Estimation of the nares-to-epiglottis distance and the nares-to-vocal cords distance in young children

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Editor’s key points

• This study addresses the calculation of correct size of tracheal tubes for use in children.
• In 211 children, the nares-to-epiglottis and nares-to-vocal cord distances were measured.
• Importantly, these distances could be predicted by patient characteristics and some external measurements.
• This study adds another method to aid the correct size calculation of tracheal tubes for use in children.

Background. Estimation of the nares-to-epiglottis and nares-to-vocal cords distances would facilitate the selection of properly sized nasopharyngeal airways and appropriate positioning of a fiberoptic bronchoscope in young children. The purposes of this study were to measure the nares-to-epiglottis and nares-to-vocal cords distances and to create an algorithm to predict these distances based on anatomical landmarks and paediatric characteristic data.

Methods. Two hundred and eleven children, aged 1–10 yr, undergoing elective surgery were investigated. After induction of general anaesthesia, the distances from the nares to the epiglottis/vocal cords were measured using a nasogastric tube. After intubation, the distances from the lateral border of the nose to the ipsilateral mandible angle (nares-to-mandible distance) and the tragus of the ear (nares-to-tragus distance) were measured using a tape measure.

Results. The nares-to-epiglottis and nares-to-vocal cords distances were significantly correlated with the age, weight, height, and external measurements (P < 0.001). By stepwise multiple linear regression analysis, formulas were obtained for the nares-to-epiglottis distance (cm) = 2.606 + 0.058 × height (cm) + 0.231 × the nares-to-mandible distance (cm) – 0.304 (gender) (r² = 0.754) and for the nares-to-vocal cords distance (cm) = 4.947 + 0.06 × height (cm) + 0.228 × nares-to-mandible distance (cm) – 0.283 (gender) (r² = 0.803).

Conclusions. The nares-to-epiglottis and nares-to-vocal cords distances can be predicted using the height and the nares-to-mandible distance in young children.

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Keywords: airway anatomy; airway management; fiberoptic intubation; nasopharyngeal airway; nasotracheal intubation; paediatric anaesthesia

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A nasopharyngeal airway is a useful device to relieve upper airway obstruction in paediatric airway management. The insertion depth of the airway is critical because improper positioning of the nasopharyngeal airway tip may not maintain airway patency and can even lead to complete respiratory obstruction. The ideal position of the nasopharyngeal airway is considered to be that the distal tip should protrude beyond the pharyngeal end of the soft palate but should not pass more distally than the epiglottis. Therefore, prediction of the distance from the nostril to the epiglottis (NE distance) could make it easier to determine the proper length of the nasopharyngeal airway used in children.

Nasotracheal intubation is preferred for surgical procedures performed in the oral cavity, for respiratory care after surgery, and for fiberoptic intubation in difficult airways. In young children, the depth from the nostril to the vocal cords is important as the tip of a fibrescope or nasotracheal tube can easily protrude over the vocal cords. Knowing the distance from the nares to the vocal cords (NV distance) may be helpful for appropriate positioning of the fiberoptic bronchoscope or nasotracheal tube tip during nasal intubation.

The purposes of this study were to measure the NE and NV distances in young children and to examine the relationships of these distances with patient characteristics and external facial measurements.
Methods

After institutional review board approval and informed written consent were obtained from the parents, children, aged 1–10 yr, undergoing elective surgery under general anaesthesia were enrolled in this study. Patients with an abnormal airway, facial deformity, obesity (>50% above the ideal body weight), congenital heart disease, prematurity or a bleeding tendency, or those at risk for aspiration were excluded. The patient gender, age, height, and weight were recorded.

When the patients arrived in the operating theatre, standard monitors were applied, including pulse oximetry, ECG, and non-invasive arterial pressure. Anaesthesia was induced by i.v. thiopental 5 mg kg\(^{-1}\) or sevoflurane 8% and rocuronium 0.8 mg kg\(^{-1}\), and the patients were ventilated with oxygen 5 litre min\(^{-1}\) and sevoflurane. After adequate mask ventilation and confirming muscle relaxation, a nasogastric tube well lubricated with lidocaine jelly (Lidocaine HCl Jelly 2%, Arlico Pharm Co., Ltd, Seoul, Republic of Korea) was inserted into the right nostril. If the nasogastric tube could not be gently inserted, insertion of the left side was attempted. When gentle insertion of the nasogastric tube was not possible on either side, the patient was excluded from the study. After insertion of the nasogastric tube into the nostril, direct laryngoscopy was used to check the position of the nasogastric tube as it was advanced under direct vision using a Magill forceps. The nasogastric tube was marked twice: when the tip of the tube was positioned at the level of the epiglottis and when it was just between the vocal cords (Fig. 1). The laryngoscope was advanced with minimal force and there was no displacement of the epiglottis and little movement of the head during marking of the level of the epiglottis tip on the nasogastric tube. However, moderate head extension was needed during the marking of the position of the vocal cords. The nasogastric tube was then removed and orotracheal intubation was performed using direct laryngoscopy.

After tracheal intubation, the tracheal tube was taped to the right corner of the patient’s mouth, and the distances from the left lateral border of the nose to the ipsilateral mandible angle (NM distance) and to the tragus of the ear (NT distance) were measured using a tape measure. All measurements were performed by a single investigator.

All variables are expressed as median (inter-quartile range (IQR) (range)) or number. The normality of the data distribution was assessed using the Kolmogorov–Smirnov test. To compare numerical variables between the groups, the Mann–Whitney U-test was performed. Correlations between each of the NE and NV distances and other variables were assessed using the Spearman correlation analysis. Multiple linear regression with forward stepwise selection was used to develop a model for the NE and NV distances using other measured variables with P-values of <0.10 in the simple regression. All statistical data were analysed using SPSS 12.0 (SPSS Inc., Chicago, IL, USA). A P-value of <0.05 was considered statistically significant.

Results

Two hundred and eleven children were enrolled in this study. Patient characteristics and details of the measured data are presented in Table 1. Table 2 shows the measured NM, NE, and NV distances according to the patient age group. The NE distance significantly correlated with patient age (r = 0.844, P < 0.001), weight (r = 0.849, P < 0.001), height (r = 0.864, P < 0.001), the NM distance (r = 0.738, P < 0.001), and the NT distance (r = 0.742, P < 0.001). The NV distance significantly correlated with patient age (r = 0.886, P < 0.001), weight (r = 0.892, P < 0.001), height (r = 0.896, P < 0.001), the NM distance (r = 0.762, P < 0.001), and the NT distance (r = 0.763, P < 0.001). Using stepwise multiple-linear regression, the following formulas best predicted the NE and NV distances:

- NE distance = 2.606 + 0.058 × height + 0.231 × NM distance − 0.304 × (gender) (r\(^2\) = 0.754, P < 0.001)
- NV distance = 4.947 + 0.06 × height + 0.228 × NM distance − 0.283 × (gender) (r\(^2\) = 0.803, P < 0.001)

| Table 1 Patient characteristic data and external patient measurements. Values represent the median [IQR (range)] or number. NE distance, nares-to-epiglottis distance; NV distance, nares-to-vocal cords distance; NT distance, nares-to-tragus distance; NM distance, nares-to-mandible distance |
|------------------|------------------|------------------|------------------|------------------|------------------|
| Age (months)     | 65.0 [56 (12–131)] |
| Weight (kg)      | 19.5 [12.3 (6.6–56.5)] |
| Height (cm)      | 113.0 [32 (73–153)] |
| NE distance (cm) | 11.3 [2.3 (8.0–14.4)] |
| NV distance (cm) | 14.0 [2.0 (9.5–17.3)] |
| NT distance (cm) | 10.5 [1.0 (9–13)] |
| NM distance (cm) | 9.5 [1.0 (7.8–12.3)] |
| Sex ratio (M/F)  | 118:93            |

Fig 1 Schematic diagram for measurement of the nares-to-epiglottis distance (a) and the nares-to-vocal cords distance (a).
with distances and height being presented in centimetres, and gender as a binary factor (0, boy; 1, girl).

Figure 2 shows the relationship between the measured and predicted NE and NV distances according to this formula. Patient age had no effect on the difference between the measured and predicted NE ($r = 0.0078$, $P = 0.9099$) or NV distance ($r = 0.0309$, $P = 0.9897$).

We compared the measured NE distance with the NM and NT distances because these external facial distances have been commonly used for determining the size of the nasopharyngeal airways in children.\(^6\)\(^7\) A Bland–Altman plot demonstrated a large variation in the difference between each of these two values and the NE distance (Fig. 3). The mean difference of the NM distance was −1.64 cm [95% confidence interval (CI) −1.55, −1.77], and the width of the 95% limits of agreement was 3.94 cm. The mean difference of the NT distance was −0.80 cm (95% CI −0.66, −0.93), and the width of the 95% limits of agreement was 3.99 cm. There was a significant correlation between patient age and the difference between each of the NM and NT distances and the NE distance ($r = 0.5097$, $P < 0.0001$ and $r = 0.5648$, $P < 0.0001$, respectively).

None of the patients showed desaturation or laryngeal injury during the determination of the NE and NV distances, and no patient developed a laryngospasm or bronchospasm during the study protocol.

**Discussion**

This study showed that there is a significant correlation between the NE/NV distance and patient age, weight, height, the NM distance, and the NT distance. The NE and NV distances can be predicted from the patient height and NM distance, with the lengths in girls being ~0.3 cm shorter than those of boys. We also found that the NM and NT distances, commonly used for determining the size of

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**Table 2** Measured nares-to-mandible distance, nares-to-epiglottis distance and nares-to-vocal cords distance according to age. Values are median [IQR (range)]

<table>
<thead>
<tr>
<th>Years</th>
<th>Months</th>
<th>n</th>
<th>Nares-to-mandible distance (cm)</th>
<th>Nares-to-epiglottis distance (cm)</th>
<th>Nares-to-vocal cords distance (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18.5 [4.8 (12–23)]</td>
<td>22</td>
<td>8.5 [0.9 (8.0–9.5)]</td>
<td>9.0 [0.7 (8.2–9.8)]</td>
<td>11.8 [0.8 (11.2–12.0)]</td>
</tr>
<tr>
<td>2</td>
<td>30 [3.5 (25–35)]</td>
<td>23</td>
<td>8.5 [0.6 (7.8–9.7)]</td>
<td>9.8 [0.8 (8.0–11.5)]</td>
<td>12.2 [0.8 (11.8–12.6)]</td>
</tr>
<tr>
<td>3</td>
<td>41 [5.0 (36–47)]</td>
<td>21</td>
<td>9.0 [0.5 (8.5–10.0)]</td>
<td>10.2 [1.2 (9.3–11.6)]</td>
<td>12.8 [0.7 (12.5–13.2)]</td>
</tr>
<tr>
<td>4</td>
<td>54 [6.0 (47–59)]</td>
<td>24</td>
<td>9.5 [0.7 (8.5–10.5)]</td>
<td>11.1 [0.8 (9.5–12.3)]</td>
<td>13.7 [0.8 (13.2–14.0)]</td>
</tr>
<tr>
<td>5</td>
<td>64 [5.0 (60–70)]</td>
<td>24</td>
<td>9.5 [1.0 (8.5–10.5)]</td>
<td>11.4 [0.9 (10.5–12.7)]</td>
<td>14.0 [0.5 (13.7–14.2)]</td>
</tr>
<tr>
<td>6</td>
<td>77.5 [6.0 (72–82)]</td>
<td>24</td>
<td>9.8 [0.5 (9.0–10.7)]</td>
<td>11.5 [0.8 (10.6–13.7)]</td>
<td>14.2 [0.9 (13.6–14.5)]</td>
</tr>
<tr>
<td>7</td>
<td>90.5 [5.5 (84–95)]</td>
<td>20</td>
<td>10.2 [0.9 (9.5–11.2)]</td>
<td>12.3 [1.1 (11.0–14.3)]</td>
<td>14.5 [0.7 (14.2–14.9)]</td>
</tr>
<tr>
<td>8</td>
<td>102 [5.5 (97–107)]</td>
<td>16</td>
<td>10.5 [0.6 (9.0–12.0)]</td>
<td>12.7 [1.4 (11.4–14.3)]</td>
<td>15.8 [0.8 (15.0–15.8)]</td>
</tr>
<tr>
<td>9</td>
<td>112 [4.0 (108–117)]</td>
<td>21</td>
<td>10.0 [0.5 (9.3–11.0)]</td>
<td>12.5 [1.4 (11.0–14.0)]</td>
<td>15.0 [1.2 (14.3–15.5)]</td>
</tr>
<tr>
<td>10</td>
<td>125.5 [6.3 (120–131)]</td>
<td>16</td>
<td>10.5 [1.0 (9.7–12.3)]</td>
<td>12.5 [1.1 (11.0–14.4)]</td>
<td>15.6 [0.9 (15.3–16.2)]</td>
</tr>
</tbody>
</table>

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**Fig 2** The predicted NE (A) and NV distances (B) are plotted against the measured NE distance ($r^2 = 0.764$, $P < 0.001$) and the NV distance ($r^2 = 0.896$, $P < 0.0001$) for 211 children. NE distance, nares-to-epiglottis distance; NV distance, nares-to-vocal cords distance.
the nasopharyngeal airways of children, were significantly less than the NE distance and that the difference is significantly correlated with patient age.

In adults, the NE distance is known to correlate significantly with the patient height,2 and the NV distance can be estimated using the patient height or the distance from the nares to the tragus of the ear.8 However, few studies have measured the nasal airway dimension in children. Shen and colleagues9 found that the length from the nostril to the vocal cord has a significantly high correlation with the body length, weight, and age in infants. In their study, the anthropometric length was measured from the nose tip to the earlobe. In our study, we used the lateral border of the nose because it is generally assumed to be a preferable point to the tip of the nose due to the relative differences in various ethnic populations.8 Holm-Knudsen and colleagues5 reported that the optimal depth for the placement of a nasopharyngeal airway estimated by listening to the breath sound was 8.0 cm from the nostril in the first year of life and 8.5 cm in the second year; these measurements are comparable with those identified in our study in those patient age groups.

Although the distance from the nares to the angle of the mandible6 or tragus of the ear7 has been used to predict the proper length of the nasopharyngeal airway in children, these conventional methods lack evidence and are not supported by anatomic measurement. It is known that an ideally placed nasopharyngeal airway lies within 10 mm above the epiglottis and separating the soft palate from the posterior wall of the oropharynx.1 In the present study, the NT distance was significantly less than the NE distance, and such discrepancy becomes greater when compared with the NM distance. Therefore, our results suggest that the conventional methods to select the size of the nasopharyngeal airway using the NM or NT distance can lead to failure in securing nasal patency by having the distal tip of the nasopharyngeal airway lying rostral to the soft palate behind the tongue.

The growth of the vocal tract is non-uniform, and there is sex-specific anatomic development of segments within the oral and pharyngeal portions of the vocal tract. In a recent imaging study,10 the vocal tract vertical length including the posterior cavity and nasopharyngeal length showed large sex differences during early childhood. In accordance with these findings, our measured data and regression formula predicting the NE and NV distances show a discrepancy between the sexes of 3.0 mm for the NE distance and 2.8 mm for the NV distance, respectively.

In this study, we showed that the NE and NV distances between 1- and 10-yr-old children can be predicted according to patient height and the NM distance. To allow easy prediction of the NE/NV distance based on the height and NM distance and with size increments of 1 cm, we made nomograms as we also did in our previous study,11 in which we attempted to estimate the optimal size of the oropharyngeal airway (Fig. 4).

There are several limitations and some methodological issues in this study. First, although the investigator attempted to minimize the distortion of the nasogastric tube by using a Magill forceps, there can be some bias in the measured distances because it cannot be assumed that the nasogastric tube was kept in a midline position within the curvature of the nasopharyngeal tract for every patient. Secondly, there inevitably was moderate head extension during the marking of the level of vocal cords on the nasogastric tube. This may have led to a relatively short measurement in the NV distance; however, not too close positioning of the fibreoptic bronchoscope to the glottis would provide better visualization of the vocal cords and the ability to easily manipulate the tip of the scope or nasotracheal tube.5 Finally, although we present references to determine the optimal length of the nasopharyngeal

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**Fig 3** Bland–Altman plot of the difference between the NE distance and the measured NM (A) or NT distance (B). The mean differences were −1.64 and −0.80 cm, respectively. NE distance, nares-to-epiglottis distance; NM distance, nares-to-mandible distance; NT distance, nares-to-tragus distance.
airway, it should be noted that our formulas were based on the theoretical length of the nasopharyngeal airways. Therefore, further studies are warranted to prospectively evaluate the formula using manufactured nasopharyngeal airways.

In conclusion, the NE and NV distances can be predicted using the patient height and the NM distance in young children. The formula proposed in our study can provide a useful guideline for determining the proper size of the nasopharyngeal airway and appropriate positioning of the fibreoptic bronchoscope or nasotracheal tube tip during nasal intubation.

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Declaration of interest
None declared.

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References

Fig 4 Nomograms showing the relationship between the height and the nares-to-mandible distance required to predict the nares-to-epiglottis (A) and the nares-to-vocal cords distance (B) in boys and girls. The isobars show the predicted distance derived from the regression equation. For example, if the measured nares-to-mandible distance and height are 10.0 and 127 cm, respectively, then the predicted nares-to-epiglottis distance of the child is 12.0 cm in a girl whereas 12.3 cm in a boy. Note that the solid line (boys) is always depicted at below the dotted line (girls), although both of them represent the same distance.