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Upper airway modifications in head extension during development[☆]

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ABSTRACT

Background: One of the requirements of laryngoscopy is to determine which head position will result in optimal visualization. Our hypothesis was that parameters derived from magnetic resonance imaging (MRI) can help quantify the effect of age on airway modifications due to head extension during development.
Method: In children undergoing planned MRI, additional sequences on the upper airways were performed: one in a near-neutral position, the other with the head extended at 35°. The axis of the face, the pharynx, the larynx, the trachea, and the line of glottic visualization were determined. The following angles were calculated: the Visu-Lar angle, formed by the line of glottic visualization and the laryngeal axis, and the Phar-Lar angle, formed by the pharyngeal and laryngeal axes.
Results: One hundred and fifty-five patients (1 to 222 months of age [25–145] months) were included and 54% were under general anaesthesia. Age had no effect on the variation in the Visu-Lar angle, which diminished as a function of head extension, nor on the variation in the Phar-Lar angle, which was minimal in the neutral position. During extension, anatomical axes rotated similarly, and the visualization axis rotated the most, followed by the pharyngeal and laryngeal axes. These results were not correlated with general anaesthesia.
Conclusion: Regardless of age, head extension diminished the Visu-Lar angle, and increased the Phar-Lar angle. This study supports that, as in adults, head extension is probably the key factor for good visualization conditions during laryngoscopy on children, but clinical data is needed to confirm this result.

1. Introduction

Since the publication of Bannister's work in 1944 in *The Lancet* [1], airway imaging has generated much discussion. Nevertheless, solid evidence elucidating airway configuration during laryngoscopy and intubation in children is rare.

Airway access in children is considered to be more complex and difficult than in adults, as paediatric airways and cephalic proportions differ throughout growth, which frequently frustrates non-experienced or non-specialized healthcare providers. To the best of our knowledge, empirical recommendations for the optimal head position have never been precisely analysed using objective data [4]. One of the key requirements for laryngoscopy is the determination of which head position will enable optimal conditions for glottic visualization. This issue can be approached by anatomical angle measurement via magnetic resonance imaging (MRI) studies of the airway in different head positions. With this method, Adnet et al. concluded that for anatomical angle variations (measured via MRI imaging), the sniffing position does not differ from simple head extension [2]. The clinical potential associated with the MRI study was later confirmed when a subsequently initiated clinical trial could not demonstrate a

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significant advantage of the sniffing position over simple head extension [3].

Our hypothesis was that MRI imaging data in children would be a first important step before clinical studies by providing objective data describing and quantifying the effect of age on airway configuration during head extension.

Our main objective was to determine the effect of age on two clinically significant anatomical angles for laryngoscopy and intubation: the angle between the visualization and laryngeal axes (Visu-Lar angle) and the angle between the pharyngeal and laryngeal axes (Phar-Lar angle).

The secondary objective was to describe all the axes of the airway during head extension.

2. Methods

From July 2009 to September 2011, all children who had a planned MRI (with our without general anaesthesia) were considered for inclusion in the study. The MRIs were indicated by paediatricians not involved in the study. Indication of general anaesthesia was not protocoled, and followed the routine practice of the physicians involved. General anaesthesia was proposed by the paediatrician or the radiologist (after failure of awake procedures, and indicated by an anaesthesiologist). The children and their parents received oral and written information about the study and the added time for the MRI. Informed written consent was obtained from the parents.

Exclusion criteria included the following: obesity (Body mass index [BMI] > 97th percentile) [5], macro- or microcephaly [6], head dysmorphism, tumour or abnormality near the upper airway, need for upper airway control (i.e., laryngeal mask or tracheal tube) if general anaesthesia was chosen, an emergency MRI or the lack of consent from the child or either of the parents. The patients under general anaesthesia did not receive any premedication and were anaesthetised with sevoflurane via a high concentration mask. During the MRI examination, the inspired fraction concentration was between 2 to 3%.

For the first head position, the child was in the supine position, directly on the flat MRI table, and the head was positioned in Frankfort's plane [7], defined as the plane between the external auditory canal and the external corner of the eye, perpendicular to the table. For the second head position (extension), after the first MRI acquisition, the head was extended at an incline of 35° to the Frankfort's plan. Before each sequence, the head was positioned by the MRI technician and verified with a non-magnetic square from the MRI tube.

All studies were performed using a 1.5 Tesla system (Maestro class; Siemens, Erlanger, Germany). The study sequences were completed using an ear-nose-throat antenna. The acquisition technique was a spin echo sequence with a repetition time of 703 ms and an echo time of 13 ms. T1-weighted images were obtained in the sagittal plane.

Demographic characteristics for each patient were recorded.

For both head positions for each patient, the axes measured included the axis of the face (face), which extends from the brow to the chin; the pharyngeal axis (Phar) (Fig. 1), which extends through the anterior portion of the atlas and C2; the laryngeal axis (Lar), which extends through the centre of the lower (cricoid cartilage) and upper (airway centre at the base of the epiglottis) laryngeal orifices; the tracheal axis (Trac), which extends from the lower laryngeal orifice through the centre of the trachea at the second ring level; and the line of glottic visualization (Visu), which extends from the lower end of the upper incisors or the gum (in edentulous children) to the corniculate cartilage (posterior part of the thyroid cartilage).

The following angles were calculated: the Visu-Lar angle, formed by the line of the glottic visualization and laryngeal axis, and the Phar-Lar angle, formed by the pharyngeal and laryngeal axes. Variations between the resting position and head extension of the Face, Phar, Lar, Visu, Visu-Lar angle and Phar-Lar angle were also calculated.

Every MRI study was interpreted independently by two of the authors. When the difference between the measurements was less than 10°, the final measurement was the average of the two measurements. When the difference was greater than 10°, a third measurement was made by the two authors together.

Inclusions were prospectively made following an age-stratified plan (Table 1). The results from a previous study [8] helped determine the number of patients per age group; thus, a total number of 150 patients was needed for an α-risk of 0.05 and a β-risk of 0.80. Then, an age-stratified plan was determined: after verification of linearity, correlation coefficients (parametric and polychoric) were calculated for each age group and their significance tested. Then, coefficients were established for each age group.

The demographic data are reported as medians and quartiles. The head extension values in the first and second positions are reported as averages and standard deviations. The number of children in each head extension group is displayed in a histogram (Fig. 2).

Multivariate analysis (a general linear model) was used to test for an age effect and included head extension, weight, sex, general anaesthesia (yes or no) and cranial circumference as variables.

The relationships between the axis positions and head extension were analysed using non-parametric Spearman correlation.

A *P*-value of less than 0.05 was considered statistically significant.

All data analyses were performed using SPSS v17.0 software (SPSS, Inc., Chicago IL).

3. Results

Over a period of 27 months, 168 patients were included in the study and a total of 155 examinations were studied. After several months of inclusion, we encountered difficulties in including children over 24 months old (Appendix 1). After approval by the statistician, we accepted a deviation in the scheduled stratification plan (Table 2).

Twenty examinations were excluded from the study because of examination interruption at the child's request or because the images were otherwise unusable (metal-induced artefacts/movement of the child). The patients' characteristics are shown in Table 1 and the age distribution is reported in Table 2.

The study design was expected to describe two levels of head extension in each child (0° and 35°). However, continuous degrees of head extension (Fig. 2) were obtained in both groups. In the neutral extension group, there was in fact an average extension of −13° (±8). In the extension group, the average extension was 13° (±11). The mean amplitude in extension achieved in our population was 26° (±9).

Multivariate analysis showed that age was not statistically correlated with Visu-Lar or Phar-Lar angle variation during head extension while considering weight, gender, cranial circumference and the presence or absence of general anaesthesia (Table 3). The t-value was −1.66 ($P = 0.1$) for the Visu-Lar angle and −0.64 ($P = 0.52$) for the Phar-Lar angle. Age was correlated with movement of the axes: Visu ($t = -2.51$ [$P = 0.01$]), Phar ($t = -2.35$ [$P = 0.02$]), Lar ($t = -2.87$ [$P < 0.01$]) and Trac ($t = 2.66$ [$P < 0.01$]) (Fig. 1).