# Rounding of birth weights in a Neonatal Intensive Care Unit over 20 years

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Note: The following files were submitted by the author for peer review, but cannot be converted to PDF. You must view these files (e.g. movies) online.

- Figure1.wmf
- Figure2.wmf
- Figure3.wmf
Title Page

Rounding of birth weights in a Neonatal Intensive Care Unit over 20 years

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Key words

Birth weights
Adverse drug events
Drug safety
Digit preference

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ABSTRACT

Objective

To determine the frequency of birth weight digit preference for infants admitted to a large Neonatal Intensive Care Unit (NICU); the scale of rounding depending on prematurity; variability over time and the impact on prescribing accuracy.

Design

Birth weights extracted retrospectively from a single clinical database.

Setting and participants

Birth weights from 9170 inborn infants recorded on an electronic prescribing database admitted to a NICU over 20 years.

Statistical approach

Data are presented for the frequency of each of the possible pairs of final digits. A statistical model of digit preference assuming rounding is used to quantify the proportions rounding to specific accuracy levels. These proportions are compared between those <1000g and those above and over time.

Results

From a population of 9170 infants admitted over 20 years, there was a highly statistically significant digit bias with an increased prevalence of multiples of 100 (P<0.0001), 50 (P=0.007), 20 (P<0.0001), 10 (P<0.0001), 5 (P<0.0001), and 2 (P=0.0005). There was clear evidence of a reduced 100g digit bias for infants 500-1000g (0%) compared with those between 1000-4500g (3.7%).

The maximum birth weight error due to digit bias for all infants was 5%. There was clear evidence of an improvement in accuracy over the 20 years.

Conclusions

Digit bias in birth weights over 20 years in a tertiary NICU is highly significant at the 100, 50, 20, 10, 5 and 2 digit levels. There has been a substantial improvement in the accuracy of birth weight measurements over the twenty years. The likely maximum error due to birth weight digit bias is 5% and is within an acceptable tolerance for drug dosing even at very low birth weights.

(275 words)
ARTICLE SUMMARY

Article Focus

- To determine whether rounding of birth weights or digit preference occurs with infants admitted to a regional Neonatal Intensive Care Unit over a 20 year period
- To investigate the potential impact of rounding of birth weights on the accuracy of drug prescribing for different birth weight groups and whether changes in accuracy have occurred over time.

Key Messages

- There was rounding to the nearest 100g in 3.7% of infants greater or equal to 1000g birth weight and rounding to the lower level of 50g in 4.5% of infants <1000g. This level of rounding does not lead to drug dose errors outwith pharmacy accepted tolerances.
- There has been progressively more accurate weighing of infants over the 20 years with only 18% having birth weights recorded to the 1g level in 1995 compared with 98% in 2013. This change has been incremental and may reflect increased understanding of the importance of accuracy relating to prescribing.

Strengths and limitations

- The strengths of this study include 9170 birth weight measurements from a single Unit entered prospectively into a neonatal prescribing database.
- It is not possible to investigate the rationale for rounding and digit bias retrospectively.
INTRODUCTION

Accurate birth weight measurements are essential for safe delivery of care to newborn preterm and term infants especially for prescriptions. Drug related events in the hospital setting are the highest cause of recorded errors both in the USA \(^1\) and in the UK National Health Service (NHS) \(^2\). The UK National Patient Safety report *Safety in doses: medication safety incidents in the NHS* \(^2\) reported on drug errors across all areas of medicine in 2007-8 and showed that 28.7% of reported drug errors in adult patient groups were due to the wrong dose, strength or frequency of medications.

There are a range of potential sources of drug error including documentation, calculation, preparation and administration errors \(^3,4\). Whilst in adult health care the dose administered may not be weight related, in neonatal intensive care almost all doses are prescribed based on the weight of the infant. Drugs are frequently prescribed shortly after birth with the birth weight used for calculation.

Drug errors in neonatal care are common with 3380 drug errors being reported to the UK National Patient Safety reporting and learning system (RLS) between April 2008-April 2009 \(^5\). There were 507 neonatal drug errors due to gentamicin administration \(^5\). Whilst 96% were reported to cause no harm there was concern that there may be under reporting as long term renal impairment or hearing loss may not become evident until after discharge. Errors in birth weight measurement or recording may therefore lead to over or under treatment.

Newborn infants admitted to a tertiary NICU range in birth weight widely from under 500g to over 4500g. Many infants require an early prescription for drugs and infusions and the accuracy of the birth weight is critical for prevention of drug errors. Infants who weigh less than 1000g at birth require particularly accurate weighing and the scales used in the tertiary NICU weigh to the 1g level. To increase the accuracy of the birth weights, nursing protocol requires deduction of the weight in grams of any item that was unable to be removed prior to the measurement of the birth weight such as an endotracheal tube inserted as part of resuscitation. The definitive birth weight recorded should therefore be at the 1g level.

Infants with birth weights of less than 1000g are at greater risk of drug errors as the impact from rounding or truncating effects is much greater and they are a particularly vulnerable group. Small birth weight rounding differences could potentially increase the adverse drug effects.

Digit bias and rounding has been identified in several areas of medicine \(^6\) including in the measurement of birth weights \(^7\) and is a well recognised phenomenon. One previous study involving birth weight registrations from the 1980s included predominantly term infants weighed in a variety of institutions across Canada and recorded on a civil registration system. The potential for digit preference in this system by a number of individuals was increased.

It is unknown whether a similar digit preference with rounding or truncation of birth weights might occur for infants admitted to a neonatal intensive care unit where there is an expectation of accuracy of prescription and administration of drug and fluid medications. Over the last 20 years there have been national and local drives for
quality care with improved drug safety. It is unclear whether this has resulted in an identifiable behavioural change on the accuracy of weighing and whether there has been any alteration in the frequency of rounding or truncation of birth weight measurements.

Neonatal specific computerised prescribing systems are used in order to minimise drug calculation and prescription errors, but these rely on accurate birth weight measurements for the calculation of the dosages of drugs and infusions. The accuracy of these systems would be reduced if the recorded birth weights were significantly altered by digit bias.

Methods

All infants were weighed on admission to the NICU within 60 minutes of birth using fully calibrated Weylux 850BT/BMI class III baby scales, H Fereday & Sons, Harlow Essex, CM19 5QP, UK. These record a stable digital weight at a 1g level but have a defined absolute accuracy of ±5g. These scales, or their equivalent, have been used consistently over the last 20 years. The scales are regularly calibrated in line with the manufacturer’s standards.

All birth weights were entered into an electronic patient database record utilised predominantly for accurate prescribing of intravenous drugs and fluids. This system has been used for all prescriptions on the NICU over the last 20 years. The electronic patient record database system was initiated in May 1993 specifically to minimise prescribing error risk. Infants born in other institutions and subsequently admitted were excluded.

Birth weight data was extracted over a 20 year period to April 2013. A subset of infants < 1000g was also analysed. During that time 9170 inborn infants were admitted to the tertiary NICU and 100% of birth weights were extracted.

Data extracted from the database was analysed to determine the frequency of weight measurements at 1g intervals from 500-4500g. Weights outside this range were excluded as the numbers of infants above and below this weight range were very small. The use of data from the database was approved by the NHS Research Ethics Committee (Haydock) 13/NW/0159.

Statistical analysis

Birth weights were recorded with a 1g resolution and the number of measurements with each of the possible 100 last two digits was determined and displayed graphically along with the observed/expected ratio based on a uniform distribution of digits. The significance of the peaks at multiples of 2, 5, 10, 20, 50 and 100 were determined using a Poisson regression model.

A statistical model was devised assuming that the underlying distribution of the last 2 digits was uniform with the number of each digit pair observed following a Poisson distribution. It was postulated there were subsets of observations which were then rounded to the nearest 100, 50, 20, 10, 5 or 2 which gives an expected distribution of
digits as a function of the proportion rounded to each level of accuracy. The proportions, based on each behaviour, were fitted to the observed distribution by direct maximisation of the likelihood. Alternative models with more or fewer rounding points were tested by fitting the appropriate models and testing using likelihood ratio tests. The statistical significance of specific rounding points was similarly tested by fitting models excluding the single points.

RESULTS

There were 9170 inborn infants admitted over the 20 year period. Of these 911 (10%) were < 1000g and are considered a particularly vulnerable group. The distribution of birth weights is shown in Figure 1.

Figure 1  Numbers of infants by weight

The observed number in each of the digit bands between 0 and 99 are shown in Figure 2 and show a marked excess of 11.5 times that expected having both last digits zero assuming all digits would have an equal likelihood of being measured. There was a striking excess of recorded birth weights at multiples of 10g (5-8 fold) with multiples of 20 and 50 being more common. Multiples of 5 are also more common than the remaining digits. The increased prevalence of multiples of 100 (P<0.0001), 50 (P=0.007), 20 (P<0.0001), 10 (P<0.0001), 5(P<0.0001), and 2 (P=0.0005) are all highly significant.
Figure 2 Distributions of recorded weight measurements for infants < 1000g and \( \geq 1000g \). The horizontal lines show the expected number if digits were randomly distributed.

Modelling the rounding for the whole dataset shows that 3.2\% of the time there was rounding to the nearest 100g and 46.7\% to the nearest 10g (Table 1).

Table 1
Modelled estimates of the degree of rounding, showing the proportions rounding to various digits.

<table>
<thead>
<tr>
<th>Rounding to nearest...</th>
<th>All data</th>
<th>&lt;1000g</th>
<th>( \geq 1000g )</th>
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<tr>
<td>( 100 )</td>
<td>3.2 (0.5)</td>
<td>0.0 (1.1)</td>
<td>3.7 (0.5)</td>
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<td>( 50 )</td>
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<tr>
<td>( 20 )</td>
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<td>( 10 )</td>
<td>46.7 (1.2)</td>
<td>15.7 (3.0)</td>
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</tr>
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<td>( 5 )</td>
<td>8.9 (0.6)</td>
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<td>( 2 )</td>
<td>2.1 (0.6)</td>
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<td>( 1 )</td>
<td>27.2 (-)</td>
<td>59.0 (-)</td>
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Analysis of infants < 1000g shows that there is a greater degree of accuracy with no detectable rounding to 100g level but 4.5% were rounded to 50g and 15.7% to 10g. 76.4% of the weights were accurate to the 5g level compared with 33.9% for infants ≥1000g birth weight (Table 1 and Figure 2).

4.5% of infants with birth weights between 500-999g were recorded to 50g accuracy which if we assume that this is due to rounding gives a maximum error of 5%. 3.7% of infants with birth weights between 1000-4500g had rounding to 100g giving a maximum percentage error of 5%.

The accuracy of weighing has increased steadily over the twenty year period (Figure 3) with for the smallest babies (<1000g) only 18% being recorded accurately (to 1g) in 1995 but this rising to 98% in 2013.

**DISCUSSION**

Neonatal intensive requires accuracy over drug dosing as small errors can potentially lead to significant adverse effects especially as they are a particularly vulnerable group with immature renal and hepatic function affecting drug handling. In view of the 10 fold weight difference between the smallest and largest newborn infants...
admitted to a NICU most infant drug doses are administered based on weight criteria. For infant safety it is important to ensure accuracy of calculated doses by using reliable weight measurements. Longstanding nursing protocol has required deduction of the weight of any extraneous item not able to be removed at the time of weighing after birth. It was surprising therefore to find that our data showed that for infants <1000g, 4.5% had their birth weight’s were rounded to the 50g level and 23.5% had rounding by 10g or more. For infants ≥1000g more of the weights were rounded with 61.1% rounded by 10g or more however the overall error level was nevertheless lower.

Many drug errors are due to poor manual calculation and there is evidence that the use of computerised prescribing can reduce errors significantly. All neonatal prescribing software packages rely on the accuracy of the measured weight. The need for precise birth weight measurements may not be fully appreciated by those undertaking weighing but the reason for digit bias leading to rounding or truncation of the absolute measured weight remains unclear.

The formal analysis of the data was based on the assumption that would be an equal number of birth weights in each digit weight group. Given that the range of weights (500-4500kg) is much greater than the putative digit preferences (0-100g) this is a reasonable approximation and only small biases in digit frequencies can be accounted for by the non-uniform distribution of birth weights, unlike the situation in other digit preference studies for example, age.

The difference between rounding or truncation in very small infants compared with the infants ≥1000g suggests that there is a modification in the nurses behavioural response to the measured weight and an understanding that rounding or truncation may influence the outcome to a greater degree in the very small infants (Figure 2). It is interesting to note that there was also a reduced incidence of digit bias in infants <1000g in the Canadian provincial study from 1981-91 compared to those ≥1000g. It was also considered that part of the reason for digit bias in the Canadian study was the use of analogue scales and that a move to digital scales would provide an automatic increase in accuracy. Our data has been derived solely from digital readout electronic scales and yet there is evidence of digit bias and significant rounding in a significant number of cases.

It is clear from the current study that for both groups of infants there has been an improvement in accuracy of recording the birth weight and that this has been greater for those <1000g compared with those ≥1000g. This is likely to be due to progressive improvements in nurse training and to some degree the greater involvement by nurses in dose checking and non medical prescribing over the last decade increasing their understanding of the importance of the accuracy of weight in drug dose calculation. The absence of any step change in this reflects a steady group behavioural change with increasing attention to accurate weight measurement.

Whilst it is clear that rounding or truncation occurs, our data shows that the likely maximum error in the recorded birth weight was 5% for infants ≥1000g. For infants <1000g, the maximum digit bias was 50g rather than 100g which again gives a maximum 5% recorded weight error. However the maximum error from rounding the
birth weights is within the required pharmacy standards for accuracy. Thus, this degree of error in birth weights, even for the smallest of infants, is tolerable.
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2. Safety in doses: medication safety incidents in the NHS: The fourth report from the Patient Safety Observatory

3. Reducing prescribing errors: Evidence Scan. The Health Foundation.


Acknowledgements
We would like to thank the many neonatal nurses who weighed the infants at birth and the junior doctors that entered the birth weights onto the electronic patient record.

Contributorship Statement
AE conceived of the study, extracted the data and wrote the paper
SR provided statistical analysis, reviewed and contributed to the final draft

Competing interests
None

Ethical approval
The use of the database data was approved by the NHS Research Ethics Committee (Haydock) 13/NW/0159

Funding
None

Data sharing
There are no additional data available
Article summary for

Rounding of birth weights in a Neonatal Intensive Care Unit over 20 years

Article Focus

- To determine whether rounding of birth weights or digit preference occurs with infants admitted to a regional Neonatal Intensive Care Unit over a 20 year period
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- There has been progressively more accurate weighing of infants over the 20 years with only 18% having birth weights recorded to the 1g level in 1995 compared with 98% in 2013. This change has been incremental and may reflect increased understanding of the importance of accuracy relating to prescribing.

Strengths and limitations

- The strengths of this study include 9170 birth weight measurements from a single Unit entered prospectively into a neonatal prescribing database.
- It is not possible to investigate the rationale for rounding and digit bias retrospectively.

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Data sharing

There is no additional data available
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Key words

Birth weights
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Digit preference

Word Count

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ABSTRACT

Objective

To determine the frequency of birth weight digit preference for infants admitted to a large Neonatal Intensive Care Unit (NICU); the scale of rounding and its dependence on birth weight; and time and the impact on prescribing accuracy.

Design

A consecutive cohort of birth weights extracted retrospectively from a single clinical database.

Setting and participants

Birth weights from 9170 inborn infants recorded on an electronic prescribing database admitted to a NICU over 20 years.

Statistical approach

Data are presented for the frequency of each of the possible pairs of final digits. A statistical model of digit preference assuming rounding is used to quantify the proportions rounding to specific accuracy levels. These proportions are compared between those <1000g and those above and over the 20 year time period.

Results

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The maximum birth weight error due to digit bias for all infants was 5%. There was clear evidence of an improvement in accuracy over the 20 years.

Conclusions

Digit bias in birth weights over 20 years in a tertiary NICU is highly significant at the 100, 50, 20, 10, 5 and 2 digit levels. There has been a substantial improvement in the accuracy of birth weight measurements over the twenty years. The likely maximum error due to birth weight digit bias is 5% and is within an acceptable tolerance for drug dosing even at very low birth weights.

(284 words)
ARTICLE SUMMARY

Article Focus

- To determine whether rounding of birth weights or digit preference occurs with infants admitted to a regional Neonatal Intensive Care Unit over a 20 year period and whether this varies for different weight groups.

- To explore the potential impact of rounding of birth weights on the accuracy of drug prescribing for different birth weight groups and whether changes in accuracy have occurred over time.

Key Messages

- There was rounding to the nearest 100g in 3.7% of infants greater or equal to 1000g birth weight and rounding to the lower level of 50g in 4.5% of infants <1000g. This level of rounding does not lead to drug dose errors outwith pharmacy accepted tolerances.

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Accurate birth weight measurements are essential for safe delivery of care to newborn preterm and term infants especially for prescriptions. Drug related events in the hospital setting are the highest cause of recorded errors both in the USA\(^1\) and in the UK National Health Service (NHS)\(^2\). The UK National Patient Safety report *Safety in doses: medication safety incidents in the NHS*\(^2\) reported on drug errors across all areas of medicine in 2007-8 and showed that 28.7% of reported drug errors in adult patient groups were due to the wrong dose, strength or frequency of medications.

There are a range of potential sources of drug error including documentation, calculation, preparation and administration errors\(^3,4\). Whilst in adult health care the dose administered may not be weight related, in neonatal intensive care almost all doses are prescribed based on the weight of the infant. Drugs are frequently prescribed shortly after birth with the birth weight used for calculation.

Drug errors in neonatal care are common with 3380 drug errors being reported to the UK National Patient Safety reporting and learning system (RLS) between April 2008-April 2009\(^5\). There were 507 neonatal drug errors due to gentamicin administration\(^5\). Whilst 96% were reported to cause no harm there was concern that there may be under reporting as long term renal impairment or hearing loss may not become evident until after discharge. Errors in birth weight measurement or recording may therefore lead to over or under treatment.

Newborn infants admitted to a tertiary NICU range in birth weight widely from under 500g to over 4500g. Many infants require an early prescription for drugs and infusions and the accuracy of the birth weight is critical for prevention of drug errors. Infants who weigh less than 1000g at birth require particularly accurate weighing and the scales used in the tertiary NICU weigh to the 1g level. To increase the accuracy of the birth weights, nursing protocol requires deduction of the weight in grams of any item that was unable to be removed prior to the measurement of the birth weight such as an endotracheal tube inserted as part of resuscitation. The definitive birth weight recorded should therefore be at the 1g level.

Infants with birth weights of less than 1000g are at greater risk of drug errors as the impact from rounding or truncating effects is much greater and they are a particularly vulnerable group. Small birth weight rounding differences could potentially increase the adverse drug effects.

Digit bias and rounding has been identified in several areas of medicine\(^6\) including in the measurement of birth weights\(^7\) and is a well recognised phenomenon. One previous study involving birth weight registrations from the 1980s included predominantly term infants weighed in a variety of institutions across Canada and recorded on a civil registration system. The potential for digit preference in this system by a number of individuals was increased.

It is unknown whether a similar digit preference with rounding or truncation of birth weights might occur for infants admitted to a neonatal intensive care unit where there is an expectation of accuracy of prescription and administration of drug and fluid medications. Over the last 20 years there have been national and local drives for
quality care with improved drug safety. It is unclear whether this has resulted in an identifiable behavioural change on the accuracy of weighing and whether there has been any alteration in the frequency of rounding or truncation of birth weight measurements.

Neonatal specific computerised prescribing systems are used in order to minimise drug calculation and prescription errors, but these rely on accurate birth weight measurements for the calculation of the dosages of drugs and infusions. The accuracy of these systems would be reduced if the recorded birth weights were significantly altered by digit bias.

The study therefore set out to answer whether birth weights from a single tertiary NICU showed evidence of digit bias and if so did this vary across different weight bands groups and over time. The impact on prescribed dose error of any identified digit bias was then explored.

Methods

All infants were weighed on admission to the NICU within 60 minutes of birth using fully calibrated Weylux 850BT/BMI class III baby scales, H Fereday & Sons, Harlow Essex, CM19 5QP, UK. These record a stable digital weight at a 1g level but have a defined absolute accuracy of ±5g. These scales, or their equivalent, have been used consistently over the last 20 years. The scales are regularly calibrated in line with the manufacturer’s standards.

Birth weights for all infants between 500 and 4500g admitted to the NICU between Jun 1993 and May 2013 were extracted from an electronic patient database utilised predominantly for accurate prescribing of intravenous drugs and fluids. This system has been used for all prescriptions on the NICU over the last 20 years. The electronic patient record database system was initiated in May 1993 specifically to minimise prescribing error risk. Infants born in other institutions and subsequently admitted were excluded.

A subset of infants < 1000g was also analysed. During that time 9170 inborn infants were admitted to the tertiary NICU and 100% of birth weights were extracted.

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Statistical analysis

Birth weights were recorded with a 1g resolution and the number of measurements with each of the possible 100 last two digits was determined and displayed graphically along with the observed/expected ratio based on a uniform distribution of digits. The significance of the peaks at multiples of 2, 5, 10, 20, 50 and 100 were determined using a Poisson regression model.
A statistical model was devised assuming that the underlying distribution of the last 2 digits was uniform with the number of each digit pair observed following a Poisson distribution. It was postulated there were subsets of observations which were then rounded to the nearest 100, 50, 20, 10, 5 or 2 which gives an expected distribution of digits as a function of the proportion rounded to each level of accuracy. The proportions, based on each behaviour, were fitted to the observed distribution by direct maximisation of the likelihood. Alternative models with more or fewer rounding points were tested by fitting the appropriate models and testing using likelihood ratio tests. The statistical significance of specific rounding points was similarly tested by fitting models excluding the single points.

RESULTS

There were 9170 inborn infants admitted over the 20 year period. Of these 911 (10%) were <1000g and are considered a particularly vulnerable group. The distribution of birth weights is shown in Figure 1.

Figure 1  Numbers of infants by weight

The observed number in each of the digit bands between 0 and 99 are shown in Figure 2 and show a marked excess of 11.5 times that expected having both last digits zero assuming all digits would have an equal likelihood of being measured. There was a striking excess of recorded birth weights at multiples of 10g (5-8 fold) with multiples of 20 and 50 being more common. Multiples of 5 are also more common than the remaining digits. The increased prevalence of multiples of 100 (P<0.0001), 50 (P=0.007), 20 (P<0.0001), 10 (P<0.0001), 5 (P<0.0001), and 2 (P=0.0005) are all highly significant.

Figure 2 Distributions of recorded weight measurements for infants < 1000g and ≥1000g. The horizontal lines show the expected number if digits were randomly distributed.

Modelling the rounding for the whole dataset shows that 3.2% of the time there was rounding to the nearest 100g and 46.7% to the nearest 10g (Table 1).
Table 1

Modelled estimates of the degree of rounding, showing the proportions rounding to various digits.

<table>
<thead>
<tr>
<th>Rounding to nearest...</th>
<th>All data</th>
<th>&lt;1000g</th>
<th>≥1000g</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% (SE)</td>
<td>% (SE)</td>
<td>% (SE)</td>
</tr>
<tr>
<td>100</td>
<td>3.2 (0.5)</td>
<td>0.0 (1.1)</td>
<td>3.7 (0.5)</td>
</tr>
<tr>
<td>50</td>
<td>1.5 (0.6)</td>
<td>4.5 (1.5)</td>
<td>1.0 (0.6)</td>
</tr>
<tr>
<td>20</td>
<td>10.4 (0.9)</td>
<td>3.3 (2.1)</td>
<td>11.1 (1.0)</td>
</tr>
<tr>
<td>10</td>
<td>46.7 (1.2)</td>
<td>15.7 (3.0)</td>
<td>50.2 (1.2)</td>
</tr>
<tr>
<td>5</td>
<td>8.9 (0.6)</td>
<td>9.0 (2.3)</td>
<td>8.8 (0.6)</td>
</tr>
<tr>
<td>2</td>
<td>2.1 (0.6)</td>
<td>8.4 (3.0)</td>
<td>1.5 (0.6)</td>
</tr>
<tr>
<td>1</td>
<td>27.2 (-)</td>
<td>59.0 (-)</td>
<td>23.6 (-)</td>
</tr>
</tbody>
</table>

Analysis of infants < 1000g shows that there is a greater degree of accuracy with no detectable rounding to 100g level but 4.5% were rounded to 50g and 15.7% to 10g. 76.4% of the weights were accurate to the 5g level compared with 33.9% for infants ≥1000g birth weight (Table 1 and Figure 2).

4.5% of infants with birth weights between 500-999g were recorded to 50g accuracy which if we assume that this is due to rounding gives a maximum error of 5%. 3.7% of infants with birth weights between 1000-4500g had rounding to 100g giving a maximum percentage error of 5%.

The accuracy of weighing has increased steadily over the twenty year period (Figure 3) with for the smallest babies (<1000g) only 18% being recorded accurately (to 1g) in 1995 but this rising to 98% in 2013.

Figure 3
Change in accuracy over time: Modelled proportions recorded exactly, rounded by a small amount (to nearest 2 or 5g) or a larger amount (to nearest 10,20,50 or 100g)

DISCUSSION

Neonatal intensive requires accuracy over drug dosing as small errors can potentially lead to significant adverse effects especially as they are a particularly vulnerable group with immature renal and hepatic function affecting drug handling. In view of the 10 fold weight difference between the smallest and largest newborn infants admitted to a NICU most infant drug doses are administered based on weight criteria. For infant safety it is important to ensure accuracy of calculated doses by using reliable weight measurements. Longstanding nursing protocol has required deduction of the weight of any extraneous item not able to be removed at the time of weighing after birth. It was surprising therefore to find that our data showed that for infants <1000g, 4.5% had their birth weight’s were rounded to the 50g level and 23.5% had
rounding by 10g or more. For infants ≥1000g more of the weights were rounded with 61.1% rounded by 10g or more however the overall error level was nevertheless lower. The data also showed that there was improvement in accuracy over time with a lower proportion showing digit bias.

Many drug errors are due to poor manual calculation and there is evidence that the use of computerised prescribing can reduce errors significantly. All neonatal prescribing software packages rely on the accuracy of the measured weight. The need for precise birth weight measurements may not be fully appreciated by those undertaking weighing but the reason for digit bias leading to rounding or truncation of the absolute measured weight remains unclear. The strength of this study is the large number of infants that were able to be analysed even at <1000g. The data was entered contemporaneously and was all used for prescribing throughout the study period so the importance of accurate data entry was clear. One weakness is that, due to the retrospective nature of the study, it is not possible to explore with staff the reasoning for rounding or truncating the measurements. There are, to our knowledge, no other studies of a similar population over a prolonged period.

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The difference between rounding and truncation in very small infants compared with the infants ≥1000g suggests that there is a modification in the nurses behavioural response to the measured weight and an understanding that rounding or truncation may influence the outcome to a greater degree in the very small infants (Figure 2). It is interesting to note that there was also a reduced incidence of digit bias in infants <1000g in the Canadian provincial study from 1981-91 compared to those ≥1000g. It was also considered that part of the reason for digit bias in the Canadian study was the use of analogue scales and that a move to digital scales would provide an automatic increase in accuracy. Our data has been derived solely from digital readout electronic scales and yet there is evidence of digit bias and significant rounding in a significant number of cases.

It is clear from the current study that for both groups of infants there has been an improvement in accuracy of recording the birth weight and that this has been greater for those <1000g compared with those ≥1000g. This is likely to be due to progressive improvements in nurse training and to some degree the greater involvement by nurses in dose checking and non-medical prescribing over the last decade increasing their understanding of the importance of the accuracy of weight in drug dose calculation. The absence of any step change in this reflects a steady group behavioural change with increasing attention to accurate weight measurement. There are no comparable data within the literature.

Whilst it is clear that rounding or truncation occurs, our data shows that the likely maximum error in the recorded birth weight was 5% for infants ≥1000g. For infants <1000g, the maximum digit bias was 50g rather than 100g which again gives a
maximum 5% recorded weight error. However the maximum error from rounding birth weights is within the published recommended rounding tolerances\textsuperscript{11}. Thus, this degree of error in birth weights, even for the smallest of infants, is tolerable.
Acknowledgements
We would like to thank the many neonatal nurses who weighed the infants at birth and the junior doctors that entered the birth weights onto the electronic patient record.

Contributorship Statement
AE conceived of the study, extracted the data and wrote the paper
SR provided statistical analysis, reviewed and contributed to the final draft

Competing interests
None

Ethical approval
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Funding
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Data sharing
There are no additional data available.
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3. Reducing prescribing errors: Evidence Scan. The Health Foundation.  


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Title Page

**Rounding of birth weights in a Neonatal Intensive Care Unit over 20 years**

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**Key words**

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Adverse drug events  
Drug safety  
Digit preference

**Word Count**

3213
ABSTRACT

Objective

To determine the frequency of birth weight digit preference for infants admitted to a large Neonatal Intensive Care Unit (NICU); the scale of rounding and its depending dependence on prematurity birth weight; variability over and time and the impact on prescribing accuracy.

Design

A consecutive cohort of birth birth weights extracted retrospectively from a single clinical database.

Setting and participants

Birth weights from 9170 inborn infants recorded on an electronic prescribing database admitted to a NICU over 20 years.

Statistical approach

Data are presented for the frequency of each of the possible pairs of final digits. A statistical model of digit preference assuming rounding is used to quantify the proportions rounding to specific accuracy levels. These proportions are compared between those <1000g and those above and over time the 20 year time period.

Results

From a population of 9170 infants admitted over 20 years, there was a highly statistically significant digit bias with an increased prevalence of multiples of 100 (P<0.0001), 50 (P=0.007), 20 (P<0.0001), 10 (P<0.0001), 5(P<0.0001), and 2 (P=0.0005). There was clear evidence of a reduced 100g digit bias for infants 500-1000g (0%) compared with those between 1000-4500g (3.7%).

The maximum birth weight error due to digit bias for all infants was 5%. There was clear evidence of an improvement in accuracy over the 20 years.

Conclusions

Digit bias in birth weights over 20 years in a tertiary NICU is highly significant at the 100, 50, 20, 10, 5 and 2 digit levels. There has been a substantial improvement in the accuracy of birth weight measurements over the twenty years. The likely maximum error due to birth weight digit bias is 5% and is within an acceptable tolerance for drug dosing even at very low birth weights.

(2847 words)
ARTICLE SUMMARY

Article Focus

- To determine whether rounding of birth weights or digit preference occurs with infants admitted to a regional Neonatal Intensive Care Unit over a 20 year period and whether this varies for different weight groups.

- To investigate-explore the potential impact of rounding of birth weights on the accuracy of drug prescribing for different birth weight groups and whether changes in accuracy have occurred over time.

Key Messages

- There was rounding to the nearest 100g in 3.7% of infants greater or equal to 1000g birth weight and rounding to the lower level of 50g in 4.5% of infants <1000g. This level of rounding does not lead to drug dose errors outwith pharmacy accepted tolerances.

- There has been progressively more accurate weighing of infants over the 20 years with only 18% having birth weights recorded to the 1g level in 1995 compared with 98% in 2013. This change has been incremental and may reflect increased understanding of the importance of accuracy relating to prescribing.

Strengths and limitations

- The strengths of this study include 9170 birth weight measurements from a single Unit entered prospectively into a neonatal prescribing database.

- It is not possible to investigate the rationale for rounding and digit bias retrospectively.
INTRODUCTION

Accurate birth weight measurements are essential for safe delivery of care to newborn preterm and term infants especially for prescriptions. Drug related events in the hospital setting are the highest cause of recorded errors both in the USA\textsuperscript{1} and in the UK National Health Service (NHS)\textsuperscript{2}. The UK National Patient Safety report Safety in doses: medication safety incidents in the NHS\textsuperscript{2} reported on drug errors across all areas of medicine in 2007-8 and showed that 28.7\% of reported drug errors in adult patient groups were due to the wrong dose, strength or frequency of medications.

There are a range of potential sources of drug error including documentation, calculation, preparation and administration errors\textsuperscript{3,4}. Whilst in adult health care the dose administered may not be weight related, in neonatal intensive care almost all doses are prescribed based on the weight of the infant. Drugs are frequently prescribed shortly after birth with the birth weight used for calculation.

Drug errors in neonatal care are common with 3380 drug errors being reported to the UK National Patient Safety reporting and learning system (RLS) between April 2008-April 2009\textsuperscript{5}. There were 507 neonatal drug errors due to gentamicin administration\textsuperscript{5}. Whilst 96\% were reported to cause no harm there was concern that there may be under reporting as long term renal impairment or hearing loss may not become evident until after discharge. Errors in birth weight measurement or recording may therefore lead to over or under treatment.

Newborn infants admitted to a tertiary NICU range in birth weight widely from under 500g to over 4500g. Many infants require an early prescription for drugs and infusions and the accuracy of the birth weight is critical for prevention of drug errors. Infants who weigh less than 1000g at birth require particularly accurate weighing and the scales used in the tertiary NICU weigh to the 1g level. To increase the accuracy of the birth weights, nursing protocol requires deduction of the weight in grams of any item that was unable to be removed prior to the measurement of the birth weight such as an endotracheal tube inserted as part of resuscitation. The definitive birth weight recorded should therefore be at the 1g level.

Infants with birth weights of less than 1000g are at greater risk of drug errors as the impact from rounding or truncating effects is much greater and they are a particularly vulnerable group. Small birth weight rounding differences could potentially increase the adverse drug effects.

Digit bias and rounding has been identified in several areas of medicine\textsuperscript{6} including in the measurement of birth weights\textsuperscript{7} and is a well recognised phenomenon. One previous study involving birth weight registrations from the 1980s included predominantly term infants weighed in a variety of institutions across Canada and recorded on a civil registration system. The potential for digit preference in this system by a number of individuals was increased.

It is unknown whether a similar digit preference with rounding or truncation of birth weights might occur for infants admitted to a neonatal intensive care unit where there is an expectation of accuracy of prescription and administration of drug and fluid medications. Over the last 20 years there have been national and local drives for
quality care with improved drug safety. It is unclear whether this has resulted in an identifiable behavioural change on the accuracy of weighing and whether there has been any alteration in the frequency of rounding or truncation of birth weight measurements.

Neonatal specific computerised prescribing systems are used in order to minimise drug calculation and prescription errors, but these rely on accurate birth weight measurements for the calculation of the dosages of drugs and infusions. The accuracy of these systems would be reduced if the recorded birth weights were significantly altered by digit bias.

The study therefore set out to answer whether birth weights from a single tertiary NICU showed evidence of digit bias and if so did this vary across different weight bands groups and over time. The impact on prescribed dose error of any identified digit bias was then explored.

Methods

All infants were weighed on admission to the NICU within 60 minutes of birth using fully calibrated Weylux 850BT/BMI class III baby scales, H Fereday & Sons, Harlow Essex, CM19 5QP, UK. These record a stable digital weight at a 1g level but have a defined absolute accuracy of ±5g. These scales, or their equivalent, have been used consistently over the last 20 years. The scales are regularly calibrated in line with the manufacturer's standards.

All birth weights for all infants between 500 and 4500g admitted to the NICU between Jun 1993 and May 2013 were extracted from were entered into an electronic patient database utilised predominantly for accurate prescribing of intravenous drugs and fluids. This system has been used for all prescriptions on the NICU over the last 20 years. The electronic patient record database system was initiated in May 1993 specifically to minimise prescribing error risk. Infants born in other institutions and subsequently admitted were excluded.

Birth weight data was extracted over a 20 year period to April 2013. A subset of infants < 1000g was also analysed. During that time 9170 inborn infants were admitted to the tertiary NICU and 100% of birth weights were extracted.

Data extracted from the database was analysed to determine the frequency of weight measurements at 1g intervals from 500-4500g. Weights outside this range were excluded as the numbers of infants above and below this weight range were very small. The use of data from the database was approved by the NHS Research Ethics Committee (Haydock) 13/NW/0159.

Statistical analysis

Birth weights were recorded with a 1g resolution and the number of measurements with each of the possible 100 last two digits was determined and displayed graphically along with the observed/expected ratio based on a uniform distribution of
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AE conceived of the study, extracted the data and wrote the paper
SR provided statistical analysis, reviewed and contributed to the final draft

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