Nasotracheal intubation depth in paediatric patients

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Editor’s key points
- The depth of nasotracheal tube placement has traditionally been guided by formulae based on patient age, body weight, or both.
- These formulae are made for uncuffed tracheal tubes, but cuffed tracheal tubes are increasingly used in neonates and children.
- In this study, using different formulae to guide Microcuff paediatric endotracheal tube (PET) placement would have caused misplacement in most cases.
- The depth mark of the Microcuff PET should be used to determine proper tube placement.

Background. The aim of this study was to compare intubation depth using the Microcuff paediatric endotracheal tube (PET) placed with the intubation depth mark between the vocal cords with that of different published formulae/recommendations for nasotracheal intubation depth in children.

Methods. Children aged from birth to 10 yr undergoing elective surgery with nasotracheal intubation were included. Tracheal tubes were adjusted according to the intubation depth mark between the vocal cords using direct laryngoscopy. Nasal intubation depth was recorded and the distance ‘tube tip to carina’ was measured endoscopically. Based on the recorded nasal intubation depth and measured distance ‘tube tip to carina’, the position of tube tip and cuff was calculated according to six published formulae/recommendations.

Results. Seventy-six children were studied. For the Microcuff PET, the median tube tip advancement within the trachea was 52.9% (41.1–73.8%) of tracheal length. The shortest distance from the ‘tube tip to carina’ was 15 mm for a 3.5 mm internal diameter tube. If the six published formulae/recommendations had been used, this would have resulted in endobronchial tube placement in up to 9.1% of cases, and the tube tip would have been placed above the glottis in up to 2.6% of cases. The upper border of the cuff would have been placed in the subglottic area in up to 42.1% of cases and in a supraglottic position in up to 63.2% of cases.

Conclusions. This study indicates that nasal intubation with the intubation depth mark placed between the vocal cords was superior to formula-based nasotracheal tube positioning. The latter would result in a high rate of endobronchial intubations, excessively high cuff positions and even tracheal extubations.

Keywords: airway; children; complications, intubation nasotracheal; tracheal tube; intubation

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Tracheal intubation depth in children is critical because of their short trachea.1 Correct insertion depth of tracheal tubes is essential to avoid accidental endobronchial intubation, irritation of the carina, misplacement of the cuff between the vocal cords, and accidental tracheal extubation. Moreover, there is an increased risk of tube malpositioning, mainly for neonates, infants, and small children, during head–neck movement.2–5 Nasotracheal intubation is considered to allow more stable tube placement within the trachea.6

In the past, several formulae and recommendations for adjusting nasotracheal intubation depth at the nose have been published (Tables 1 and 2). In recent years, cuffed tracheal tubes have become standard in paediatric anaesthesia.7 However, there are no data so far with regard to proper positioning of tracheal tube tip and cuff, when using common formulae for nasotracheal intubation depth in cuffed paediatric tracheal tubes.

The aim of this study was to compare intubation depth using the Microcuff paediatric endotracheal tube (PET) placed with the intubation depth mark between the vocal cords with different published formulae/recommendations for nasotracheal intubation depth in children.

Methods

After obtaining Hospital Ethics Committee approval in 2003 (STV 23-03) and informed parental consent, a prospective study including paediatric patients aged between birth and
10 yr was conducted from 2003 until 2009. Patients included were undergoing elective surgery or dental procedures requiring general anaesthesia and nasotracheal intubation. Exclusion criteria were known or suspected airway anomalies and difficult tracheal intubation. Premedication and induction of anaesthesia (inhalation or i.v.) depended on the patient’s medical condition and preference. A non-depolarizing neuromuscular blocking agent was administered and anaesthesia was maintained with sevoflurane in oxygen/nitrous oxide.

The patient’s trachea was intubated using the Microcuff PET (Microcuff GmbH, Weinheim, Germany) and tracheal tube size was selected according to the manufacturer’s instructions (Table 3). Nasotracheal intubation was performed in all patients and the glottic intubation mark was placed between the vocal cords using direct laryngoscopy (depth mark-based tracheal tube placement). Subsequently, intubation depth at the base of the nose was recorded and the tube was secured by tapes. With the patient supine and the head in a neutral position, the distance from the tube tip to the carina was measured endoscopically using the drawback technique.14

### Table 1: Formulae/recommendations for nasotracheal intubation depth

<table>
<thead>
<tr>
<th>No.</th>
<th>Formula/recommendation age (yr), weight (kg)</th>
<th>Source, author, year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14 + (age/2)</td>
<td>Paediatric Anaesthesia, Davenport, 3rd Edn, 1980</td>
</tr>
<tr>
<td>2</td>
<td>&lt;4 yr</td>
<td>Antona and colleagues, 2002</td>
</tr>
<tr>
<td>3</td>
<td>&gt; 3 kg</td>
<td>Yates and colleagues, 1987</td>
</tr>
<tr>
<td>4</td>
<td>(a) &lt;1 yr: 9 + (weight/2)</td>
<td>Lau and colleagues, 2006</td>
</tr>
<tr>
<td>5</td>
<td>Recommendation (see Table 2)</td>
<td>Manual of Pediatric Anesthesia, Steward, 5th Edn, 2001</td>
</tr>
<tr>
<td>6</td>
<td>Recommendation</td>
<td>Kim and colleagues, 2003</td>
</tr>
</tbody>
</table>

### Table 2: Nasal intubation depth according to recommendation 5

<table>
<thead>
<tr>
<th>Approximate age of patient (yr)</th>
<th>Nasal intubation length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn</td>
<td>14</td>
</tr>
<tr>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>6</td>
<td>19</td>
</tr>
<tr>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td>10</td>
<td>22</td>
</tr>
</tbody>
</table>

### Table 3: Age-based tube size selection of the Microcuff PET (2004)

<table>
<thead>
<tr>
<th>ID (mm)</th>
<th>Age (yr)</th>
<th>Distance depth mark to tube tip (mm)</th>
<th>Distance depth mark to upper cuff border (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>Newborn</td>
<td>24</td>
<td>9</td>
</tr>
<tr>
<td>3.5</td>
<td>1 to &lt;2</td>
<td>27</td>
<td>10</td>
</tr>
<tr>
<td>4.0</td>
<td>2 to &lt;4</td>
<td>30</td>
<td>12</td>
</tr>
<tr>
<td>4.5</td>
<td>4 to &lt;6</td>
<td>34</td>
<td>12</td>
</tr>
<tr>
<td>5.0</td>
<td>6 to &lt;8</td>
<td>39</td>
<td>16</td>
</tr>
<tr>
<td>5.5</td>
<td>8 to &lt;10</td>
<td>45</td>
<td>16</td>
</tr>
</tbody>
</table>

### Data analysis

Tracheal length (vocal cords to carina distance) was calculated by adding the ‘intubation depth mark to tube tip distance’ to the measured distance from the ‘tube tip to carina’. The percentage of tube tip advancement within the trachea was then calculated.

The position of the tracheal tube tip related to the carina was calculated when the tracheal tube would have been inserted according to one of the formulae (1–4) and recommendation (5) for nasotracheal intubation depth. Tube tip position with formula 3 [formula including internal diameter (ID)] was also calculated for age-related uncuffed tubes (ID + 0.5 mm ID), resulting in formula 3b.

The number of tracheal tubes placed endobronchially (below the carina) and the number of tracheal tubes at risk for tracheal extubation after 30° head–neck flexion (maximum downward tube movement (mm) = [(0.83 × age (yr)) + 9.3]) were calculated.15 Similarly, the number of tracheal tube tips placed in the supraglottic area and the number of tracheal tubes at risk for tracheal extubation after 30° head–neck extension [maximum upward tube movement (mm) = 0.71 × age (yr) + 9.9] were calculated.15

Under the assumption that the upper cuff border of the Microcuff PET is placed just below the level of the cricoid cartilage if inserted according to the intubation depth mark, the resulting position of the upper cuff border of the Microcuff PET related to the cricoid ring was calculated with each of the four formulae and two recommendations.16 The number of tubes with cuff position in the subglottic and supraglottic area were calculated. The subglottic area was derived from previous anatomical data of the vocal cord to cricoid ring, the distance being 9 mm in a newborn and 14 mm in an 11-yr-old child.17, 18

Data are presented as mean (sd) or median (range) as appropriate.

### Results

In total, 76 paediatric patients (40 females, 36 males) aged from 3 weeks to 10 yr (mean 5.0 yr) were included in the study. Depth mark-based nasotracheal intubation resulted in a minimum tube tip to carina distance of 15 mm in a 1.9-yr-old infant to a maximum of 56 mm in a 7.4-yr-old girl. The mean tube tip advancement into the trachea was 52.8%
**Fig 1** Tube tip to carina distance with depth mark-based tracheal tube placement (filled diamond) and recalculated with each of the four formulae and two recommendations (open diamond). Shaded areas indicate tube tip at risk for endobronchial intubation after 30° head–neck flexion and endobronchially placed tubes.
Fig 2  Position of tube upper cuff border (thick line) with nasotracheal intubation depth calculated with each of the four formulae and two recommendations. The position of the upper cuff border of the Microcuff tracheal tube (not shown in the figure) is placed directly below the cricoid, as given by the anatomically based design of the Microcuff tracheal tube. Shaded areas indicate the upper cuff border located within the subglottic area and in the supraglottic area.
### Table 4
Number of tracheal tube tips and tube cuffs placed in an abnormal and critical position when used with the four formulae or two recommendations for nasotracheal tube positioning.

Calculation 3b: modified if uncuffed tubes (+ 0.5 mm ID) had been used in this study

<table>
<thead>
<tr>
<th>No.</th>
<th>Formula/recommendation (length in cm) age (yr), weight (kg)</th>
<th>No. of tubes at risk for endobronchial intubation</th>
<th>No. of tubes placed endobronchial</th>
<th>No. of cuffs in the subglottic space</th>
<th>No. of cuffs placed supraglottically</th>
<th>No. of tube tips at risk for tracheal extubation</th>
<th>No. of tube tips placed supraglottically</th>
<th>No. of tube tips placed in correct position</th>
<th>No. of cuffs placed in correct position</th>
<th>Median (range) tube tip advancement within the trachea in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14+(age/2)</td>
<td>3/76 (3.9%)</td>
<td>2/76 (2.6%)</td>
<td>32/76 (42.1%)</td>
<td>20/76 (26.3%)</td>
<td>1/76 (1.3%)</td>
<td>0</td>
<td>0</td>
<td>70/76 (92.1%)</td>
<td>47.0% (16.1–129.3%)</td>
</tr>
<tr>
<td>2</td>
<td>&lt;4 yr; 10.5+(weight/2)</td>
<td>11/33 (33.3%)</td>
<td>3/33 (9.1%)</td>
<td>1/33 (3.0%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>19/33 (57.6%)</td>
<td>78.7% (50.9–111.1%)</td>
</tr>
<tr>
<td>3a</td>
<td>&gt;3 kg L=(3×ID)+2</td>
<td>1/76 (1.3%)</td>
<td>0</td>
<td>16/76 (21.1%)</td>
<td>48/76 (63.2%)</td>
<td>24/76 (31.6%)</td>
<td>2/76 (2.6%)</td>
<td>49/76 (64.5%)</td>
<td>51.3%</td>
<td>28.4 (–12.7–82.0%)</td>
</tr>
<tr>
<td>3b</td>
<td>&gt;3 kg L=(3×(ID+0.5))+2</td>
<td>4/76 (5.3%)</td>
<td>1/76 (1.3%)</td>
<td>27/76 (35.5%)</td>
<td>8/76 (10.5%)</td>
<td>1/76 (1.3%)</td>
<td>0</td>
<td>70/76 (92.1%)</td>
<td>51.0%</td>
<td>51.3% (11.1–106.6%)</td>
</tr>
<tr>
<td>4a</td>
<td>&lt;1 yr: 9+(weight/2)</td>
<td>0</td>
<td>0</td>
<td>2/7 (28.6%)</td>
<td>1/7 (14.3%)</td>
<td>0</td>
<td>0</td>
<td>7/7 (100%)</td>
<td>51.0%</td>
<td>51.3% (26.0–71.4%)</td>
</tr>
<tr>
<td>4b</td>
<td>&gt;1 yr: 15+(age/2)</td>
<td>10/69 (14.5%)</td>
<td>0</td>
<td>17/69 (24.6%)</td>
<td>4/69 (5.8%)</td>
<td>0</td>
<td>0</td>
<td>59/69 (85.5%)</td>
<td>60.5%</td>
<td>60.5% (26.7–99.7%)</td>
</tr>
<tr>
<td>5</td>
<td>Recommendation (age-based list)</td>
<td>9/76 (11.8%)</td>
<td>4/76 (5.3%)</td>
<td>13/76 (17.1%)</td>
<td>2/76 (2.6%)</td>
<td>0</td>
<td>0</td>
<td>63/76 (82.9%)</td>
<td>60.7%</td>
<td>60.7% (27.0–128.6%)</td>
</tr>
<tr>
<td>6</td>
<td>Recommendation 2 cm above the carina</td>
<td>0</td>
<td>0</td>
<td>7/76 (9.2%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>76/76 (100%)</td>
<td>60.0%</td>
<td>69.0% (52.4–79.0%)</td>
</tr>
<tr>
<td>7</td>
<td>Depth mark-based intubation</td>
<td>0/76</td>
<td>0/76</td>
<td>0/76</td>
<td>0/76</td>
<td>0/76</td>
<td>0/76</td>
<td>0/76</td>
<td>0/76</td>
<td>52.9% (41.1–73.8%)</td>
</tr>
</tbody>
</table>
(6.4) of the tracheal length, with a minimum of 41.1% and a maximum of 73.8%. Using depth mark-based intubation, none of the tube tips was at risk for endobronchial intubation after potential 30° head–neck flexion (Fig. 1).

The measured tube tip positions for the depth mark-based intubation and the calculated tube tip positions are shown and compared in Figure 1. The position of the upper cuff border of a Microcuff PET when intubated according to the depth mark or according to the formulae/recommendations is shown and compared in Figure 2. Table 4 explicitly lists the number of tracheal tube tips and cuffs placed in an undesirable or critical position using one of the four formulae and two recommendations.

Discussion
This study compared depth mark-based nasotracheal tube placement with the Microcuff PET with standard formulae and recommendations for adjusting nasotracheal intubation depth with regard to safe tracheal tube tip and cuff placement. The main finding was that depth mark-based tracheal intubation allowed safe positioning of the tracheal tubes in all patients. However, standard formulae/recommendations used for adjusting nasotracheal intubation depth resulted in a high number of misplaced or critical tracheal tube tip and cuff positions with the exception of recommendation 6, which advises using a constant, clinically determined distance ‘tube tip to carina’ of 2 cm in paediatric patients.13

Standard formulae/recommendations for nasotracheal intubation depth have been introduced for adjusting tracheal tubes if depth marks are missing or not visible at direct laryngoscopy and providing a quick guide for appropriate tracheal tube positioning. As shown in this study, all formulae and recommendation 5 resulted in tubes that risked either accidental endobronchial intubation, especially with assumed head–neck flexion, or extubation, especially with head–neck extension, respectively. These results apply equally to cuffed and uncuffed tracheal tubes. Neither were the formulae and recommendations useful for proper cuff position, even with correction of ID for cuffed tracheal tubes in formula 3b. Surprisingly, recommendation 6 revealed safe tracheal tube positioning and only a very low rate of tube cuffs reaching the subglottic area, by advising placement of all tracheal tubes 2 cm above the carina. However, using auscultation of breath sounds or inspiratory pressure decrease during drawback of a tube placed endobronchially as a method for tube positioning 2 cm above the carina does not appear to be very practicable in clinical practice and can be interfered with by a Murphy eye, still present in some tube brands.13 Tube positioning 2 cm above the carina would be helpful if fibreoptic nasotracheal intubation is performed in children.

Occasionally, depth mark-based tracheal tube placement is criticized as being imprecise because of head-extension (if at all) during direct laryngoscopy which leads to caudal displacement of the tracheal tube when the head is again placed in a neutral position. However, as shown in this study by endoscopy, all tracheal tube tips were placed within a safe tracheal range.

There are only limited data and no follow-up clinical studies confirming safety and appropriateness of published formulae.13 19–21 All of these formulae (1–4) and recommendations (5/6) were developed for uncuffed tracheal tubes and were only focused on tube tip position. The present work is the first study investigating cuff position with these formulae and recommendations, clearly demonstrating that these tube positioning techniques do not guarantee proper cuff position below the cricoid. Subglottic cuff placement may cause vocal cord palsy by compressing the recurrent laryngeal nerve.20 Supraglottic cuff position will lead to cranial movement of the tracheal tube with cuff inflation and may result in accidental extubation. Other control techniques of tube tip or cuff position (palpation, fibreoptic, ultrasound, lighted stylet, X-ray) do not reliably prevent such complications.21–28

The clinical implication of the present study is that for the Microcuff PET, depth mark-based intubation is reliable, whereas the use of standard formulae/recommendations for nasal intubation depth is not helpful and may lead to dangerous tube tip or cuff position. The fact that formulae and recommendations for nasotracheal intubation depth are not sufficiently reliable is not surprising, since craniofacial dimensions and tracheal lengths vary among children with the same age or weight, whose tracheas will be intubated with the same tube size. Thus, similar to orotracheal intubation, placing a nasotracheal tube relying on depth marks is superior to formula-based tube placement.29 Accordingly, tracheal tube cuffs can only be placed properly using an intubation depth mark which is situated at an anatomically correct distance from the upper cuff border.16

A limitation to our study is the number of patients included. However, only patients from birth to 10 yr were studied, so the number of patients is comparable with that of other studies.13 11 Our results are only representative for the Microcuff PET that was used in this study for two reasons: first, as known from prior investigations, other paediatric cuffed tracheal tube brands have longer, higher, or both tube cuffs. This would have resulted in an even higher incidence of subglottic and supraglottic cuff position.13 Secondly, many cuffed paediatric tracheal tubes have no, misleading, or incorrectly placed intubation depth marks.19 30

In conclusion, depth mark-based nasotracheal intubation is superior to formula and recommendation-based nasotracheal tube placement. The latter resulted in a high rate of endobronchial intubations, excessively high cuff positions and even tracheal extubations.

Authors’ contributions
M.K.: calculations, graphs, and writing of the manuscript. A.D.: patient recruitment. A.R.S.: calculations and writing of the manuscript. A.G.: measurements. M.W.: ethical protocol, study protocol, measurements, and writing of the manuscript.

Declaration of interest
None declared.
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