A framework to address key issues of neonatal service configuration in England: the NeoNet multimethods study

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Disclaimer: This report contains transcripts of interviews conducted in the course of the research and contains language that may offend some readers.

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Scientific summary

The NeoNet multimethods study

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Scientific summary

Objectives

The aim of this study was to develop an analytical framework to address key issues in the configuration of neonatal services in England. The primary component objectives were to:

- Analyse neonatal service organisation and explore the trade-offs that are inherent in reconfiguration.
- Understand the benefits and costs, both to the NHS and to parents, of service centralisation and model the impact of different configurations. To use simulation, modelling and location analyses to understand the behaviour of this complex system and investigate trade-offs at the national level.
- Model costs and outcome changes associated with service reconfiguration. To explore the impact of service reconfiguration on clinical outcomes (e.g. mortality) and costs [e.g. neonatal bed-days, length of stay (LOS) and parent costs] and to undertake qualitative research on factors that families and policy-makers see as important in determining service configuration.
- Investigate the use of visualisation tools to communicate research findings. To understand the informational requirements of the key stakeholder groups and to research and develop effective communication tools to convey the research findings.
- Consult with the parents of neonatal infants. To ensure that the needs and concerns of parents and families are taken into account, to explore the best ways to communicate findings to parents and the public, and to involve them in decision-making in neonatal service configuration.

Methods

A wide range of approaches was employed. Descriptive statistics, location analysis, mathematical algorithms and simulation were used for modelling work. In the health economic analysis, cost and mortality models were developed and structured qualitative interviews with both policy-makers and parents were conducted. For data visualisation, user requirements and tools for communication were investigated, and patient and public involvement (PPI) workshops were held with parents.

Location analysis and modelling

Data sources

- The geographic areas used were 2011 lower-layer super output areas (LSOAs).
- Demographic data for LSOAs were obtained from the Office for National Statistics.
- Road travel times were obtained from a geographic information system (Maptitude® 2016; Caliper, Newton, MA, USA).
- Birth data (at the LSOA level) for 2013–15 were obtained from Hospital Episode Statistics.
- Neonatal unit designation was obtained from the 2015 National Neonatal Audit Programme report.
- Neonatal care data for 2013/14 were obtained from the 2015 National Neonatal Research Database (NNRD). Of the 161 neonatal units, 90% gave permission to access NNRD data [100% of neonatal intensive care units (NICUs), 85% of local neonatal units (LNUs) and 90% of special care units (SCUs)].

Location analysis

For both maternity and neonatal care configuration, there is a trade-off between competing objectives. Prioritising parent travel time entails more small neonatal units close to the locations of mothers' homes. Prioritising health outcomes entails fewer neonatal units providing intensive treatment and greater travel times.

When competing objectives exist, there are many possible solutions, and increasing performance in one objective is accompanied by a reduction in the performance of at least one other objective. This is known as the 'Pareto front'. We used a genetic algorithm to identify good solutions that approach the theoretical optimal Pareto front.

There are no national target times for access to maternity or neonatal care. We analysed mean and maximum travel times and the proportion of mothers within 30, 45 and 60 minutes of the place of care. The 30-minute target is most discriminatory between options and, therefore, it is the target that is most commonly referred to in this report.

The Royal College of Obstetricians and Gynaecologists recommends that obstetrician-led maternity units should deliver ≥ 6000 births per year to facilitate the 24/7 (24 hours a day, 7 days a week) presence of a consultant on site. Currently, only about 20% of births take place in units of this size. Our maternity location analysis shows that, to achieve 100% of births in units of this size, the number of birth centres would need to be significantly reduced: from 161 to approximately 70. However, with this reduction, the proportion of mothers attending units with ≥ 6000 births per year and travelling < 30 minutes would increase from 24% to 82% with reconfiguration (the maximum that is achievable based on our results). Although such large changes may be unrealistic, the proportion of mothers attending a unit with ≥ 6000 births per year within 30 minutes could be increased to approximately 70% with 120 units (with ≈90% of mothers living within 30 minutes of such a maternity unit).

The British Association of Perinatal Medicine (BAPM) recommends that all NICUs should admit ≥ 100 very low-birthweight (VLBW) infants per year. The genetic algorithm identified solutions in which all NICUs could meet this guideline and travel distances for parents could be reduced. This would, however, require moving the location of some NICUs. If NICUs are restricted to current NICU locations, meeting this BAPM guideline would require the closure of 12 of the current 48 NICUs, and this would increase travel times for parents.

Simulation

A discrete event simulation was used to further evaluate configurations. This mimicked admissions over time and modelled networks, transfers, different unit levels and capacities. The simulation placed infants in the closest appropriate unit (with sufficient capacity) and tracked infants, nurse workload in units, transfers and distance from mothers' home locations.

The simulation accurately predicted average travel times (within 2 minutes or within 10% of actual data). Predicted workload accuracy varied depending on proximity between units; for units that were ≥ 15 minutes apart, the typical error margin was ± 2–3 infants or ± 1 nurse-equivalent workload.

The simulation showed that the number of infants not cared for at their closest appropriate unit rises with capacity utilisations of > 60% of the maximum capacity, with a doubling of the number of infants who are > 30, 45 or 60 minutes from home when units run at an average of 75% of maximum capacity. The removal of network boundaries had a minimal impact on travel times.

The simulation also predicted that relative peaks in workload are significantly lower for higher-volume units. A unit with an average workload of 2–3 nurse equivalents will have a fourfold ratio of peak-to-trough nurse workloads (ratio of ninetieth-to-tenth percentile workloads), whereas a unit with average workload of 10 nurse equivalents will typically have a twofold ratio of peak-to-trough nurse workloads.

Two alternative scenarios, identified by the genetic algorithm, were tested in the simulation model. One scenario, selected to minimise travel distances while having all NICUs admitting ≥ 100 VLBW infants per year, reduced average travel times and increased the proportion of infants within 30, 45 and 60 minutes from home. In this scenario, the simulation replicated the expected benefits. The second scenario modelled significant centralisation of care (with 30 NICUs, 30 LNUs and 30 SCUs). In this scenario, travel times for parents were increased, but the number of nurses required to meet BAPM standards for 90% of the time was reduced by about 10%.

Economic modelling

The economic modelling explored the impact of service reconfiguration on clinical outcomes (e.g. mortality) and costs (e.g. neonatal bed-days, LOS and parent costs), and involved qualitative research on family and policy-maker preferences.

Mortality

Mortality for infants born at < 32 weeks of gestational age was estimated using semiparametric and parametric neonatal mortality models in both (1) high-volume units (≥ 100 VLBW admissions per year) and (2) NICUs. Sensitivity analysis accounted for potential bias attributable to imbalance in the distribution of extremely premature babies across treatment (hospital of birth) groups. Causal effect was estimated using an instrumental variable (IV) approach, using travel time or distance as an instrument. Secondary analysis of the relative effects of birth in a hospital with a NICU versus a SCU and versus a LNU used an IV approach with three instruments: travel time to the closest (1) NICU, (2) LNU and (3) SCU.

It was found that exposure to a high-volume unit at birth reduces mortality relative to birth in other neonatal units. A very preterm infant has a 5-percentage-point lower risk of death by being born in a hospital with a high-volume unit than being born in another neonatal unit (when travel time is used as the instrument) when semiparametric models are used and a 1.2-percentage-point lower risk when parametric models are used. Sensitivity analysis, excluding infants born at a gestational age of < 26 weeks, halves the mortality effect of birth in high-volume units compared with other units, but the estimates are imprecise. For babies born at a gestational age of < 32 weeks, being born in a hospital with a NICU appears to not affect the risk of death compared with being born in other units. The secondary analysis suggests that NICUs reduce mortality by 1.9 percentage points compared with LNUs.

Costs

The limitations of national Healthcare Resource Groups (HRGs) were investigated based on data analysis and interviews with policy-makers and the impact of high-volume units on LOS, and the costs of neonatal care for families were estimated.

Site visits and discussions with policy-makers made it clear that national neonatal HRG costs do not currently accurately reflect actual costs, mainly because units typically use average neonatal nursing costs across all infants and do not use the BAPM guidelines to attribute nursing to different levels of care. In addition, apportioning of costs (e.g. diagnostic costs) differs across neonatal units and other units within hospitals, and staff composition varies greatly; for example, junior doctors and advanced neonatal nurse practitioners cover similar tasks, but vary on the salary scale. Our evaluation focuses on (1) the impact of high-volume units on LOS and reimbursement and (2) costing reconfigurations based on nursing cost estimates from the model rather than relying on HRG costs.

The impact of service configuration on LOS was explored and LOS was costed using a microcosting approach. The analysis compared high-volume units with other units using an IV approach. LOS and costs were modelled using a log-normal distribution, whereas probit equations were used for SCU and LNU binary treatment indicators. The instruments and estimates (as for the mortality analysis) included covariates for gestational age, gestational age squared, birthweight, infant sex, last decile of the Index of Multiple Deprivation score, mode of delivery and number of fetuses.

The mean total LOS following a birth in a high-volume unit is 9 days longer and has a mean cost of £5715 more than for a birth in another neonatal unit. The mean total LOS following a birth in a LNU is shorter by 1–2 hospital days, and in a SCU it is shorter by 3–4 hospital days, relative to the mean LOS following birth in a NICU. The mean cost of a SCU birth is £1770 less than a birth in a NICU, although the effects are imprecisely estimated. In contrast, mean reimbursement costs for births in a LNU are £834 more costly than NICU births, but this result is not significant.

A linear regression cost model was developed to capture 'out-of-pocket' expenses that have an impact on family budgets. The Baby Life Support Systems (BLISS) data on parent costs suggested that key factors were entitlement to unpaid leave, food, travel, accommodation, baby care and parking. In addition, the support from the employer of the mother's partner can reduce costs, as can the availability of the partner to help.

What is important to families?

A flexible topic guide for individual interviews with parents was developed (after piloting prior to data collection). The semistructured probing questions were based on a review of the literature and PPI workshop feedback. From the transcripts of the interviews with parents, a thematic framework was developed to code relevant themes and subtheme factors.

The qualitative interviews found that people talked about the infant as a whole, rather than separating out risks of death and health problems. Families connected the health of the baby and the mother, considering the mother's health alongside that of the child. The interviews also highlighted other process outcomes (e.g. communication with the families and family support) and raised questions about the ability and willingness of parents to trade off health attributes with process attributes. Mothers were unlikely to want to sacrifice 'core' aspects of their baby's health for improvements in process outcomes.

Evaluation

We estimated the incremental cost-effectiveness based on a comparison of (1) high-volume units and all other units, and NICUs and other unit designations, and (2) three service reconfigurations from the simulation modelling.

For high-volume units compared with all other units, dividing the additional cost (£5715) by the reduction in neonatal mortality (absolute risk difference 0.012) results in a cost per neonatal life saved of £460,887. Costs and effects were discounted by 2.5% for the first 30 years of life, 3% from the 31st to the 75th year and 2.5% from the 76th to the 81st year (as recommended by the HM Treasury Green Book for longer term interventions[135]). This results in an incremental cost-effectiveness ratio (ICER) per life-year gained of £15,620. In addition, birth in a NICU is more clinically effective and cost saving, with an incremental cost per neonatal life saved of –£43,096 when compared with birth in a LNU.

Exploring three service configurations, it was found that nursing costs are the largest cost component, being approximately 18 times higher than travel costs and 33 times higher than transfer costs. Nursing costs also reduce during centralisation, because of economies of scale, and are the key driver for overall costs. Although centralisation increases family travel costs, it reduces costs from a societal perspective.

Data visualisation

Policy-makers, commissioners, clinicians and care workers, researchers, parents and the public all have an interest in the organisation of neonatal care. These diverse groupings generally have both different informational needs and expertise. Therefore, the way in which information is communicated, just as much as what is communicated, needs to reflect these differing requirements.

A range of potential formats and media for the presentation of findings from the study was investigated and a number of graphical methods and specific tools (some developed within our research) was identified to address audience requirements. Policy-makers emphasised the importance of clear methods to communicate technical outputs and their relation to strategic issues. Parents found maps, Pareto fronts and narrative- and picture-based presentations based on case study information powerful additions to, but not substitutes for, traditional text-based information. Importantly, any development of communication tools needs to start with a clear understanding of the objectives and the specific audience requirements.

Parental involvement

Five PPI workshops were carried out, which allowed the team to develop an ongoing dialogue with parents about the design of aspects of the project, the implications of the findings for neonatal services and parents, and how potential negative consequences of centralisation might be mitigated. Importantly, these workshops demonstrated that parents can be involved in complex, evidence-based discussions about the design and delivery of neonatal services if they are supported and provided with the relevant information in an accessible manner.

Conclusion

In this study, a structured approach is presented to address key questions in the configuration of NHS neonatal care services in England. Although many issues still need further investigation, it is believed that the research framework outlined here provides a valuable basis to support evidenced and informed policy-making in this area of health and care.

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