What factors predict length of stay in a neonatal unit: a systematic review

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ABSTRACT

Objective: In the UK, 1 in 10 babies require specialist neonatal care. This care can last from hours to months depending on the need of the baby. The increasing survival of very preterm babies has increased neonatal care resource use. Evidence from multiple studies is crucial to identify factors which may be important for predicting length of stay (LOS). The ability to predict LOS is vital for resource planning, decision-making and parent counselling. The objective of this review was to identify which factors are important to consider when predicting LOS in the neonatal unit.

Design: A systematic review was undertaken which searched MEDLINE, EMBASE and Scopus for papers from 1994 to 2016 (May) for research investigating prediction of neonatal LOS. Strict inclusion and exclusion criteria were applied. Quality of each study was discussed, but not used as a reason for exclusion from the review.

Main outcome measure: Prediction of LOS in the neonatal unit.

Results: 9 studies were identified which investigated the prediction of neonatal LOS indicating a lack of evidence in the area. Inherent factors, particularly birth weight, sex and gestational age allow for a simple and objective prediction of LOS, which can be calculated on the first day of life. However, other early occurring factors may well also be important and estimates may need revising throughout the baby’s stay in hospital.

Conclusions: Predicting LOS is vital to aid the commissioning of services and to help clinicians in their counselling of parents. The lack of evidence in this area indicates a need for larger studies to investigate methods of accurately predicting LOS.

BACKGROUND

In the UK, 1 in 10 babies1 will require specialist neonatal care. Although the most preterm and smallest babies have the highest risk of mortality, if they survive their length of stay (LOS) in the neonatal unit will be very long. As neonatal survival has improved over recent years, particularly for very preterm babies,2 the number of babies requiring long-term neonatal care has increased. Consequently, the workload of the healthcare service, including the total number of days of care required has increased.

METHODS

Selection of studies

MEDLINE, EMBASE and Scopus were searched systematically for papers from 1994 to 2016 (May) which investigated the prediction of mortality and/or LOS. All articles were screened by one author, and a random 10% were screened by a second author to ensure reliability of the reviewing process.
Any differences in identified articles were discussed between the two authors. The results presented here relate to the prediction of LOS. The full search strategy is provided in the online supplementary table.

Inclusion criteria
Studies were included which reported risk factors for LOS in the neonatal unit, irrespective of the outcome for the baby, from a multivariable model (eg, logistic regression, linear regression). To be included studies needed to have been undertaken in a human population and have been published in English. Neonatal survival dramatically improved in 1994 with the introduction of routine surfactant use and antenatal steroids and therefore the search was started from this year. Studies which included data from before and after 1994 were included.

Exclusion criteria of studies
Exclusion criteria were determined in advance and included:

- Conference proceedings, as these were not peer-reviewed, although efforts were made to investigate if the conference abstract was subsequently published;
- Review articles, letters and editorials as these did not contain original research;
- Countries which were outside the Organisation for Economic Co-operation and Development in 1994 to identify countries with a different demographic profile and healthcare service;
- Clinical trials, as the population would be unlikely to be representative of other babies in neonatal care;
- Wrong study population, for example, investigation of a paediatric or maternal population, or outcome, for example, predicting readmission;
- Specific disease areas (eg, *Escherichia coli* outbreaks or infections) as these babies are very different to other babies in neonatal care;
- Work that was subsequently updated or validation studies.

Data extraction
A data extraction form was prepared in advance to aid extraction of all necessary information. Information extracted related to: general details of the study (to determine eligibility); study characteristics; study population; outcome; clinical predictors and the quality of the study. Reference lists of included studies were examined for any additional studies which were relevant. Identified prognostic factors were grouped into broad categories of: inherent factors; antenatal treatment and maternal factors; conditions of the baby; treatment of the baby and organisational factors.

Study quality
The quality of research is known to often be poor in prognostic studies, and therefore quality was not used as a reason for exclusion from this review. However, study quality was considered and discussed using an adaptation of Quality In Prognostic Studies (QUIPS) tool. Domains of quality included consideration of: study participation; study attrition; prognostic measurement (eg, measurement, validity, completeness of data); outcome measurement (eg, definition and measurement); risk adjustment and predictors (eg, discussion of missing data) and statistical analysis and reporting (eg, was the model building appropriate, validation considered). A study was considered to be of reasonable quality if potential bias introduced by these domains was minimised as far as practical.

This review was registered with PROSPERO (registration number: CRD42013006020). Ethical approval was not required for this review.

RESULTS
A total of 7996 studies were identified from a systematic search of MEDLINE, EMBASE and Scopus (see figure 1). After removing duplicates, 5042 studies were screened for inclusion in this review. For 4978 articles it was clear from the title and abstract that they did not satisfy the inclusion criteria. The remaining 64 articles were read in full and manual searching of references, led to a final total of 24 being identified. Of these nine studies investigated the prediction of LOS and are included in this review. Summary characteristics of the studies are provided in table 1.

Of the nine identified articles, eight were identified by both authors performing the screening, and the ninth was agreed on after discussion between the authors.

Description of LOS studies
Inclusion and exclusion criteria of LOS studies
Exclusions within the nine studies, included: (major) congenital anomalies (as defined by study authors as no standard exists), deaths in hospital or before admission to intensive care; babies who were admitted for comfort care (neither intubation or cardiorespiratory resuscitation was provided); step down care; ambiguous sex; implausible birth weight; non-normal care pathways; in hospital >1 year; previously discharged and readmitted, transfers, and transfers to long-term care facilities.

Although most studies excluded infants who died in hospital; two papers included deaths in the calculation of LOS. One paper accounted for this in the methodology implemented and another acknowledged ‘mortality rates may have introduced bias, since non-survival truncates observed LOS’. One study which excluded deaths acknowledged that accounting for deaths in LOS ‘may be particularly complex…’

Study populations within LOS studies
Studies investigated a variety of gestational ages and a range of different study settings (table 1) leading to varied populations. Studies appear to have been largely
based in intensive care units, although it is difficult to comment on whether individual babies within a study required or received intensive care (eg, mechanical ventilation) as no study stated this explicitly.

Prognostic factors in LOS studies

The nine identified studies investigating the prediction of LOS presented a total of 39 prognostic factors. These variables were grouped into broad categories of: inherent factors; antenatal treatment and maternal factors; conditions of the baby; treatment of the baby and organisational factors. Details of the prognostic factors identified by each study are given in table 2.

All nine studies accounted for some form of inherent factor, with the most common being birth weight (88.9%, 8/9), gestational age (55.5%, 5/9) and sex (55.5%, 5/9). Seven studies attempted to account for the condition of the baby. However, there was little consensus on what factor would be appropriate, with variables ranging from those occurring early in the care pathway (eg, admission reason) to those potentially occurring later on (eg, Retinopathy of Prematurity). Similarly, variables such as congenital anomalies were only accounted for by three studies (33.3%, 3/9); however, this often comprised part of the exclusion criteria (55.5%, 5/9).

Organisational factors were considered in 5 (55.5%) studies, with most relating to the setting of the care being received including transfers between units.14

Study quality of the LOS studies

Quality of research is well acknowledged as an issue in prognostic or prediction studies.5 Therefore, an adapted form of the QUIPS tool was used to discuss the quality of the studies (table 3), although poor quality was not used as a reason for exclusion from the review. Domains of bias which were examined included: level of study participation; exclusion and attrition; how the outcome was measured; details about risk adjustment and information about the analyses, specifically if validation was conducted. Study participation was not an issue as all studies used data from routine sources and none actively recruited participants. Attrition caused by infants being transferred out of the area covered by the hospital/study was potentially an issue in all studies except one10 which included LOS in other facilities. However, this study10 was based in a single centre, and although they lost no infants to attrition, the details about the population they recruited only included care received while within that hospital site.

Seven studies used continuous LOS/postmenstrual age (PMA) as their outcome.7 9–13 15 Two studies categorised LOS, one by dichotomising into <21 days and ≥21 days14 and the other by classifying discharge as early or late (lowest and highest quartile of PMA).8 The decision of how to model LOS was based on the statistical analysis being implemented. There were no issues in the measuring of LOS, as this is an objective, simple measurement.

Five studies had validated their results by splitting the sample during the initial analysis and holding some data back for validation purposes.8–11 13 Two studies acknowledged that further validation was needed before results could be generalised12 14 and one acknowledged that further work was needed to assess the modelling techniques.15 One study, as part of their analyses, had conducted a preplanned external validation on a model presented in their paper, but concluded that the non-validated model was statistically superior.10 Only one study did not mention validation of the results.7 Therefore, a strength of these studies was that most addressed the issue of validation in some way.

In general, study quality was considered to be good with low levels of potential bias. There were few issues with study participation as most studies obtained data from medical notes which would introduce a low risk of bias. All studies had a defined outcome which could be

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**Table 2**

<table>
<thead>
<tr>
<th>Category</th>
<th>Studies (% of total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inherent factors</td>
<td>9 of 9</td>
</tr>
<tr>
<td>Antenatal treatment and maternal factors</td>
<td>8 of 9</td>
</tr>
<tr>
<td>Conditions of the baby</td>
<td>7 of 9</td>
</tr>
<tr>
<td>Treatment of the baby</td>
<td>9 of 9</td>
</tr>
<tr>
<td>Organisational factors</td>
<td>5 of 9</td>
</tr>
</tbody>
</table>

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**Figure 1** Flow chart documenting the results of the systematic review search. This review focuses on the articles identified which investigated the prediction of LOS. LOS, length of stay; OECD, Organisation for Economic Co-operation and Development.
<table>
<thead>
<tr>
<th>Study Authors</th>
<th>Country of study</th>
<th>Year of publication (data)</th>
<th>Exclusions in study</th>
<th>Number of patients in study</th>
<th>Population investigated</th>
<th>Physical location of study</th>
<th>Model selection</th>
<th>Statistical methods</th>
<th>Model fit methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altman et al</td>
<td>Sweden</td>
<td>2009 (2004–2005)</td>
<td>Congenital anomalies; death; surgery.</td>
<td>2388</td>
<td>30–34 weeks gestational age</td>
<td>Neonatal units of varying levels of care</td>
<td>Univariate analysis then significant (p&lt;0.2) entered into stepwise linear regression</td>
<td>Linear regression</td>
<td>$R^2$</td>
</tr>
<tr>
<td>Bender et al</td>
<td>USA</td>
<td>2013 (1999 and 2002)</td>
<td>Congenital anomalies; death; admitted for comfort care.</td>
<td>293 (validated on 615)</td>
<td>All gestations</td>
<td>Neonatal intensive care unit</td>
<td>Prior knowledge</td>
<td>Accelerated failure time parametric models</td>
<td>Cross validation $R^2$</td>
</tr>
<tr>
<td>Berry et al</td>
<td>Canada</td>
<td>2008 (2002)</td>
<td>Admitted for step down care.</td>
<td>604</td>
<td>All gestations</td>
<td>Neonatal intensive care unit</td>
<td>Prior knowledge</td>
<td>Logistic regression</td>
<td>None, but validation in other centres recommended (acknowledged as weakness)</td>
</tr>
<tr>
<td>Hintz et al</td>
<td>USA</td>
<td>2010 (2002–2005)</td>
<td>Congenital anomalies; in hospital &gt;1 years; transferred to long-term care.</td>
<td>2254</td>
<td>&lt;27 weeks gestational age</td>
<td>Unclear but likely to be neonatal intensive care due to gestational age</td>
<td>Prior knowledge</td>
<td>Linear mixed model</td>
<td>$R^2$</td>
</tr>
<tr>
<td>Lee et al</td>
<td>USA</td>
<td>2016 (2008–2011)</td>
<td>Congenital anomalies; death; surgery; readmitted.</td>
<td>23 551</td>
<td>All babies 401 g–1500 g or 22–29 weeks gestational age plus larger babies meeting specified criteria</td>
<td>Neonatal intensive care units</td>
<td>Prior knowledge then minimum AIC</td>
<td>Negative binomial model with hospital as random effect</td>
<td>Root mean-square error (RMSE)</td>
</tr>
<tr>
<td>Manktelow et al</td>
<td>UK</td>
<td>2010 (2005–2007)</td>
<td>Death; non-normal care.</td>
<td>4702</td>
<td>23–32 weeks gestational age</td>
<td>Neonatal unit.</td>
<td>Prior knowledge and then change in deviance to decide how to model variables</td>
<td>Quantile regression</td>
<td>Observed vs predicted comparison</td>
</tr>
</tbody>
</table>
Table 2: Prognostic factors for predicting length of stay included in the analysis of each study

<table>
<thead>
<tr>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Birth weight (modelled in multiple ways including categorised, SGA, z score)</td>
<td>X (SGA)</td>
<td>X</td>
<td>X</td>
<td>X ( +SGA)</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Congenital anomalies</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Date/year of birth</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Ethnicity/race/nationality</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Gestational age</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Head circumference</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Length of baby at birth</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
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<td></td>
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<tr>
<td>Multiplicity</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Sex</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
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<td></td>
<td></td>
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<tr>
<td>SNAPPE-II</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Any inherent factor: X X X X X X X X X 9

Antenatal treatment and maternal factors

| Antenatal steroids                                               | X            |             | X           | X               |                   |                 |                |              |
| Diabetes                                                         | X            |             | X           | X               |                   |                 |                |              |
| Emergency delivery                                               | X            |             | X           | X               |                   |                 |                |              |
| Fetal distress                                                   | X            |             | X           | X               |                   |                 |                |              |
| Hypertension                                                     | X            |             | X           | X               |                   |                 |                |              |
| Maternal age                                                     | X            |             | X           | X               |                   |                 |                |              |
| Mode of delivery                                                 | X            |             | X           | X               |                   |                 |                |              |
| Other maternal/obstetric condition                               | X            |             | X           | X               |                   |                 |                |              |
| Received prenatal care                                           | X            |             | X           | X               |                   |                 |                |              |

Any antenatal treatment or maternal factor: X X X X X 4

Conditions of the baby

| Admission reason                                                | X            |             | X           | X               |                   |                 |                |              |
| Apgar score                                                      | X            |             | X           | X               |                   |                 |                |              |
| Bronchopulmonary Dysplasia                                      | X            |             | X           | X               |                   |                 |                |              |
| Hypertirilubaemia                                               | X            |             | X           | X               |                   |                 |                |              |
| Hypoglycaemia                                                   | X            |             | X           | X               |                   |                 |                |              |
| Infection                                                       | X            |             | X           | X               |                   |                 |                |              |
| Respiratory distress syndrome                                    | X            |             | X           | X               |                   |                 |                |              |
| Retinopathy of prematurity (stage 3 or higher)                   | X            |             | X           | X               |                   |                 |                |              |
| Sepsis episode or NEC                                           | X            |             | X           | X               |                   |                 |                |              |
| Severe morbidity§                                                | X            |             | X           | X               |                   |                 |                |              |
| SNAPPE§                                                          | X            |             | X           | X               |                   |                 |                |              |
| SNAPPE-II                                                       | X            |             | X           | X               |                   |                 |                |              |

Any condition of the baby: X X X X X 4

Continued
<table>
<thead>
<tr>
<th>Any condition of the baby</th>
<th>XX X X X X X 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment of the baby</td>
<td></td>
</tr>
<tr>
<td>Surgery while in hospital</td>
<td>X 1</td>
</tr>
<tr>
<td>Surgery for patent ductus arteriosus, necrotising enterocolitis, or retinopathy of prematurity</td>
<td></td>
</tr>
<tr>
<td>Umbilical vein catheter</td>
<td></td>
</tr>
<tr>
<td>Ventilation</td>
<td></td>
</tr>
<tr>
<td>Any treatment of the baby</td>
<td>XX X 3</td>
</tr>
<tr>
<td>Organisational factors</td>
<td></td>
</tr>
<tr>
<td>Centre (random effect)</td>
<td>X X X 3</td>
</tr>
<tr>
<td>Domiciliary care</td>
<td>X 1</td>
</tr>
<tr>
<td>Fixed discharge criteria</td>
<td></td>
</tr>
<tr>
<td>Level 3 centre</td>
<td></td>
</tr>
<tr>
<td>Transferred/outborn status</td>
<td></td>
</tr>
</tbody>
</table>

*The final model is taken to be the SNAP one as this model was validated.
†This study stratified analyses by birth weight, and different variables were used for each stratification. All variables from all models are listed here.
‡The calculation of the SNAPPE-II score includes: MBP; lowest temperature; Po2/FIO2 ratio; lowest serum pH; multiple seizures; urine output; birth weight; SGA and Apgar score. These are a combination of inherent conditions of baby factors and so SNAPPE II appears in both categories.
§Severe morbidity is defined as: any of: IVH 3-4; ROP>=3; BPD.
¶This is the original SNAP score, devised in 1993, and comprised of 34 items, largely related to the condition of the baby. Examples of items belonging to the score include heart rate, blood pressure and pallet count.

BMJ Open: first published as 10.1136/bmjopen-2015-010466 on 18 October 2016. Downloaded from http://bmjopen.bmj.com/ on December 4, 2022 by guest. Protected by copyright.
Table 3  Quality assessment of the included studies using a modified version of the QUIPS tool

<table>
<thead>
<tr>
<th>Study participation</th>
<th>Study exclusion/attrition</th>
<th>Outcome measurement (eg, definition and measurement)</th>
<th>Risk adjustment and clinical predictors* (eg, missing data)</th>
<th>Statistical analyses and reporting (eg, validation considered)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altman et al⁷</td>
<td>Study is population based (and included 21/34 units in Sweden) but infants were excluded if moved to a hospital not included in study. Data is collected</td>
<td>Infants discharged to other clinics were excluded.</td>
<td>Continuous postmenstrual age at discharge.</td>
<td>Detailed information about how factors were measured.</td>
</tr>
<tr>
<td>Bender et al¹⁰</td>
<td>Single centre study.</td>
<td>Transfers were included in the analysis and their LOS in other facilities was included in the total LOS. Sensitivity analyses excluded them.</td>
<td>Continuous LOS (days).</td>
<td>Made use of mortality scores with large number of elements included. Potential issues if there was missing data.</td>
</tr>
<tr>
<td>Berry et al¹⁴</td>
<td>Study based in two hospitals. Data extracted from ward registers, charts and patient records.</td>
<td>LOS days after transfer to another centre were not included.</td>
<td>LOS categorised into: &lt;21 days or ≥21 days. No justification for these cut points.</td>
<td>Made use of mortality scores with large number of elements included. Potential issues if there was missing data.</td>
</tr>
<tr>
<td>Hinchliffe et al¹⁵</td>
<td>Population-based study covering a region of hospitals. Data is extracted from medical records and stored in a routine database used for research purposes.</td>
<td>Minimal losses to follow-up when discharged out of region covered by study. Included in analysis as censored observations.</td>
<td>Continuous LOS (days).</td>
<td>Detailed information about how factors were measured.</td>
</tr>
<tr>
<td>Hintz et al⁸</td>
<td>Population-based study within a large network containing multiple hospitals. Data extracted from a routine database set up for research.</td>
<td>Attrition of infants transferred out of the region covered by study.</td>
<td>Early (lowest quartile of age at discharge) or late discharge (high quartile of age at discharge). No justification for these cut points.</td>
<td>Variables clearly defined. Some factors subjective in measurement (eg, Bells staging for NEC).</td>
</tr>
<tr>
<td>Lee et al⁸</td>
<td>Population-based study of a large number of intensive care units.</td>
<td>Attrition from transfers to lower levels of care (acknowledged as causing bias).</td>
<td>Continuous LOS in days (log transformed).</td>
<td>Limited details about variables but most could be measured objectively.</td>
</tr>
<tr>
<td>Lee et al¹¹</td>
<td>Population-based study in 90% of intensive care units in large American state</td>
<td>Only babies inborn or transferred to unit in study within one day of life.</td>
<td>Continuous LOS (days).</td>
<td>Variables clearly defined and objectively measured. Missing data not discussed.</td>
</tr>
<tr>
<td>Manktelow et al¹³</td>
<td>Population-based study covering a region of hospitals. Data is extracted from medical records and stored in a routine database used for research purposes.</td>
<td>Minimal attrition: when discharged out of region covered by study.</td>
<td>Continuous LOS (days).</td>
<td>Some factors subjectively measured (eg, reason for admission to intensive care).</td>
</tr>
<tr>
<td>Zemikow et al¹³</td>
<td>Single centre study</td>
<td>Transfers excluded from the study.</td>
<td>Continuous LOS (days).</td>
<td>Limited information about variables but most objective to measure.</td>
</tr>
</tbody>
</table>

*Unmeasured and unknown confounders are always a potential issue within observational research, so no study has this specifically mentioned.

LOS, length of stay; NEC, necrotising enterocolitis.
those born preterm. This was discussed by Lee11 who
very different reasons for being in the neonatal unit to
perform well as the babies born near term may have
in this review even before adjustment for inherent
stay. However, there were a variety of study populations
baby, and the quality of care provision, during the baby
over time depending on the clinical progress of the

diction for LOS on the

All studies accounted for some form of inherent factors
which have the advantage of being generally simple and
objective to measure, and being present at birth. A pre-
diction for LOS on the first day of life can be made
using these factors. However, this prediction may change
over time depending on the clinical progress of the
baby, and the quality of care provision, during the baby’s
stay. However, there were a variety of study populations
in this review even before adjustment for inherent
factors, with predictions for extremely preterm15 and for
all babies.10 14 A prediction model for all babies, such as
that proposed by Bender16 or Berry14 is unlikely to
perform well as the babies born near term may have
very different reasons for being in the neonatal unit to
those born preterm. This was discussed by Lee11 who
stratified their analyses by different birth weight groups
to attempt to group similar babies together. They
acknowledged that babies born at a normal birth weight
may need further stratification by the reason for their
admission, for example: sepsis or respiratory disease.11
The approach appears reasonable, and future LOS pre-
dictions should focus on groups of babies with similar
characteristics, for example, very preterm or very low
birth weight, or analyses should be stratified by clinical
condition.

It has been acknowledged that while this information
from the first day of life is useful,15 prediction is gener-
ally poor unless perinatal factors8 or severity of illness10
factors are also considered. However, there was little con-
sensus on what this factor should be, with potential
factors ranging from early occurring conditions (eg,
reason for admission to intensive care) to those that
occurred later in the care pathway (eg, retinopathy of
prematurity). Therefore, while it may be important to
account for the condition of the baby, there is little
agreement over which factors should be used to do so.
It is difficult to adjust for conditions which will only be
experienced by surviving children. To provide an early
prediction of LOS the clinical condition should be an
event which occurs early in the care pathway, for
example, Apgar score.

Congenital anomalies were not accounted for by many
studies, but often formed part of the exclusion criteria
within a study, indicating the importance of their consid-
eration. However, there is no accepted list of what consti-
tutes a major anomaly, and the term is often used to
refer to a wide and varied range of conditions, making
statistical adjustment or exclusions from a study difficult.
Some congenital anomalies are unlikely to impact on
LOS at all, whereas some severe anomalies or those that
require surgery (eg, gastroschisis) may have a significant
impact on LOS. Consequently even when studies
exclude or adjust for major anomalies it can never be
guaranteed that it is a comparison of ‘like with like’. Thus,
while congenital anomalies may have an impact on
LOS, it is likely too broad a term to include in a LOS
prediction model, but it should be considered by cli-
nicians when revising LOS estimates using their clinical
judgement.

It is difficult to account for organisational factors,
although around half the studies attempted to do this in
some way. However, one major issue with organisational
factors is the variation between countries. Similarly, even
within a country, the level of the unit may not indicate
the type of care given to the infant. Despite this, these
factors were seen by some authors to be equally or even
more important than perinatal risk factors.7 This
demonstrates the importance of considering the varying
levels of care provision within the country of the study.
Studies focused in one or two centres such as those by
Berry14 or Bender16 are likely to be inappropriate to
draw definitive conclusions from as they may have high
levels of loss to follow-up or loss of detail related to the
baby’s care, causing issues with estimating LOS. Within
the UK, neonatal services are focused in clinical net-
works16 with each network providing the full range of
neonatal care. Therefore, it may be appropriate to focus
analysis and prediction at a network level to cover all var-
ieties of care, attempting to avoid some of the issues pre-
sented by differing organisational factors, and to allow
generalisability of the findings. Population-based studies
may assist with this; however, these should potentially
investigate the use of a random effect term for hospital or
equivalent to allow for variation between different healthcare services. Future work should consider the impact of a baby transferring between hospitals on their LOS.

**Thresholds for discharge**

Thresholds for determining the timing of discharge informally exist within neonatal medicine. Babies are rarely discharged before they gain the ability to suck and feed (around 35 weeks of gestational age). Irrespective of clinical conditions experienced, most preterm born babies (particularly <32 weeks) are likely to have matured and recovered enough to be discharged at this point, their prematurity being the overwhelming reason for their LOS. For a small number of babies, later occurring conditions (eg, late occurring sepsis, surgical needs) may cause a dramatic increase in their LOS. However, these will not be identifiable for a long period after birth and so potentially, prediction of LOS should be adapted in light of these conditions, if appropriate.

While the LOS of preterm babies is largely determined by their prematurity, normal birthweight babies and those born closer to term are likely to have varied reasons for their LOS making predictions complex. These babies should be considered separately or adjustment or stratification should be made in any prediction model.

**Clinical use of prediction models**

Clinically, prediction models with a smaller number of factors are easier to use, and this also reflects the concept of statistical parsimony (‘simplicity’). This was seen in the area of predicting neonatal mortality, where complex risk scores, such as the Score for Neonatal Acute Physiology (SNAP), were developed and subsequently simplified to allow easier use. Even following simplification, these risk scores are, at times, still difficult to implement. For example, the simplified SNAP score still requires the assumption that where medical tests are not performed, the results should be considered normal. Therefore, while accurate prediction is needed, this must be balanced against the need for a simple model, suitable for ‘bedside use’.

Clinical judgement is important and potentially informative for predicting LOS, although this was not possible to investigate here. However, prediction models, such as those identified, are useful because they can provide estimates that are more accurate than clinical judgement and assessment alone. It is likely that a statistical estimate of LOS, used in conjunction with clinician judgement, for example, when considering congenital anomalies, may provide the best estimate.

**Strengths and limitations of this review**

There is little research in the area of predicting LOS and this review investigates the limited evidence for the first time. However, it was difficult to identify a clearly defined population for whom to predict LOS. A variety of settings and gestational groups were considered in the different studies in this review, and it is likely that different gestational ages will require different prediction models, incorporating very different factors. Future research will need to specifically investigate this in large studies.

A meta-analysis of the data presented in this review was not undertaken, due to the varying analyses and adjustments made in each study. Theoretically, an individual patient data meta-analysis could have been undertaken in order to overcome these issues; however, this is known to be difficult, particularly with acquiring the necessary data. Similarly, it was not possible to investigate publication bias due to the varying analyses and potentially this could have been an important issue. Owing to these limitations, as suggested in other medical areas, a large-scale study may be important and clinically useful.

**CONCLUSIONS**

The ability to predict LOS would be valuable to parents and families, clinicians and service providers, but it is a complex issue. Inherent factors appear to be the most important to account for, particularly birth weight, gestational age and sex. This information from the first day of life is informative for predicting LOS in a simple model and these estimates are a useful early indicator of LOS.

It may be important to consider revising this initial estimate over time if a late occurring condition dramatically adds to the initial LOS prediction. However, it is hypothesised that many medical conditions will resolve before the point at which the baby is well enough in terms of their prematurity to be discharged. In cases where this assumption is unrealistic more complex (dynamic) risk-prediction models would possibly be required. Studies predicting LOS should be at a population level to avoid the issue of organisational factors, and to allow generalisability of the findings.

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REFERENCES


