Foot length, an accurate predictor of nasotracheal tube length in neonates

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Abstract

Background—Existing guidelines for optimal positioning of endotracheal tubes in neonates are based on scanty data and relate to measurements that are either non-linear or poorly reproducible in sick infants. Foot length can be measured simply and rapidly and is related to a number of external body measurements in neonates.

Objectives—To evaluate the relation of foot length to nasotracheal length in direct measurements at post mortem examinations, and then compare its clinical relevance with traditional weight based estimates in a randomised controlled trial.

Methods—The dimensions of the upper airway were measured at autopsy in 39 infants with median (range) postmenstrual age and birth weight of 32 (24–43) weeks and 1630 (640–3350) g. The regression equations with 95% prediction intervals were calculated to estimate the optimal nasotracheal length from foot length. In a randomised trial, 59 neonates were nasally intubated according to foot length and body weight based estimates to assess the achievement of “optimal” and “satisfactory” tube placements.

Results—In the direct measurements of the airway at autopsy, foot length was a better predictor of nasotracheal distances ($r^2 = 0.79$) than body weight, gestational age, and head circumference ($r^2 = 0.67$, 0.58, and 0.60 respectively). Measurement of foot length was easy and highly reproducible. In the randomised controlled trial, there were no significant differences between the foot length and body weight based estimates in the rates of optimal (44% v 56%) and satisfactory (83% v 72%) endotracheal tube placements.

Conclusions—Foot length is a reliable and reproducible predictor of nasotracheal tube length and is at least as accurate as the conventional weight based estimation. This method may be particularly valuable in sick unstable infants.

Keywords: foot length; endotracheal tube

Patients and methods

Overview

We measured the naris to midtracheal length at autopsy in 39 neonatal deaths and non-macerated still births, and investigated its relation to external body measurements (post mortem study). Foot length was the best variable for prediction of naris to midtracheal length. We then compared the accuracy and reliability of the estimation of ETT length from foot length against the body weight in a prospective randomised controlled trial.

Post Mortem Study

Data were collected on the dimensions of the upper airway and external body measurements at autopsy in 39 neonatal deaths and non-macerated fresh stillbirths; the parents had given consent for post mortem examination.
Foot length used to predict nasotracheal tube length

We excluded babies with fetal hydrops, congenital malformations, or chromosomal anomalies. Post mortem body weight, occipitofrontal head circumference (OFC), crown-rump length (CRL), shoulder-umbilicus length (SUL), sternal notch-umbilicus length (STUL), and foot length were measured before autopsy dissection.

The upper airway dimensions were measured with the trachea in situ. After removal of the sternum, the left lung and heart were displaced to the right. The carina was identified and incised. A firm graduated 3 mm catheter was then inserted and passed upwards through the trachea, larynx, pharynx, and nasal cavity until the tip of the tube appeared at the nostril. The nose-carina (NC) length was then measured using the graduations on the tube. The vocal cord-carina (VC) distance was measured directly after removal of the thoracic organs and opening of the posterior wall of the larynx and trachea. The naso-midtracheal length (NMTL) was calculated as NC – (0.5 × VC). All these lengths were measured in mm.

**Statistical analysis**

Linear regression analysis was used to investigate the relation of NMTL to potential predictors, including corrected gestational age, weight at autopsy, OFC, CRL, SUL, STUL, and foot length.

**CLINICAL STUDY**

**Variability in foot length measurement**

Interobserver variability in foot length measurement was assessed by having the same foot measured by 10 different nurses within six hours in seven infants. Intraobserver variability was evaluated by measurement of the same foot by the same observer on 10 occasions in four babies. The within subject standard deviations (σw) were estimated by one way analysis of variance, and the repeatability (the difference between two measurements for the same subject for 95% pairs of observations) was calculated as 2.77σw.

We designed a prospective randomised clinical study to assess the accuracy of the new foot length based prediction against the traditional weight based estimates. In view of the nature of the study, local research ethics committees did not stipulate informed parental consent while granting approval for the study.

**Study subjects**

The study subjects were all neonates needing nasotracheal intubation by the neonatal unit staff, including those intubated by the neonatal interhospital transport team. We excluded babies who were hydropic, dysmorphic, or intubated solely by the referring paediatricians.

**Study design**

Randomisation was performed in advance with computer generated codes, and assignments were inserted in sealed consecutively numbered opaque envelopes. The randomisation code was revealed when an eligible infant was considered for nasotracheal intubation. If nasotracheal intubation was unsuccessful, then the envelope was discarded.

In infants assigned to “weight”, the birth weight or the most recent weight (if greater than the birth weight) were used to determine the predicted nasotracheal tube length. For infants drawing “foot length”, this was defined as the distance from the tip of the heel to the tip of the great toe, and this length was measured using a plastic ruler. The foot length was rounded to the nearest 0.5 cm mark. The estimated ETT length was then read off the appropriate charts. For both groups, up to 0.5 cm was added to the predicted ETT length to allow for the fixation of the tube. The infant was then nasally intubated using the ETT appropriate to the infant’s weight and nasal size.

The nasotracheal tubes were fixed using the method described by Gregory. The equality of air entry was checked by auscultation, and radiological confirmation of the tip of the ETT was obtained as soon as possible. The chest radiograph after intubation was obtained with the infant lying directly on the roentgenogram plate with the head in the midline and the neck in the neutral position. The beam was centred on the sternal angle.

**Outcome measures**

The primary outcome measure was the achievement of “optimal midtracheal” ETT position defined as the tip of the tube at the body of the first thoracic vertebra. Secondary outcome measures were (a) achievement of “satisfactory” ETT position defined as the tip of the tube located within the trachea from between the medial ends of the clavicle to at least 1.5 cm above the carina, and (b) the need for reintubation. If the ETT position was considered unsatisfactory, needing adjustment or reintubation, this was considered a failure.

**Statistical analysis**

Based on previous data, we assumed that body weight based estimates will achieve optimal ETT placement in 60%. To enable a 30% difference in the achievement of optimal ETT placement with 80% power at the 5% significance level, we needed 32 infants in each group. Statistical analysis was performed with STATA 5.0 for Macintosh (Stata Corporation, College Station, Texas, USA). The basic characteristics of the two groups were compared by Mann-Whitney U test for continuous and χ² test for the categorical variables. The outcome data were compared by the two tailed χ² test with Fisher’s exact modification where necessary.

**Results**

**POST MORTEM STUDY**

The median (range) postmenstrual age and birth weight of the infants were 32 (24–43) weeks and 1630 (640–3530) g respectively. Ten infants were less than 30 weeks gestation, and seven weighed less than 1000 g. Table 1 shows the regression equations and residual SDs for each of the anthropometric measurements (weight, OFC, CRL, SUL, and foot length) and gestational age with NMTL. Foot length was the best single anthropometric measure for...
Table 1  Regression equations for naris to midtracheal distance in mm derived from gestational age (Gest), body weight (Wt), Occipitofrontal head circumference (OFC), crown-rump length (CRL), shoulder to umbilicus length (SUL), and foot length (FL)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Regression equation</th>
<th>Residual SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gest (weeks)</td>
<td>25.7 + 1.97 Gest</td>
<td>8.89</td>
</tr>
<tr>
<td>Wt (g)</td>
<td>64.3 + 0.01 Wt</td>
<td>7.80</td>
</tr>
<tr>
<td>OFC (mm)</td>
<td>16.7 + 0.26 OFC</td>
<td>8.67</td>
</tr>
<tr>
<td>CRL (mm)</td>
<td>2.20 + 0.30 CRL</td>
<td>6.56</td>
</tr>
<tr>
<td>SUL (mm)</td>
<td>23.4 + 0.49 SUL</td>
<td>8.39</td>
</tr>
<tr>
<td>FL (mm)</td>
<td>24.4 + 1.06 FL</td>
<td>6.42</td>
</tr>
</tbody>
</table>

Figure 1  Graph for prediction of optimal endotracheal tube (ETT) length (with 95% prediction intervals) for nasotracheal intubation based on measurement of foot length. (Add 0.5 cm to the measured ETT length if the tube is sutured to a tape.)

Discussion

Our direct measurements of the airway dimensions in post mortem examinations showed that foot length was the best predictor of naris-midtracheal length. In a subsequent randomised clinical trial against traditional body weight based estimates, foot length proved an accurate, reproducible, and easy to measure alternative predictor for estimating optimal nasotracheal tube length for neonatal intubation.

Table 2  Baseline characteristics of study infants

<table>
<thead>
<tr>
<th>Method of estimating nasotracheal tube length</th>
<th>Body weight (n=36)</th>
<th>Foot length (n=36)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsuccessful nasal intubation or confirmatory radiograph unavailable</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Infants successfully randomised with x ray confirmation of ETT position</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>Boys:girls</td>
<td>14:11</td>
<td>11:19</td>
</tr>
<tr>
<td>Birth weight (g)*</td>
<td>1210 (990–1770)</td>
<td>1467 (915–1790)</td>
</tr>
<tr>
<td>Gestational age (weeks)*</td>
<td>30 (27–36)</td>
<td>30.5 (27–32)</td>
</tr>
<tr>
<td>Age at intubation (days)*</td>
<td>1 (0–1)</td>
<td>0 (0–3)</td>
</tr>
<tr>
<td>Weight at intubation (g)*</td>
<td>1210 (990–1770)</td>
<td>1467 (915–1790)</td>
</tr>
<tr>
<td>Number of infants &lt;1000 g</td>
<td>9</td>
<td>8</td>
</tr>
</tbody>
</table>

*Median (interquartile range).

Each group (infants, although all these infants were successfully ventilated and none required reintubation. The baseline characteristics were similar for the two groups of randomised infants (table 2). Seventeen infants weighed less than 1000 g at intubation.

There were no statistically significant differences in the rates of achievement of optimal and satisfactory placements of the ETTs between the two groups (table 3). In three infants from the body weight group and two from the foot length group, the ETTs needed repositioning. Of 10 infants in whom the ETT tip was located at vertebral bodies C6–8, one was between, and nine were above, the medial ends of the clavicles. Of 32 infants in whom the ETT tip was between the first and second thoracic vertebrae, 19 were between the medial ends of the clavicles, with the remainder just below it. Of the five ETT tips at T4–5, two were in the low trachea (but safe) and three were at or below the carina.

Discussion

Our direct measurements of the airway dimensions in post mortem examinations showed that foot length was the best predictor of naris-midtracheal length. In a subsequent randomised clinical trial against traditional body weight based estimates, foot length proved an accurate, reproducible, and easy to measure alternative predictor for estimating optimal nasotracheal tube length for neonatal intubation.

STRENGTHS

Our hypothesis that foot length provides an accurate prediction of naris-midtracheal length in babies was confirmed by direct measurements of the airway at autopsy. We excluded dysmorphic infants from both studies as the tracheal length in such infants may be shorter than normal.10 We also precisely defined the optimum position for the tip of the ETT in the midtrachea as corresponding radiologically to the first thoracic vertebra.7 We included a pragmatic measure of satisfactory ETT length because babies who may not have an ideally placed ETT can still be successfully ventilated. Flexion of the head decreases the naris to carina distance (a risk for bronchial intubation) by up to 1 cm in infants under 1000 g and up to 1.6 cm in bigger infants.7 We therefore chose the distance of 1.5 cm above the carina as a safe position. Although a number of measurements other than body weight have been suggested for estimation of optimal depth of ETT placement...
Foot length was shown to be related positively to gestational age and length in fetuses, and various indices of body size in both large for dates and appropriately grown babies of all gestational ages between 26 and 42 weeks. In the latter study, there were particularly pronounced correlations of foot length with body weight (r = 0.95) and crown-heel length (r = 0.96) in premature babies. As tracheal length is a linear body measurement, it is not surprising that it correlates more closely with linear measures such as foot length or crown-rump length than body weight or head circumference.

Unlike the illuminated or magnetic ring embedded ETTs, use of foot length for prediction of ET length does require radiographic confirmation of the tube position, necessitating exposure to ionising radiation every time the location of the tube is called into question. Measurement of foot length, however, does not require any additional equipment apart from a widely available transparent plastic ruler, and can be performed easily and reproducibly even in very unstable babies. Our clinical trial confirms that foot length provides an alternative, reliable, and accurate method for determining the optimal ET length, particularly in sick unstable infants.

We wish to thank our medical and nursing colleagues and also Drs R Thiggarajan and R Wairay for their assistance with the study.


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