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The nasopharynx in infants with cleft lip and palate

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ABSTRACT

Objective: The purpose of this study was to use three-dimensional computed tomography data and computer imaging technology to assess the skeletal components of the naso-pharyngeal area in patients with cleft lip and palate and to quantify anatomical variations.
Methods: CT scans were obtained from 29 patients of Malay origin with cleft lip and palate aged between 0 and 12 months and 12 noncleft patients in the same age group, using a GE Lightspeed Plus Scanner housed in Hospital Universiti Sains Malaysia. Measurements were obtained using the 'Persona' three-dimensional software package, developed at Australian Craniofacial Unit, Adelaide.
Results: The results of the present study show that there is an increased nasopharyngeal space in cleft lip and palate that may lead to compression of the nasopharyngeal structures, including the Eustachian tube. Alterations of the medial pterygoid plate and the hamulus may lead to an alteration in the origin and orientation of the tensor veli palatini muscle leading to alteration in its function.
Conclusions: These anatomical variations may compromise the dilatory mechanism of the Eustachian tube, thus leading to recurrent middle ear infections in cleft children and subsequent loss of hearing.

1. Introduction

The pharynx is a fibromuscular tube situated behind the nose, mouth and larynx. It extends downwards from the base of the skull to the level of C6 vertebra, where it becomes continuous with the oesophagus [1].

The human nasopharynx is intimately concerned with the important functions of mastication, deglutition, respiration, olfaction and speech. Cleft lip and palate (CLP) is responsible for a number of physiological disorders. Babies born with cleft lip and palate can have difficulty in swallowing and breathing due to the communication between the nasopharynx, the nasal fossae and the oral cavity [2]. There is a high frequency of middle ear infections in children with clefts and this has been related to Eustachian tube dysfunction [3–9]. Speech is also, therefore, often impaired.

The morphology of the nasopharynx is of importance when evaluating the function of the velopharyngeal components [10]. However, this has received little attention because of the limitation of the methods available to make measurements. Previous studies of cleft lip and palate have applied two-dimensional lateral cephalometric methods but these have significant limitations, such as superimposition of structures, difficulty in identifying landmarks and poor visualization of 3D structures [1,11–15]. Furthermore, the subjects of these studies have been older children and adults, limited to specific ethnic groups. Researchers investigating CLP have recognized the potential advantages of applying 3D CT to clarify whether CLP is associated with other craniofacial malformations or is a localized anomaly [16]. However, the authors are not aware of any previous CT studies of the nasopharynx in CLP infants during their first year of life before any surgical intervention.

The main aim of this study was to use CT imaging and computer technology to compare skeletal components of the nasopharynx and to quantify anatomical variation between an unaffected group (NC) and four groups of infants with clefts: unilateral cleft lip palate (UCLP); bilateral cleft lip and palate (BCLP); isolated cleft palate (ICP); and cleft lip primary palate/alveolus (CL). The other aims were to compare the ICP group with the other affected groups, as previous embryological studies have indicated that CLP infants are etiologically and developmentally distinct from ICP group [17,18], and to compare males and females.

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2. Materials and methods

Ethical approval was obtained from the Ethics and Research Committee, Universiti Sains Malaysia (USM/PPSG/Ethic Com. / 2001 [61.3(1)], 2001). The patient population consisted of CLP cases of Malay origin requiring 3D CT examinations in Hospital Universiti Sains Malaysia. CT examinations were indicated for some of the CLP patients for medical and surgical reasons [19,20].

2.1. Data collection

The study sample consisted of 29 unoperated nonsyndromic children of Malay origin, ages 0–12 months, with CLP who had 3-D CT examinations during the period January to December 2002. CT scans for 12 NC Malay patients of the same age range were collected over the same period. These patients had presumed normal craniofacial morphology, but had indications for CT scanning for problems other than those recognized to cause abnormalities in craniofacial growth and morphology [19,20]. The distribution of clefts was as follows: cleft lip and/or alveolus (CL), $n = 7$; unilateral cleft lip and palate (UCLP), $n = 10$; bilateral cleft lip and palate (BCLP), $n = 4$; isolated cleft palate (ICP), $n = 8$; unaffected non-cleft (NC), $n = 12$.

2.2. CT protocol

Helical scans were obtained with a GE Lightspeed Plus CT Scanner System (GE Healthcare Technologies, Waukesha, WI) at the Department of Radiology, Hospital Universiti Sains Malaysia. The tube voltage and current that were used were 120 kV and 120 mA, respectively, but minor adjustments to these parameters were made according to the patient's size. Axial slices of 1.25 mm thickness with a spacing of 1.25 mm were written to CD for transfer to a workstation for measurement. The Persona software package developed at the Australian Craniofacial Unit, Adelaide, Australia, was used to create 3-D CT reconstruction and to determine the 3-D coordinates of osseous landmarks on a Silicon Graphics Octane workstation (SGI, Mountain View, CA) [19,20].

2.2.1. Nasopharyngeal variables

The hamulus is one of the important anatomical structures associated with the function of the Eustachian tube. The hamular notch was located at the junction of the maxilla and the hamulus of pterygoid process of the sphenoid bone [5,6,17]. Linear and angular variables were computed from selected landmarks to quantify nasopharyngeal width, height and depth, as well as enabling the angulation of the hamulus, nasopharyngeal, vomerine and sphenopalatine angles to be determined. Areas of the posterior part of the maxilla and zygoma were measured to determine if there was any change in the width of the bony nasopharynx and whether this affected the maxilla and zygoma. The left and right sides were compared to see if there was any asymmetry in these bony landmarks. Definitions of landmarks and distances are shown in Table 1 and the variables are diagrammatically presented in Figs. 1A–D and 2A and B, respectively.

2.3. Statistical analysis

In this study comparisons between the control group (NC) with all other groups, and comparisons between the ICP group (a distinct cleft type) with other cleft groups were conducted using the generalized linear model (PROC GLM, SAS/STAT User's Guide, Version 8, SAS Institute, Inc., Cary, NC) incorporating the fixed effects of sex and using age (14–340 days) as a covariate. The purpose of GLM is to test differences in means for statistical significance. This is accomplished by analysing the variance, that is, by partitioning the total variance into a component that is due to true random error and components that are due to differences

Table 1
Definitions of the variables included in the study.

Variable	Definition
Nasion	The most anterior point of the frontonasal suture. (If suture not clearly identified then the deepest point on the nasal notch can be substituted in the midline.)
Hamulus	The tip of the hamular process
Pterygo-lateralis	The most lateral point on the lateral pterygoid plate located at the posterior/inferior angle
Zygomaxillare	The lowest point on the external suture between zygomatic and maxillary
Hormion	The most posterior and medial point on the junction of the vomer and sphenoid bones
Basion	The mid-sagittal point on the anterior margin of the foramen magnum (determined as the point of maximum convexity on the clivus of the skull at the anterior margin of the foramen magnum)
Anterior nasal spine	The apex of the anterior nasal spine
Sella	The centre of the sella turcica
Inter-hamular notch distance	The distance measured between the deepest points of the left and right hamular notches that were located posteriorly between posterior tuberosities and the pterygoid processes of sphenoid (Fig. 1A)
Inter-hamular process distance	The distance measured from the tip of the left and right hamular processes of the medial pterygoid plates of the sphenoid (Fig. 1A)
Inter-lateral pterygoid plate distance	The distance measured between the most lateral points on the left and right lateral pterygoid plates located at their posterior/inferior points (Fig. 1A)
Hamulus–lat pterygoid plate distance	The distance measured from the left and right hamulus on the medial pterygoid plate to the most lateral points on the left and right lateral pterygoid plates located at their posterior-inferior points (Fig. 1B)
Intermaxillary tuberosity distance	The distance measured from the most posterior-inferior point in the midline of the maxillary tuberosity on left and right sides (Fig. 1B)
Width of the zygoma	The distance measured between landmarks that were located at the lowest point on the external suture between zygomatic and maxillary bones to determine if this area was also affected (Fig. 1B)
Nasopharyngeal height (hormion–hamulus)	The distance measured from the landmarks on the posterior part of the vomer called hormion to the hamulus (Fig. 1C)
Depth of the nasopharynx (hormion–basion)	The most anterior part of the foramen magnum (basion) to the posterior part of the vomer (hormion) as shown in Fig. 1C
Basion–hamulus	The distance measured from basion to the hamulus (Fig. 1C)
Hamulus angle	The distance measured using landmarks on the tip of the hamulus, the posterior-inferior point on the maxillary tuberosity and the most inferior-posterior point on the lateral pterygoid plate (Fig. 1D)
Sphenopalatine angle	Angle between the anterior nasal spine, sella and nasion (Fig. 2A)
Vomerine angle	Angle of the midface was obtained by joining the line extending from the anterior nasal spine-posterior part of the vomer and nasion-sella (Fig. 2B)