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ORIGINAL ARTICLE

Nasal Airway Dimensions of Children With Repaired Unilateral Cleft Lip and Palate

Inge Elly Kiemle Trindade, Ph.D., Adriana de Oliveira Camargo Gomes, Ph.D., Marilyse de Bragança Lopes Fernandes, M.D., M.S., Sergio Henrique Kiemle Trindade, M.D., Ph.D., Omar Gabriel da Silva Filho, D.D.S.

Objective: **To measure cross-sectional areas of the main nasal constrictions as a function of the distance into the nose in children with repaired unilateral cleft lip and palate, as compared with children without cleft, by acoustic rhinometry.**

Design: **Prospective analysis.**

Setting: **Craniofacial anomalies hospital.**

Participants: **A total of 39 children with repaired unilateral cleft lip and palate and 34 healthy controls without cleft, of both genders, aged 6 to 9 years.**

Interventions/Variables: **Nasal cross-sectional areas measured at the three main deflections of the rhinogram (CSA1, CSA2, CSA3) and distances from the nares (dCSA1, dCSA2, dCSA3) were assessed by means of an Eccovision Acoustic Rhinometer, before and after nasal decongestion. Differences were analyzed at a significance level of 5%.**

Results: **At the cleft side, mean CSA1, CSA2, and CSA3 values ± standard deviation obtained before nasal decongestion were 0.17 ± 0.12, 0.29 ± 0.20, and 0.40 ± 0.28 cm^2, respectively, and dCSA1, dCSA2, and dCSA3 values ± standard deviation were 2.02 ± 0.40, 3.74 ± 0.51, and 5.50 ± 0.44 cm, respectively. At the noncleft side, these were 0.33 ± 0.11, 0.65 ± 0.28, and 0.90 ± 0.43 cm^2, respectively, and 1.69 ± 0.48, 3.67 ± 0.53, and 5.60 ± 0.70 cm, respectively. Increased cross-sectional area means were seen after nasal decongestion in the control and cleft groups. Mean cross-sectional area values at the cleft side were significantly smaller than noncleft side and control values, and the mean dCSA1 value was smaller at the noncleft side before and after decongestion.**

Conclusions: **Objective assessment of internal nasal dimensions has shown that children with unilateral cleft lip and palate have a significant impairment of nasal patency due to the reduced cross-sectional areas seen at the cleft side.**

KEY WORDS: *acoustic rhinometry, cleft lip, cleft palate, nasal cavity, nasopharynx*

Unilateral cleft lip and palate (UCLP) adversely affects the nasomaxillary complex, causing nasal deformities such as septal deviation, nostril atresia, and turbinate hypertrophy that reduce nasal internal dimensions, increase resistance to respiratory airflow, and produce mouth breathing.

Acoustic rhinometry has been used as a specific test for assessing nasal patency (Lal and Corey, 2004; Corey, 2006; Roithmann, 2007). The technique is minimally invasive, rapid, well tolerated by adults and children, and requires little patient cooperation. It is based on an analysis of the cross-sectional areas of the nasal cavity, usually at the nasal valve and at the anterior and posterior parts of the turbinates. Examination is also carried out after nasal decongestion with a topical vasoconstrictor, in order to discriminate functional and structural aspects of nasal patency. Procedures have been standardized and were shown to be reliable (Hilberg and Pedersen, 2000; Hilberg, 2002; Clement and Gordts, 2005; Corey, 2006; Clement et al., 2014).

Dr. I.E. Trindade is Full Professor, Department of Biological Sciences, Bauru School of Dentistry and Laboratory of Physiology, Hospital for Rehabilitation of Craniofacial Anomalies, University of São Paulo, Bauru, Brazil. Dr. Gomes is Adjunct Professor, Department of Speech Pathology, Federal University of Pernambuco, Pernambuco, Recife, Brazil, and former Ph.D. student in Rehabilitation Sciences, Hospital for Rehabilitation of Craniofacial Anomalies, University of São Paulo, Bauru, Brazil. Dr. Fernandes is Pediatric Surgeon, Bauru State Hospital, and Ph.D. student in Rehabilitation Sciences, Hospital for Rehabilitation of Craniofacial Anomalies, University of São Paulo, Bauru, Brazil. Dr. S.H. Trindade is Ear, Nose, and Throat Surgeon, Division of Otolaryngology, Department of Ophthalmology, Otolaryngology, Head and Neck Surgery, Botucatu School of Medicine, São Paulo State University, Botucatu, Brazil, and Bauru State Hospital, Bauru, Brazil. Dr. Silva Filho is Orthodontist, Hospital for Rehabilitation of Craniofacial Anomalies, University of São Paulo, Bauru, Brazil.

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Address correspondence to: Dr. Inge Elly Kiemle Trindade, Laboratório de Fisiologia, Hospital de Reabilitação de Anomalias Craniofaciais, Universidade de São Paulo, Rua Silvio Marchione 3–20, CEP 17012-900, Bauru, SP, Brasil. E-mail ingetrin@usp.br.

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Acoustic rhinometry has been extensively used in the general adult and pediatric population to objectively assess nasal patency. A few studies have used the technique to assess nasal obstruction in adults with cleft lip and palate, demonstrating a wide range of impairment, mostly on the affected side (Kunkel et al., 1997, 1999; Huempfner-Hierl et al., 2009; Trindade et al., 2009; Mani et al., 2010; Reiser et al., 2011). However, findings on adults are not applicable to children because nasal airflow resistance changes with age (Saito and Nishihata, 1981). In this regard, previous publications focused only on adolescents with UCLP (Trindade et al., 2010) or on mixed groups of children and adults with UCLP (Kunkel et al., 1997; Huempfner-Hierl et al., 2009; Trindade et al., 2009).

This study evaluated cross-sectional areas of the main nasal constrictions and their specific sites in children with repaired UCLP, at the cleft and noncleft sides, as compared with control children, by acoustic rhinometry. It is the first to report a cohort of UCLP children within a narrow age range (6 to 9 years old), aiming to provide some baseline data in this age group.

Materials and Methods

Subjects

The institutional Research Ethics Committee (No. 033/2005/UEP) approved this study and informed consent was obtained from all parents.

A convenience sample of 39 nonsyndromic children with repaired UCLP participated in the study (26 boys and 13 girls). All underwent primary cleft palate repair in early infancy. Timing and type of surgery were not controlled variables. Mean age at examination was 8.1 years (range, 6 to 9 years). A total of 34 children without cleft participated as controls (18 boys and 16 girls). Mean age at examination was 8.0 years (range, 6 to 9 years). The control children were selected among those about to start preventive treatment at an external orthodontics clinic.

Children who had previously undergone maxillary expansion or nasal surgery were not included, nor were those with respiratory or allergic symptoms resulting in nasal congestion at the exam or who had residual palatal fistulae and/or other obvious diseases.

Procedures

Acoustic rhinometry was carried out by using an Eccovision Acoustic Rhinometer (Pembroke, MA), as described elsewhere (Gomes et al., 2008; Trindade et al., 2009; Trindade et al., 2013).

The area-distance graph (rhinogram) was used for the assessment of nasal cross-sectional areas in centimeters squared and the distance relative to the nostril (dCSA) in centimeters. Measurements were done at the second notch of the rhinogram (CSA1 and dCSA1), corresponding to the area of the nasal valve; at the third notch (CSA2 and dCSA2), corresponding to the anterior head of the inferior and/or middle turbinate; and at the fourth notch (CSA3 and dCSA3), corresponding to the middle-posterior portion of the middle turbinate (Corey, 2006), as shown in Figure 1. The first notch of the rhinogram, which corresponds to the nostril's area, was not considered for analysis. For this reason, the three notches described here were considered as the first, second, and third constrictions, respectively.

Examination was done before and 10 minutes after administering three drops of a nasal vasoconstrictor (0.1% xylometazoline hydrochloride).

Data Analysis

Results are expressed as mean $\pm$ standard deviation. An analysis of variance (ANOVA) test was used as the first step for assessing differences between groups (cleft and noncleft), nasal sides (left and right), and nasal conditions (before and after decongestion). When interaction between factors was identified, a Tukey test was used for multiple comparisons ($P < .05$). When analyzing combined data for the right and left sides, Bonferroni correction was used for post hoc comparisons. Differences were analyzed at a significance level of 5%.

Results

Mean nasal cross-sectional areas and distances observed in the control and cleft groups, before and after nasal decongestion, are seen in Table 1. For the control group, the mean of left and right areas and distances are shown; and for the UCLP group, cleft and noncleft sides are shown separately. In Table 2, left and right areas from both groups were added with the aim of comparing the overall nasal patency between groups.

Effect of Nasal Decongestion

Nasal decongestion, used to eliminate the mucosal aspect of the nasal cavity, resulted in a significant increase of cross-sectional area means for both the UCLP group and the control group (Table 1).

Cleft Side Versus Noncleft Side

In the UCLP group, mean cross-sectional areas (CSA1, CSA2, CSA3) were significantly smaller at the cleft side than at the noncleft side, before and after nasal decongestion (Table 1). Mean dCSA1 at the noncleft side was statistically shorter, in relation to the nostril, than at the cleft side, before and after nasal decongestion. Mean dCSA2 and dCSA3 did not differ between sides.

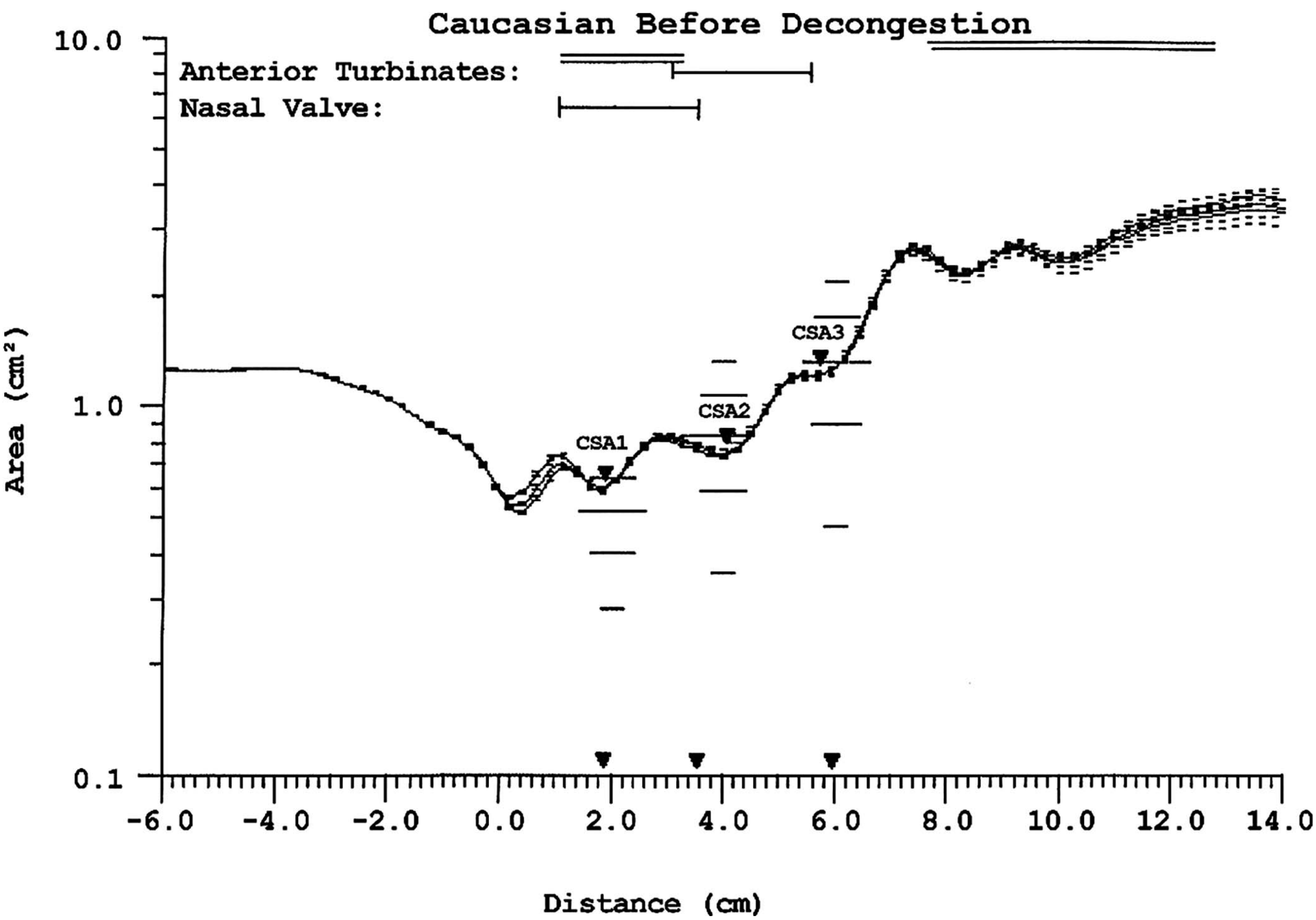

FIGURE 1 Rhinogram showing the sites where nasal cross-sectional areas (CSA1, CSA2, and CSA3) and their distances in relation to the nostril (0.0) were measured.

UCLP Children Versus Age-Matched Controls

Table 1 shows that mean cross-sectional areas (CSA1, CSA2, CSA3) at the cleft side were significantly smaller than control mean areas, before and after nasal decongestion. Mean cross-sectional areas (CSA1, CSA2, CSA3) at the noncleft side did not differ from control mean areas, before and after nasal decongestion. Mean dCSA1 at the noncleft side of the UCLP children was significantly shorter than in controls. Mean dCSA2 and dCSA3 did not differ between groups.

By adding up the right and left cross-sectional areas in the cleft group and the control group and recalculating mean values (Table 2), it was seen that the cleft group

TABLE 1 Cross-Sectional Areas of Three Segments of the Nasal Cavity (CSA1, CSA2, and CSA3) and Their Distances From the Nostril (dCSA1, dCSA2, and dCSA3) Determined by Acoustic Rhinometry in Children With Repaired Unilateral Cleft Lip and Palate, on the Cleft Side and Noncleft Side, and in Age-Matched Controls, Before Nasal Decongestion (Pre-ND) and After (Post-ND)*

	Cleft Group				*Control Group*	
	Cleft Side		*Noncleft Side*		*Mean of Both Sides*	
Variable	*Pre-ND (n = 39)*	*Post-ND (n = 38)*	*Pre-ND (n = 39)*	*Post-ND (n = 38)*	*Pre-ND (n = 34)*	*Post-ND (n = 32)*
CSA1 (cm^2)	0.17 ± 0.12†‡	0.22 ± 0.14 [41%]†‡§	0.33 ± 0.11	0.40 ± 0.10 [41%]§	0.33 ± 0.11	0.41 ± 0.17 [31%]§
CSA2 (cm^2)	0.29 ± 0.20†‡	0.54 ± 0.33 [114%]†‡§	0.65 ± 0.28	0.93 ± 0.32 [83%]§	0.60 ± 0.11	0.94 ± 0.69 [80%]§
CSA3 (cm^2)	0.40 ± 0.28†‡	0.73 ± 0.43 [118%]†‡§	0.90 ± 0.43	1.23 ± 0.46 [79%]§	0.89 ± 0.49	1.31 ± 0.78 [70%]§
dCSA1 (cm)	2.02 ± 0.40†‡	1.71 ± 0.38 [−13%]†‡§	1.69 ± 0.48	1.39 ± 0.37 [−15%]§	1.90 ± 0.34	1.56 ± 0.30 [−17%]§
dCSA2 (cm)	3.74 ± 0.51	3.59 ± 0.56 [−3%]§	3.67 ± 0.53	3.57 ± 0.43 [−2%]§	3.76 ± 0.55	3.55 ± 0.55 [−6%]§
dCSA3 (cm)	5.50 ± 0.44	5.38 ± 0.49 [−2%]	5.60 ± 0.70	5.45 ± 0.52 [−2%]	5.68 ± 0.74	5.54 ± 0.70 [−2%]§

* All mean ± SD; n = number of children; [Δ%] = post-ND percentage change.
† $P < .05$ statistically significant difference (cleft side versus noncleft side).
‡ $P < .05$ statistically significant difference (cleft group versus control group).
§ $P < .05$ statistically significant difference (before and after decongestion).

TABLE 2 Comparison of Cross-Sectional Areas of Three Segments of the Nasal Cavity (CSA1, CSA2, and CSA3) Determined by Acoustic Rhinometry in Children With Repaired Unilateral Cleft Lip and Palate and in Age-Matched Controls, Before Nasal Decongestion (Pre-ND) and After (Post-ND)*

	Cleft Group		*Control Group*	
	Cleft + Noncleft Nasal Cavities		*Right + Left Nasal Cavities*	
Variable (cm^2)	*Pre-ND (n = 39)*	*Post-ND (n = 38)*	*Pre-ND (n = 34)*	*Post-ND (n = 32)*
CSA1	0.50 ± 0.19†	0.60 ± 0.12†	0.67 ± 0.18	0.78 ± 0.20
CSA2	0.94 ± 0.47†	1.43 ± 0.50†	1.20 ± 0.27	1.78 ± 1.07
CSA3	1.30 ± 0.36†	1.91 ± 0.41†	1.79 ± 0.83	2.47 ± 1.00

* All mean ± SD; n = number of children. Values correspond to the sum of individual left and right areas in both groups.
† $P < .05$ statistically significant difference (cleft versus control group).

still had significantly smaller mean areas than the control group.

Discussion

This the first study to report acoustic rhinometry findings in a large cohort of UCLP children with a narrow age range (6 to 9 years old). By using the technique, we have results showing that children with repaired UCLP have smaller noses than noncleft children. On the other hand, noncleft children presented smaller noses than noncleft adults in a previous study in the same setting (Gomes et al., 2008). Before nasal decongestion, mean cross-sectional areas of 0.33 ± 0.11 cm^2 (CSA1), 0.60 ± 0.11 cm^2 (CSA2), and 0.89 ± 0.49 cm^2 (CSA3) were observed in the noncleft children currently studied, and Gomes et al. (2008) observed mean cross-sectional areas of 0.54 ± 0.13 cm^2 (CSA1), 0.98 ± 0.31 cm^2 (CSA2), and 1.42 ± 0.44 cm^2 (CSA3) in noncleft adults, validating the current findings.

In addition, it was shown that in children with repaired UCLP, cross-sectional areas of the nasal valve region and of the anterior and posterior parts of the turbinates are significantly reduced at the affected side, as compared with the nonaffected side and with normal noses. Nasal cavity asymmetry and obstruction due to a unilateral cleft has already been demonstrated in adults by means of rhinomanometry (Fukushiro and Trindade, 2005; Mani et al., 2010) and acoustic rhinometry (Kunkel et al., 1997, 1999; Trindade et al., 2009), but similar data for children are lacking.

Though CSA1 differences may, at a first glance, seem of small magnitude, this is a relevant finding in practice because an insignificant decrease at the nasal valve, the main regulator of respiratory airflow (Cole, 2003), leads to a dramatic increase in airway resistance and hence in the work of breathing. According to the Poiseuille law, the resistance of a pipe is inversely proportional to the fourth power of its radius. This means that if the cross-sectional area of the nasal valve is halved, the resistance will rise 16-fold, and if the pressure difference is unchanged, the volume flow rate will decrease to a sixteenth (Bloching, 2007).

It is a consensus that in childhood, obstructed airways impair nasal function and cause oral breathing that may persist throughout adolescence, leading to problems with dental occlusion. Sleep disordered breathing may also arise, which comprises a wide spectrum of abnormalities; those related to increased upper airway resistance include snoring, upper airway resistance syndrome, and obstructive sleep apnea-hypopnea syndrome (American Academy of Sleep Medicine, 2005). In children with repaired cleft lip and palate, the obstructive conditions may persist until rhinoseptoplasty is performed or even later (Warren et al., 1992; Warren and Drake, 1993; Trindade et al., 2009; Shadfar et al., 2012; Morén et al., 2013).

Another relevant finding refers to the fact that the first nasal constriction was found to be more anteriorly located on the noncleft side than on the cleft side or in the normal nose. The difference might be due to the asymmetric action of the affected orbicularis oris muscle over the nasal base (i.e., on the columella on the noncleft side and at the alar base on the cleft side). Given that the first constriction of the rhinogram corresponds to the nasal valve, the structural modification determined by the cleft on the nonaffected side might also have had an impact on nasal patency. Current data do not allow inferences, whether positive or negative. However, it is noteworthy that adding left and right areas led to the same outcome (i.e., children with repaired UCLP still demonstrated smaller nasal size than controls).

The impact of the cleft on nasal physiology was also seen when analyzing the mucosal response to a vasoconstrictor drug. First, the percentage increase of the turbinate cross-sectional areas was clearly higher on the cleft side of the UCLP group, as observed in older patients by Kunkel et al. (1997, 1999). Second, cross-sectional areas of the children with cleft approximated the cross-sectional areas of children without cleft after decongestion, indicating that it might be possible to consider medical management aimed at treating allergic rhinitis and inferior turbinate hypertrophy. On the other hand, in the current study, the difference between sides did not disappear after decongestion, showing that obstruction in UCLP children was mainly due to the nasal deformity and not to functional disorders.

In summary, acoustic rhinometry was shown to be a useful technique for identifying the main obstructive sites and measuring the degree of airway impairment caused by the cleft and its repair. As pointed out by Mani et al. (2010), this objective approach is particularly relevant because nasal patency has become an important issue in cleft care due to the impact of nasal obstruction on the quality of life and sleep.

Conclusion

Nasal deformities of repaired UCLP children can be objectively assessed and quantified by acoustic rhinometry. At the cleft side, nasal valve and turbinates cross-sectional areas were proven to be smaller than those observed at the noncleft side and in control cases. Results confirm that children with repaired UCLP have impairment of nasal patency.

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