Estimation of teeth-to-vallecula distance for prediction of optimal oropharyngeal airway length in young children

S. H. Kim¹, D. H. Kim², H. Kang³, E. H. Suk¹* and P. H. Park¹

¹ Department of Anaesthesiology and Pain Medicine, Asan Medical Center, College of Medicine, University of Ulsan, Seoul, Republic of Korea
² Department of Radiology, College of Medicine, Chosun University, Gwangju, Republic of Korea
³ Department of Anaesthesiology and Pain Medicine, College of Medicine, Chung-Ang University, Seoul, Republic of Korea
* Corresponding author. E-mail: eusuk@medigate.net

Editor’s key points

- It can be difficult to select the optimal size of the oropharyngeal airway in children before induction of anaesthesia.
- This study designed an algorithm to estimate the teeth-to-vallecula distance from simple measurement of mouth-to-mandible distance and patient age.
- With this algorithm, the correct size of the oropharyngeal airway can be selected with reasonable accuracy in children aged 1–9 yr.

Background. Estimation of teeth-to-vallecula distance would facilitate the selection of properly sized oropharyngeal airways in young children. The aims of the present study were to measure the teeth-to-vallecula distance and to create an algorithm to predict this distance based on anatomical landmarks and patient characteristics in children.

Methods. Two hundred children, aged 1–9 yr, undergoing elective surgery were investigated. After induction of general anaesthesia, the distance from the teeth to the vallecula was measured using a laryngoscope with a straight blade. After intubation, the distances from the mouth angle to the mandible angle and the tragus of the ear were measured with a tape measure.

Results. The teeth-to-vallecula distance was significantly correlated with the age, weight, height, and external measurements ($P<0.001$). By stepwise multiple linear regression analysis, a formula was obtained for the teeth-to-vallecula distance (cm) = 3.998 + 0.017 × age (months) + the mouth-to-mandible distance × 0.286 with a high coefficient of determination ($r^2 = 0.764$).

Conclusions. The teeth-to-vallecula distance can be predicted using the age and the mouth-to-mandible distance in young children.

Keywords: airway management; anaesthesia; paediatrics; regional anatomy

Accepted for publication: 10 June 2011

Airway management is one of the key areas of paediatric anaesthetic practice. Owing to anatomical differences, young children are more prone to airway obstruction than adults,¹ and airway narrowing occurs throughout the entire upper airway under sedation or general anaesthesia.² An oropharyngeal airway is used in daily anaesthetic practice to relieve upper airway obstruction caused by a large tongue and laryngeal structures. It is important to use an oropharyngeal airway of the proper size. If the airway is too short, it will displace the tongue and obstruct the airway, and if it is too long, it may not only cause laryngospasm or traumatic injury to laryngeal structures but also aggravate airway obstruction.³

Proper alignment with the glottis opening can be achieved if the pharyngeal end of the oropharyngeal airway is placed just above the epiglottis. Apart from a small part of the airway outside the incisors, the distance from the incisors to the tip of the epiglottis can be considered to be the length of the oropharyngeal airway connecting the two orifices. However, direct measurement of this distance is not possible in typical clinical practice.

In a pilot study using the sagittal T1-weighted magnetic resonance images of the head and upper airway through the midline in 20 children, aged 1–9 yr, we found that the distance from the lower front teeth/gums to the vallecula (teeth-to-vallecula distance) was only slightly shorter (0–4.8 mm, median 2.7 mm) than the distance from the lower front teeth/gums to the tip of the epiglottis (teeth-to-epiglottis distance) (Fig. 1). This indicates that the teeth-to-vallecula distance can be used to appropriate the length of the oropharyngeal airway.

The aims of the present study were to measure the teeth-to-vallecula distance in young children and to examine the relationships among the teeth-to-vallecula...
distorted by the tube fixation and measured the distances from the left mouth angle to the ipsilateral mandible angle (mouth-to-mandible distance) and to the tragus of the ear (mouth-to-tragus distance) using a tape measure. All measurements were performed by a single investigator (E.H.S.).

All variables are expressed as median [IQR (range)] or number. Normality of data distribution was assessed using the Kolmogorov–Smirnov test. The Pearson regression or the Spearman rank test was used to assess correlations between the teeth-to-vallecula distance and other variables. Multiple linear regression with a stepwise forward approach was used to develop a model for the teeth-to-vallecula distance using other measured variables as independent variables. The Bland–Altman method was used to compare the teeth-to-vallecula distance and the mouth-to-mandible distance. 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 children were enrolled in this study. Patient characteristics and details of the measured data are shown in Table 1. Table 2 shows the measured teeth-to-vallecula distance and mouth-to-mandible distance by age group. The teeth-to-vallecula distance was significantly correlated with age (r=0.857, P<0.001), weight (r=0.83, P<0.001), height (r=0.852, P<0.001), the mouth-to-mandible distance (r=0.74, P<0.001), and the mouth-to-tragus distance (r=0.726, P<0.001). Using stepwise multiple linear regression, the following formula best predicted the teeth-to-vallecula distance:

\[
\text{Teeth-to-vallecula distance (cm)} = 3.998 + 0.017 \times \text{age(months)} + \text{mouth-to-mandible distance (cm)} \times 0.286 (r^2 = 0.764)
\]

Adding gender as an independent variable to the linear multiple regression model did not affect this formula (P=0.221). Figure 2A shows the relationship between the measured and predicted teeth-to-vallecula distance by this

**Table 1 Patient characteristics and external measurements expressed as median (range) or number. TV distance, teeth-to-vallecula distance; MM distance, mouth-to-mandible distance; ME distance, mouth-to-tragus distance**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Median (IQR) or Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (months)</td>
<td>91.5 (12–119)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>26 (9–50)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>124.9 (75–149)</td>
</tr>
<tr>
<td>TV distance (cm)</td>
<td>8.0 (5.3–9.0)</td>
</tr>
<tr>
<td>MM distance (cm)</td>
<td>8.5 (6.3–9.5)</td>
</tr>
<tr>
<td>ME distance (cm)</td>
<td>11.0 (8.7–12.0)</td>
</tr>
<tr>
<td>Sex ratio (M/F)</td>
<td>114 : 86</td>
</tr>
</tbody>
</table>

Methods

After institutional review board approval and informed written consent were obtained from the parents, children, aged 1–9 yr, undergoing elective surgery under general anaesthesia were enrolled in this study. Patients with an abnormal airway, prematurity, congenital heart disease, obesity (>50% above ideal body weight), or those at risk for aspiration were excluded. The age, gender, height, and weight of all patients were recorded.

No child was premedicated. Upon arrival in the operating theatre, standard monitors were applied including electrocardiography, pulse oximetry, and non-invasive arterial blood pressure. Anaesthesia was induced by i.v. thiopental 5 mg kg\(^{-1}\) and rocuronium 0.8 mg kg\(^{-1}\) and the patients’ lungs were ventilated with oxygen 4 litre min\(^{-1}\) and sevoflurane 4–6 vol%. After adequate mask ventilation and confirming muscle relaxation, a laryngoscope with a straight blade (Miller\(^{8}\), Welch Allyn, USA) was advanced along the midline in the oral cavity with minimal force. When the tip of the blade reached the vallecula, with no distortion of the epiglottis, a mark was placed on the lower surface of the blade at the point of the lower teeth or gums. This procedure is associated with minimal neck extension. Upon withdrawal of the laryngoscope, mask ventilation was continued and a disposable paper ruler was used to measure the length between the mark on the blade and the tip of the blade, the teeth-to-vallecula distance. Then, orotracheal intubation was performed with an appropriate tracheal tube and anaesthesia was maintained with 50% N\(_2\)O and sevoflurane. The tracheal tube was fixed to the right corner of the mouth. We confirmed that the left side of the mouth was not

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**Fig 1** Sagittal T1-weighted magnetic resonance image of head and upper airway in children. The distance from the lower front teeth (or gums) to the vallecula (teeth-to-vallecula distance, a) approximated to the distance from the lower front teeth (or gums) to the tip of the epiglottis (teeth-to-epiglottis distance, b). Note that the actual teeth-to-vallecula distance was shorter than the teeth-to-epiglottis distance by 0–4.8 mm (median 2.7 mm).
formula. There was no effect of patient age on the difference between the measured and predicted teeth-to-vallecula distance ($r = 0.007$, $P = 0.92$) (Fig. 2B).

We compared the measured teeth-to-vallecula distance with the mouth-to-mandible distance because this external facial distance has been commonly used for sizing the oropharyngeal airways of children. A Bland–Altman plot demonstrated a large variation in the difference between these two values (Fig. 3). The mean difference was 0.65 cm (95% CI 0.57–0.72) and the width of the 95% limits of agreement was 2.1 cm. In 28.5% (57/200) of children, the mouth-to-mandible distance was greater than the teeth-to-vallecula distance by 1 cm or more.

None of the patients showed desaturation or laryngeal injury during determination of the teeth-to-vallecula distance and no patient developed laryngospasm or bronchospasm.

### Table 2

<table>
<thead>
<tr>
<th>Age</th>
<th>Mouth-to-mandible distance (cm)</th>
<th>Teeth-to-vallecula distance (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(CM)</td>
<td>(CM)</td>
</tr>
<tr>
<td>1</td>
<td>6.3 (6.3–7.8)</td>
<td>7.3 (6.3–7.8)</td>
</tr>
<tr>
<td>2</td>
<td>6.5 (5.9–7.3)</td>
<td>7.4 (6.8–8.2)</td>
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<tr>
<td>3</td>
<td>7.0 (6.0–7.8)</td>
<td>7.8 (6.8–8.8)</td>
</tr>
<tr>
<td>4</td>
<td>7.2 (6.5–7.6)</td>
<td>7.8 (7.0–8.8)</td>
</tr>
<tr>
<td>5</td>
<td>7.9 (6.8–8.7)</td>
<td>8.2 (6.8–9.2)</td>
</tr>
<tr>
<td>6</td>
<td>7.5 (6.7–8.4)</td>
<td>8.7 (7.0–9.6)</td>
</tr>
<tr>
<td>7</td>
<td>8.0 (7.4–8.7)</td>
<td>9.0 (7.5–9.5)</td>
</tr>
<tr>
<td>8</td>
<td>8.3 (7.5–8.8)</td>
<td>9.7 (7.6–9.5)</td>
</tr>
<tr>
<td>9</td>
<td>8.4 (7.4–9.0)</td>
<td>9.7 (7.6–9.5)</td>
</tr>
</tbody>
</table>

**Discussion**

This study has showed that there was a significant correlation between the teeth-to-vallecula distance and patient age, weight, height, mouth-to-mandible distance, and mouth-to-tragus distance. It also demonstrated that the teeth-to-vallecula distance in young children can be predicted from patient age and mouth-to-mandible distance. As patient age and mouth-to-mandible distance are easily obtained, these might be used in clinical practice to estimate the length of the oropharyngeal airway.

The correlations between the teeth-to-vallecula distance and various patient characteristics and external facial measurements were expected because children get larger with age. However, only age and mouth-to-mandible distance were included in the formula for prediction of the teeth-to-vallecula distance in our stepwise multiple linear
regression. This may be because the development of most upper airway structures occurs before the age of 11 yr, and mandibular growth has a linear relationship with age from the first to the 11th yr.

It has been described that the appropriate length of an artificial oropharyngeal airway can be estimated as the distance from the lips to the angle of the mandible and that of an artificial nasopharyngeal airway from the nares to the angle of the mandible or the ear. Therefore, in the present study, we assessed the mouth-to-mandible distance and the mouth-to-tragus distance as possible predictors of the oropharyngeal airway. The anatomy of the upper airway changes progressively during childhood. Soft tissues of the upper airway grow more rapidly than do the skeletal part, and this might predispose to upper airway narrowing and obstruction. The disproportionate growth of these structures continues to the age of ~9 yr, so we evaluated the teeth-to-vallecula distance in children up to this age.

To the best of our knowledge, only one previous study used the patient characteristics data to determine the oropharyngeal airway size of children. Greenberg and colleagues, seeking to determine the appropriate size of an oropharyngeal airway, used magnetic resonance imaging to evaluate the oropharyngeal distance from the teeth/gums to prevertebral tissue along a plane parallel to the hard palate. However, this plane may vary among individuals and the length of a perpendicular line from this plane to the tip of the epiglottis bears little relationship with the variables in the formula suggested by the authors. Therefore, we think that our use of the teeth-to-vallecula distance is better in predicting the length of the oropharyngeal airway.

The size marked on the manufactured oropharyngeal airways is the length measured horizontally from the flanged end to the pharyngeal end (Fig. 4, line a). We found that this length of the airway was nearly equal to the length of the line connecting the midpoints of both orifices (Fig. 4, line b). The discrepancy between both lengths in seven kinds of commercially available oropharyngeal airways was 0–2 mm (median 1 mm).
Oropharyngeal airways are manufactured in 0.5 or 1 cm increments and using our formula may be too time-consuming. Thus, we made a nomogram to allow easy determination of the oropharyngeal airway based on age and mouth-to-mandible distance, with size increments of 0.5 cm (Fig. 5).

The distance from the mouth to the angle of the mandible has been used to estimate the oropharyngeal airway size by holding an oropharyngeal airway next to the child’s cheek. In this study, we found that this common clinical practice using the mouth-to-mandible distance is not accurate. This method can lead to the selection of larger sized airways because the mouth-to-mandible distance is greater than the actual teeth-to-vallecula distance by 1 cm or more in 28.5% of children.

Several important limitations of the present study should be noted, and some methodological issues require mention. First, our measured teeth-to-vallecula distance would have resulted in an underestimate of the teeth-to-epiglottis distance of <0.5 cm, as mentioned above. For this reason, it is better to round up the size of a device when the predicted oropharyngeal airway is between two isobars of our nomogram. Secondly, if the tongue is too large or the palate is too high, the oropharyngeal airway, the length of which is based on the teeth-to-vallecula distance, may be short because the manufactured airways have fixed length-to-depth ratios. Finally, although we present guidelines to determine the proper size of an oropharyngeal airway, it should be noted that our formula was based on the theoretical length of the oropharyngeal airway. We therefore recommend that the formula should be prospectively evaluated using manufactured oropharyngeal airways.

In conclusion, in young children, the teeth-to-vallecula distance can be predicted using patient age and mouth-to-mandible angle distance. The formula proposed in this study can provide a useful reference for determination of the proper size of oropharyngeal airways.

Acknowledgement

This study was presented at the American Society of Anesthesiologists Annual Meeting, San Diego, CA, USA, October 2010.

Conflict of interest

None declared.

References