Peripheral oxygen saturation, heart rate, and blood pressure during dental treatment of children with cyanotic congenital heart disease

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OBJECTIVES: In this observational study, we evaluated the peripheral oxygen saturation (SpO2), heart rate, and blood pressure of children with cyanotic congenital heart disease who were undergoing dental extraction.

METHODS: Forty-four patients between the ages of 6 and 12 years who underwent upper primary tooth extraction were included in the study. Of these, 20 patients were in the cyanotic congenital heart disease group and 24 were in the control group.

RESULTS: Peripheral oxygen saturation, heart rate, and systolic blood pressure in the cyanotic congenital heart disease group varied quite significantly during the treatment protocol ($p<0.05$), with values of 80.5% ($\pm$7.6) to 82.8% ($\pm$7.8), 95.3 beats per minute (bpm) ($\pm$11.3) to 101.3 bpm ($\pm$9.8), and 93.6 mm Hg ($\pm$13,3) to 103.8 mm Hg ($\pm$12.7), respectively. The variations in the control group during the procedure were also significant.

CONCLUSIONS: The changes observed during the study protocol, although statistically significant, were mild and lacked clinical relevance. The results indicate that dental treatment of children with cyanotic heart disease using a standardized protocol in decentralized offices without the support of a surgical center is safe.

KEYWORDS: Heart Defects; Congenital; Dentistry; Dental Anxiety; Pediatric Dentistry.

■ INTRODUCTION

Congenital heart defects constitute one of the most common types of malformation in humans. Some mild defects correct spontaneously within days or weeks after birth, while others can be complex enough to quickly lead to death (1). The incidence of congenital heart disease cited in different studies varies and is estimated to occur in 4/1,000 to 50/1,000 live births (2). Cyanotic congenital heart defects, primarily including decreased pulmonary blood flow, are the most serious.

Gradual improvement of therapeutic procedures for congenital heart disease has led to improved survival rates for these individuals, thereby increasing the demand for dental treatment in these subjects. Maintaining oral health in children with congenital heart disease (CHD) is extremely important. The oral cavity is an important entrance point for bacteria that may cause infective endocarditis, which increases the risk for unrepaired cyanotic CHD (3,4). Our initial hypothesis was that children with cyanotic congenital heart disease have low peripheral blood oxygen saturation (SpO₂) and therefore may encounter problems during dental treatment. Furthermore, children who remain agitated during dental treatment may exhibit abrupt changes in cardiovascular function due to stress and may eventually develop worsening hypoxemia or even acute heart failure (5). Despite these facts, there are no protocols in the literature regarding dental treatment for children with congenital heart disease, and there are few studies that have evaluated peripheral oxygen saturation (SpO₂), heart rate (HR), and blood pressure (BP) during dental treatment, which is considered stressful for children.

The objective of this study was to evaluate the occurrence and magnitude of changes in SpO₂, heart rate, and blood pressure during extraction of primary teeth in children with cyanotic congenital heart disease with decreased pulmonary blood flow. The procedures were performed according to an established dental treatment protocol.

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■ MATERIALS AND METHODS

Participants

We included 44 children between the ages of 6 and 12 years who were diagnosed with congenital heart disease. These children were selected from InCor's Outpatient Pediatric Cardiology Unit and were chosen based on their medical records according to the inclusion and exclusion criteria. These children were divided into two groups. One group included 20 children who had cyanotic congenital heart disease (CCHD) with decreased pulmonary blood flow, anatomically similar to tetralogy of Fallot. The control group comprised 24 children with acyanogenic congenital heart disease (ACHD). The extraction of primary teeth with any degree of root resorption required the use of anesthesia during the procedure, and all children had already undergone dental treatment at least once in their lifetime. The study was approved by the Ethics Committee for Analysis of Research Projects of the Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo (HCFMUSP) (Comissão de Ética para Análise de Projetos de Pesquisa -CAPPesq). Informed consent was obtained from the patients' legal guardians.

Protocol

The children underwent a treatment protocol with all periods and procedures included on the same day. These periods and procedures were as follows: 1) play time (PT), which consisted of recreational activities performed with the child; 2) anamnesis, clinical examination and radiography time (ACER); and 3) dental procedure (DP), which was subdivided into 4 sub-periods: pre-procedure (PPR), a period of anesthesia (PAN), the procedure itself (PP), and the post-procedure period (PPP). The selected anesthetic was 2% lidocaine without a vasoconstrictor (6), which was administered with a computer-controlled dental injection instrument referred to as The Wand (CompuDent Instrument, Milestone Scientific, Inc., Livingston, NJ, USA). This instrument guarantees that the injection is slow and steady and therefore comfortable. To minimize the discomfort of the injection, 20% benzocaine gel was used for topical anesthesia. Although there were different levels of root resorption and different degrees of dental mobility, we used the same amount of topical and infiltrative anesthetic in all patients.

Only upper deciduous teeth were treated, and the same dentist performed all procedures. The authors performed the anxiety assessment.

Parameters evaluated

Peripheral oxygen saturation (SpO$_2$), heart rate (HR), and blood pressure (BP). During the procedure, SpO$_2$, HR, and BP were measured. An ambulatory digital pulse oximeter (WristOx®, Philips Respironics, Andover, MA, USA) was used to record SpO$_2$ and HR. SpO$_2$ and HR were determined during 3 different periods, and the oximeter was set to record these parameters every 4 seconds. Changes in SpO$_2$ were also recorded when there was a decrease of $\geq$4% in SpO$_2$ lasting at least 6 seconds. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) values were recorded during the study periods using a Microlife Digital Auto Blood Pressure Gauge (Auto Pulse model APA-P00001; Microlife Corporation, Switzerland); 2 measurements were performed as recommended. If the

diastolic blood pressure showed differences greater than 4 mmHg, new measurements were taken to obtain a smaller difference (7).

All SpO$_2$ and HR records were analyzed using Nonin nVISION software (version 5.0), which is an oximetry data analysis management software package that allows several report categories and customizable analysis criteria.

Statistical analysis

To compare the means of the two groups of patients, we used Student's t test, and the proportions were compared with a chi-square or Fisher's exact test. To evaluate the behavior of the groups of patients based on the various conditions, analysis of variance for repeated measures was used. When the assumption of data normality was rejected, nonparametric Mann-Whitney and Friedman tests were used. The significance level used for the tests was 5%, and the acceptable power of the tests was set at 80%.

Assessment of anxiety

To assess anxiety, we used the Facial Image Scale during all periods. This scale is used internationally in dentistry (8) and consists of 5 faces, ranging from "very sad" to "very happy" (unhappy to very happy). The children were questioned at the end of each period about how they were feeling at that moment, and their emotional state was assigned a value from 5 to 1.

■ RESULTS

Children in the ACHD and CCHD groups were aged 9.6 ($\pm$1.5) and 9.6 ($\pm$1.9) years, respectively. A total of 13 subjects (54.2%) in the ACHD group and 10 subjects (50%) in the CCHD group were male. None of the children had any significant comorbidities.

There was no significant difference between the CCHD and ACHD groups with regard to the time spent on the procedures. The total times were 82.5 minutes in the CCHD group and 80.5 minutes in the ACHD group.

Peripheral oxygen saturation (SpO$_2$)

The groups showed significant variations in the average SpO$_2$ over the various periods. The CCHD and ACHD groups showed significant changes in SpO$_2$ during the evaluations ($p = 0.004$ and $p = 0.019$, respectively) (Table 1). Only two children presented with an SpO$_2$ below 70% during the study; both were from the CCHD group. All

Table 1 - Peripheral oxygen saturation (SpO$_2$) averaged over the different periods in the cyanotic heart disease and acyanotic heart disease groups.

Periods	SpO$_2$ (%)			
	CCHD (n = 20)		ACHD (n = 24)	
	Mean (dp)	Min; Max	Mean (dp)	Min; Max
PT	80.5 (7.6)	(67.2; 93.1)	97.6 (1.1)	(94.1; 99.3)
ACER	82.4 (7.3)	(69.1; 93.4)	98.0 (1.3)	(94.2; 99.7)
DP	82.8 (7.8)	(67.7; 94.4)	97.8 (1.2)	(94.0; 99.0)

Index - PT: play time; ACER: anamnesis, clinical examination, and radiography; DP: dental procedure; CCHD: cyanotic heart disease group; ACHD: acyanotic heart disease group; Min: minimum value found for average SpO$_2$; Max: maximum value found for average SpO$_2$.

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factors that could affect the measurement of SpO_2 were eliminated.

Heart rate (HR)

During the procedures, the mean HR in the CCHD group ($p = 0.013$) was higher throughout the study period (Table 2). Both groups showed significant changes in mean HR during the procedures ($p<0.001$).

Systemic blood pressure (BP)

No significant differences in SBP ($p = 0.579$) or DBP ($p = 0.321$) were found between the CCHD and ACHD groups during the study protocol, and the groups did not differ with respect to the mean SBP and DBP ($p = 0.624$ and $p = 0.359$, respectively). Individually, the 2 groups showed significant changes in SBP and DBP during the evaluations ($p<0.001$) (Table 3).

Anxiety measures

The anxiety scores reported by the children using the facial image scale were similar between the groups.

The ACHD and CCHD groups had no significant differences in anxiety during any of the evaluation periods (PT: $p = 0.621$; ACER: $p = 0.831$; PPR: $p = 0.900$; PAN: $p = 0.616$; PP: $p = 0.530$; PPP: $p = 0.247$).

■ DISCUSSION

Behavior of peripheral oxygen saturation (SpO_2)

Studies that correlate cardiac disease, SpO_2, and anxiety in children during dental treatment are rare; however, one study analyzed SpO_2 in healthy children who experienced stress and anxiety caused by dental treatment. Rayen et al. (9) evaluated the physiological factors of 11 healthy children between the ages of 4 and 11 and found that SpO_2 did not change during the stress induced by dental treatment. Contrary to that study (9) and the study conducted by Shirakawa et al. (5), we noted a slight but insignificant increase in the average SpO_2 in children with cyanotic heart disease ($p<0.004$) over the course of the study periods. This increase in SpO_2 most likely occurred at a time of increased stress due to the hyperventilation that occurs in these patients (10).

In healthy children, desaturation below 90% indicates the need for oxygen supplementation (11). Because children who already had low saturation due to a heart condition were included, the average limit for SpO_2 during dental

Table 2 - Mean heart rate (bpm) during the different periods in the cyanotic heart disease and acyanotic heart disease groups.

Periods	HR (bpm)		
	CCHD (n = 20)	ACHD (n = 24)	p-value*
	Mean (dp)	Mean (dp)	
PT	101.3 (9.8)	91.9 (12.4)	0.009
ACER	95.3 (11.3)	87.6 (13.3)	0.046
DP	98.7 (11.0)	90.2 (11.4)	0.017

Index – PT: play time; ACER: anamnesis, clinical examination, and radiography; DP: dental procedure; CCHD: cyanotic heart disease group; ACHD: acyanotic heart disease group; * = probability based on Student's t-test.

Table 3 - Systolic blood pressure and diastolic blood pressure in the different periods in the cyanotic heart disease and acyanotic heart disease groups.

Period	SBP		DBP	
	CCHD (n = 19)	ACHD (n = 24)	CCHD (n = 19)	ACHD (n = 24)
	Mean (dp)	Mean (dp)	Mean (dp)	Mean (dp)
PT	93.6 (13.3)	101.5 (13.9)	59.6 (8.8)	65.7 (11.6)
ACER	99.5 (11.9)	100.9 (16.6)	62.2 (8.8)	64.8 (11.1)
DP	103.8 (12.7)	103.8 (13.8)	67.3 (11.8)	68.8 (12.8)

Index – PT: play time; ACER: anamnesis, clinical examination, and radiography; DP: dental procedure; ACHD: acyanotic heart disease group; CCHD: cyanotic heart disease group.

treatment was 70%. Below this value, the treatment should be discontinued, and the cyanotic child should continue treatment with supplemental oxygen (O_2) administered by nasal catheter. During this study, only one patient in the CCHD group had an average SpO_2 below 70% in the third period, and one patient had an average CCHD and SpO_2 below 70% during the PT measurement. On occasions when there was an SpO_2 average below 70%, oxygen was administered at 2 L/minute. A child who had an SpO_2 below 70% in all 3 periods and still showed clinical signs of hyperventilation required the oxygen therapy.

Behavior of heart rate (HR) and blood pressure (BP)

Few studies in the literature have correlated HR and anxiety in children with cardiac disease undergoing dental treatment. Most studies correlating HR and anxiety have been performed in healthy children; however, this subject remains controversial. Some authors have shown that the HR in healthy children did not change in the presence of such anxiety (12). Other studies correlated stress caused during dental treatment with an increase in HR (9,13). Infiltration of the local anesthetic and the extraction are factors that are thought to contribute to the increase in HR during dental treatment, and there seems to be a significant correlation between HR and BP in healthy children (9,14). The significant decrease in average HR during ACER in both groups compared to PT ($p<0.001$) and DP ($p = 0.095$) likely occurred because during the ACER period, the child was quiet and sitting still for the clinical and radiographic examinations. Therefore, it is likely that the child's agitation during play increases the HR in the PT period, just as stress caused by dental treatment does in the DP period. Furthermore, the increase in HR that occurred in the DP and PT periods (compared to that in the ACER period) did not cause damage to the overall health of the children because, although it was statistically significant, it had no clinical relevance.

No studies were found that correlated BP and anxiety during dental treatment in children with heart disease. However, we found some studies that correlated high BP in children without heart disease undergoing dental treatment (15). Some authors consider that the process of dental extraction is a source of great stress and therefore changes in BP in children (9,16). Therefore, anxiety is associated with significant changes in SBP and DBP in healthy children undergoing dental treatment, as demonstrated in some previous studies (16,17), and these parameters can be seen both as psychological and physiological features (9).

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Therefore, a child with CCHD was not at risk of experiencing abnormally high stress during dental treatment, as the same increase occurred in the ACHD group ($p<0.001$). Therefore, it can be inferred that this increase in BP may occur in either cyanotic or acyanotic children, indicating that cyanosis is not a deterrent for dental treatment in an outpatient clinic. When comparing the CCHD and ACHD groups, we noticed that there were no differences between the groups regarding DBP ($p<0.321$) and SBP ($p<0.579$) mean or variability; i.e., children with CCHD showed the same variations in these parameters as children with acyanogenic congenital heart disease, suggesting that being cyanotic was not a problem with respect to dental treatment.

Relationship between anxiety level and SpO$_2$, HR, and BP values

Measuring dental anxiety is always controversial because it depends on subjective measures, such as the influence of parents, the behavior of the dentist, and the reason for the dental visit (18). In the present study, we used the Facial Image Scale, an approved instrument for this type of situation (8), which can also be used both in research and everyday dental practice (19). It is known that anxiety can cause physical reactions, such as tachycardia, rapid breathing, increased cortisol, and trembling (20). The increase in HR and BP during minor oral surgery in healthy children appears to be more related to fear and anxiety during dental treatment than to cardiac alterations (16). Anxious patients appear to feel more pain before the injection of local anesthesia for dental purposes than do less anxious patients (21). In this study, this relationship was strongly evidenced by the fact that in the CCHD group, the level of anxiety was higher during the anesthetic injection (PAN) than during the PP ($p<0.05$) and the PPP ($p<0.05$). In contrast, in the ACHD group, there was no difference in anxiety over the different periods. It is important to note that no studies have yet been published that demonstrate clinical complications in children with cyanotic congenital heart disease in a dental setting.

Limitations of the study

In addition to being rare, this study presents some limitations. First, only extractions of superior deciduous teeth were performed. The results may therefore not be transferable to extractions of inferior deciduous teeth because the anesthetic and surgical procedures are not similar and because the inferior deciduous teeth are associated with a different mandibular trabecular bone. Another limitation of the study is the fact that these results cannot be applied to permanent teeth in the same patients.

The small number of individuals participating in the study may appear to be another limitation. However, the number was sufficient to produce a statistically significant sample. The cardiac conditions of these children are rare, making it difficult to obtain a large sample with these medical characteristics.

In future studies, the anxiety scale should be used in a different way. Instead of asking the child how she (he) felt at the end of the treatment, she (he) should be asked during the procedure. This would avoid the confounding response of ''happy'' after any successful treatment.

Although significant changes were observed during the study period, these changes were mild and not clinically relevant. Therefore, unnecessary interruption of dental treatment or therapeutic support for children contradicts the initial hypothesis, which was based on the literature, due to the observed increase in SpO$_2$ during DP compared to periods with lower stress. The dental treatment of children with cyanotic heart disease proved to be a safe procedure when performed by trained professionals using a standardized protocol. It can be implemented in decentralized clinics supported by surgical centers, thus facilitating the treatment of these children. The levels of peripheral oxygen saturation are one of the most important criteria when considering the safety of these children when undergoing dental procedures.

■ AUTHOR CONTRIBUTIONS

Dutra RM was responsible for recruiting patients, performing the dental procedures, plotting tables, data analysis, and writing the article. Neves IL and Neves RS contributed to the study design and discussion of the results. Atik E designed the study and wrote the article. Santos UP contributed to the study design, discussion of the results, and data analysis.

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