatal units providing the full range of intensive care did not have enough staffed cots for the babies admitted.

- A quarter of twins or triplets were reported to be cared for in separate hospitals.
- A common consequence of the lack of staffed cots is that babies need to be transferred elsewhere.

Worryingly there is evidence to show that the mortality rate is increased as units become overstretched (Tucker, J., et al., Organisation and delivery of perinatal services. BMJ, 2004. 329, 730-2). In addition to units having to sometimes run at over-capacity, over a 10 year period in the former Trent Health Region, 23% of transfers were found to be inappropriate (Cusack, J., D. Field, and B. Manktelow, Impact of service changes on neonatal transfer patterns over 10 years. Arch Dis Child Fetal Neonatal Ed, 2007. 92: p. F181–F184). Transfers of infants is inherently dangerous with critical incidents occurring in about 15% of transfers (Moss SJ, Embleton ND, Fenton AC. Towards safer neonatal transfer: the importance of critical incident revier. Arch Dis Child. 2005;2005:729-32). It is possible that a model that predicts performance across a network may aid in reducing the number of unnecessary transfers made.

In 2003 a Department of Health report highlighted the limited information on the possible options for matching the available, and potentially available, workforce to the possible service models and configurations. Since then there has Page 17 been considerable data collection (e.g. the TIMMS neonatal data set) but this information has not been used to provide tools for analysis, planning and optimisation of configurations of services. In 2007 a further Department of Health report ("Caring for Vulnerable Babies: The Reorganisation of neonatal services in England") stated there was a need for commissioners and networks to coordinate the commissioning of neonatal and maternity services: This should include undertaking strategic needs assessments for the local population, taking standards set by professional bodies into account and addressing the blockages in networks which prevent efficient in-utero transfers. The same report highlights that this is an area where demand has continued to increase, suggesting needs for improved planning of services will be sustained long into the future: Year on year increases in birth rates and improvements in survival rates have placed increasing pressure on the capacity of neonatal services and led to some instances of babies being transferred long distances to receive definitive care.

Computer simulation has the potential to allow for a detailed study of how changing quantity and location of resources (cots and nurses) affects the performance of a network of neonatal units as a whole.

This project has now been endorsed by the BAPM, who recognise the pressing need for robust capacity modelling in this environment: "The British Association of Perinatal Medicine (BAPM) has looked at the outline proposal for this research programme. The need for robust capacity modelling that can deal with the complexity of neonatal care based around networks has been pressing for at least 10 years. Any programme that delivers a model applicable to across the UK and the complexity of service models will have immense value to commissioners and providers of neonatal care in planning the right capacity in the most appropriate locations to deliver best care. BAPM supports the need for development of capacity modelling in neonatal care". Bryan Gill, President of BAPM

Hospitals covered in research

Data (accessed by Allex Allwood, Plymouth, from the Clevermed Badger system) from the following hospitals will be used in the model:

- Plymouth Derriford – Plymouth Hospitls NHS trust
- Truro - Royal Cornwall Hospitals NHS Trust
- Barnstaple - The Northern Devon Healthcare NHS Trust
- Exeter - Royal Devon & Exeter NHS Foundation Trust
- Torbay - South Devon Healthcare NHS Foundation Trust

Research methodology

The model is based on discrete event simulation. In this type of simulation each 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). The simulation is animated; infants may be seen in different levels of care at each hospital and can be seen being transferred between hospitals when necessary. Each hospital of a network will be presented in the model. For each hospital the number of cots and the highest level of care each cot is capable of supporting will be specified. Care levels will be classified by Intensive Care, High Dependency Care and Special Care. These will be defined by the interventions being carried out and the level of nursing support required (according to BAPM guidelines). Though some hospitals may class levels of care slightly differently we will aim for a consensus and will be transparent about how the model has classified the level of care. Additionally each unit may have further limitations such as the gestational age they may support or specialist interventions that are not possible in a particular unit (surgery for example may only be possible in one unit in a network, or infants may have to go outside of the network for surgery). Each unit will have a specified number of nurses. Infants are born at random in the hospitals in the model requiring care (it is possible to have hospitals with births but with limited or no neonatal care facilities). The distribution of gestational age and level of care initially required will be as observed in the historic data set. The model then seeks to find a suitable cot in the following example order (rules may be changed):

- Cot in hospital of birth (or preferred hospital where hospital of birth has no neonatal care facilities).
- Closest available cot in network.
- Closest cot outside of 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. 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.

A proof of concept model has been developed. The data used in the proof of concept came from an old Excel-based DoH model. Though people have expressed doubts about the quality of data in the DoH spreadsheet it was sufficient to indicate that modelling of a neonatal network in Simul8 could be achieved.

Data requirements

The following data will be obtained from the data sets used).

- Number of births at each hospital requiring neonatal care
- Number of ICU, HDU & SCU cots at each hospital
- Number of nursing staff at each hospital (including ratio of qualified in speciality and non-qualified in speciality). Model will allow for 'base case' and also for maximum flexed resourcing at peak demand.
- Earliest gestational age that may be treated at each hospital
- Location of each hospital (used to find nearest available cot)
- Network affiliation of hospital (the model will combine multiple networks if required)
- Estimated cost of nurses & cots
- Distribution of weight/gestational age of babies requiring care
- Entry point (ICU, HDU, SCU) of babies according to weight/gestational age
- Length of stay in ICU, HDU, SCU and next destination according to weight/gestational age
- % twins in care
- Target nurse:cot ratios for ICU, HDU & SCU cots (using BAPM standards)
- Maximum permitted over-utilisation of nurses before closure of unit to new infants (ICU, HDU & SCU will be applied as defined in the BAPM 2011 Categories of Care guidelines).

30 months of data will be used (24 months as a training set of data, and 6 months as a test-set to compare model output to actual data not used to train model).

The following outputs will be provided by the model:

- ICU, HDU & SCU cot utilisation at each hospital and in network
- Staff utilisation at each hospital and in network, and % time over BAPM guidelines
- % of time that hospital/network is closed to further ICU, HDU or SCU admissions
- Number of ICU, HDU & SCU episodes at each hospital
- % of demand met locally or and in network (and average distance when displaced)
- Number of transfers required (and total miles of transfers) within or outside of network; this will include number of transfers that are potentially *in utero*.
- % episodes when no cot available (and average wait when this happens)
- Number of episodes where infant in higher grade cot (e.g. HDU care infant blocking a ICU cot)
- Costs of additional cots/nurses
- Number of infants cared for at hospital of birth

Data anonymisation

The model will use pseudo-anonymised data (the patient ID will be replaced by another unique identifier before the data is handled by the modelling team). The linking data will be kept within the NHS (with Dr Alex Allwood, Data lead for the Peninsula neonatal network).

Location data will be restricted to postcode sector (postcode without the last two letters) of the mother's home address. A post-code sector typically contains a population of 5,000-15,000.

Data analysis

Model outputs will be key performance indicators such as staff & cot utilisation, % time working above BAPM guideline capacity, % time unit closed, number of transfers within or outside of network, projected costs above/below current spend.

18 months of data will be used to determine the parameters used in the model (e.g. time in ICU, HDU, SCU depending on gestational age/weight). The model will then be validated against 6 months of network data not used in the 'training' of the model (modelled KPIs will be compared to actual KPIs) and the precision of the KPIs determined.

Following comparison of modelled results with real results the analysis will then move onto 'what if?' scenarios, specifically:

- Is there a no-cost reconfiguration of resources which would reduce periods spent above BAPM guidelines, reduce unplanned transfers, and reduce the frequency with which a unit is closed to new admissions?
- What is the relationship between available resources (cots, nurses) and % time the network works within BAPM guidelines. This component will also include cost implications of adding/reducing resources.

Project timescale and steering committee

The project is scheduled to run Jan-Dec 2013. The project will use the Peninsula Neonatal Network (Lead: John Madar, Manager: Gayle Budden) as a steering committee and will report to the Network board quarterly throughout the project, and at the completion of the project.