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Summary:

Introduction: The optimal surgical technique for the management of patients with Robin Sequence (RS) has not been established. One of the most commonly used surgical techniques, mandibular distraction osteogenesis (MDO), is still controversial because of its potential risks and the lack of clear evidence of its efficacy.

Objectives: To assess variations in airway patency, clinical symptoms, and polysomnographic parameters in children with RS who underwent MDO.

Methods: In this prospective cohort study, 38 patients with RS were evaluated before and after MDO. Symptom severity was classified using a grading scale for RS clinical manifestations. Patients underwent flexible fiberoptic laryngoscopy, and the images were classified by a blinded examiner using two validated grading scales for airway obstruction. Patients not requiring ventilatory support underwent a polysomnography.

Results: Patients' symptoms significantly improved after MDO, as shown by a decreased score in the grading scale for RS clinical manifestations (preoperative score of 2.20 vs. postoperative score of 0.81; $P < 0.001$). The two endoscopic grading scales also showed a statistically significant postoperative improvement in airway obstruction (first scale: preoperative score of 1.56 vs. postoperative score of 0.92; second scale: preoperative score of 2.19 vs. postoperative score of 1.16; $P < 0.001$ for both). Moreover, there was a statistically significant variation in the

following polysomnographic parameters evaluated pre- and postoperatively: apnea-hypopnea index, total sleep time, oxygen desaturation nadir, and oxygen desaturation index ($P < 0.05$).

Conclusions: MDO seems to be an effective surgical option for children, as shown by postoperative improvements in clinical symptoms, endoscopic grading scales, and polysomnographic parameters.

Keywords: glossoptosis; Pierre Robin syndrome; osteogenesis, distraction; polysomnography; flexible fiberoptic laryngoscopy.

1. Introduction

The term “glossoptosis” refers to a posterior displacement of the base of the tongue causing varying degrees of airway obstruction. Flexible fiberoptic laryngoscopy (FFL) is an examination procedure that assesses airway anatomy and can diagnose this obstruction (de Sousa et al., 2003; Yellon, 2006; Manica et al., 2016), while polysomnography (PSG) is a test used to quantify the degree of obstruction during sleep (Bower et al., 2000; Bravo et al., 2005; Bangiyev et al., 2016).

French stomatologist Pierre Robin described the association between micrognathia and glossoptosis in 1923 (Robin, 1923). In 1934, he included the presence of cleft palate in his reports, and this set of abnormalities was called Robin sequence (RS) (Robin, 1934). Today, however, it is known that RS without cleft palate can be found in some children.

Several studies describing surgical correction of micrognathia, such as mandibular distraction osteogenesis (MDO), have been published. However, none of them assessed airway obstruction in children using both pre- and postoperative FFL and PSG (Bangiyev et al., 2016; Reddy, 2016).

Thus, the aim of the present study was to evaluate variations in clinical symptoms, airway patency and polysomnographic parameters in children with RS undergoing MDO.

2. Materials and methods

2.1. Study design

This prospective study followed a cohort of 80 patients with RS treated at a hospital from October 2012 to September 2016 (Manica et al., 2018). It was approved by the Research Ethics Committee of the institution before the beginning of data collection.

Eligible participants were all patients aged less than six months and recently diagnosed with glossoptosis and RS who underwent MDO during the period of study were included. Written informed consent was obtained from children's parents or legal guardians.

2.2. Diagnostic method

The diagnosis of RS was established by a multidisciplinary evaluation using the following predefined criteria:

- Respiratory dysfunction: defined as the presence of symptomatic airway obstruction at rest or during an activity, such as feeding, confirmed by PSG. Only patients with overt airway obstruction or requiring intubation or another type of ventilatory support did not undergo PSG.

- Glossoptosis: diagnosed by FFL when the child was breathing spontaneously and according to the definition of RS (Robin, 1923, 1934).

2.3. Classification of RS clinical manifestations

The grading scale for RS described by Cole et al. (2008) based on the severity of respiratory and feeding symptoms was applied to all patients pre- and postoperatively:

- Grade 1: no respiratory distress in the supine position and satisfactory feeding.

- Grade 2: intermittent symptoms of mild airway obstruction in the supine position, mild feeding difficulty, and some respiratory effort.

- Grade 3: moderate to severe respiratory distress in the supine position and inability to feed orally.

Moreover, patients were divided into three groups based on RS presentation: isolated RS, RS-plus (associated with anomalies but no specific syndrome was identified), and syndromic RS (associated with a syndrome) (Tan et al., 2013).

2.4. Endoscopic evaluation and grading scales for airway obstruction

FFL was performed in all patients in the supine position with administration of sevoflurane and/or propofol by a pediatric anesthesiologist. The procedure started with an anatomic evaluation through direct laryngoscopy, followed by a dynamic evaluation with progressively superficial anesthesia using a nasopharyngolaryngoscope (2.8 or 3.4 mm of diameter), which was removed when the patient woke up. All images were digitally recorded and then assessed by one of the authors, who was blinded to additional patient information. The validated grading scales proposed by Yellon (2006) and de Sousa et al. (2003) were used to assess airway obstruction in all endoscopies. All procedures were performed before and after MDO, and the second evaluation was conducted with a minimum interval of 24 weeks after surgery.

The grading scale of Yellon (2006) is divided as follows:

- Grade 0: normal airway.

- Grade 1: prolapse of the epiglottis against the posterior pharyngeal wall but with normal position of the tongue.

- Grade 2: prolapse of the epiglottis and base of the tongue with only the epiglottic tip visible and obliteration of the vallecula.

- Grade 3: total prolapse of the tongue against the posterior pharyngeal wall with no portion of the epiglottis visible.

The grading scale of de Sousa et al. (2003) establishes the following:

- Grade 1: posterior displacement of the tongue, but most of the time the tongue does not touch the posterior pharyngeal wall.

- Grade 2: the posterior region of the tongue touches the posterior pharyngeal wall, but does not press it.

- Grade 3: the posterior region of the tongue presses the posterior pharyngeal wall and sometimes the tongue remains in the nasal cavity.

2.5. Polysomnographic analysis and parameters

All polysomnographic parameters were assessed before and after MDO. The tests were performed in a sleep laboratory, and reports were done by a specialist in paediatric sleep

medicine. Postoperative PSGs were performed at least 24 weeks after MDO. The following parameters were evaluated: apnea-hypopnea index (AHI), total sleep time (TST), oxygen desaturation nadir (ODN), oxyhemoglobin saturation index (OSI), and oxygen desaturation index (ODI).

2.6. Statistical analysis

The number of patients undergoing MDO during the study period determined the sample size. Variables were described according to their distribution. Continuous variables were tested for normality with the Shapiro-Wilk test and described as mean and standard deviation (normal distribution) or median and interquartile range or absolute range (asymmetrical distribution). Categorical variables were reported as total and absolute frequency. For paired comparisons between parameters measured before and after MDO, the paired Student's t-test or Wilcoxon signed rank test was used. To assess correlations between continuous variables, the Spearman's correlation coefficient was applied. A level of significance of 0.05 was used in the study. The SPSS software package, version 22.0, was used for statistical analysis (IBM SPSS Statistics for Windows, Armonk, NY, USA).

3. Results

Of the 80 patients followed during the study period, 38 met the inclusion criteria and were analyzed. The baseline characteristics of the included patients are shown in Table 1. During the entire study period, seven patients (18.9%) underwent tracheostomy. Of these, two patients

underwent tracheostomy intraoperatively due to difficult airway. The two endoscopic grading scales showed a statistically significant postoperative improvement, and symptom severity scores decreased postoperatively ($P < 0.001$), as presented in Table 2.

A comparison of polysomnographic parameters before and after MDO is described in Table 3 and in Figure 1. There was a significant variation in AHI ($P < 0.001$), TST, ODN, and ODI ($P < 0.05$). OSI did not show a statistically significant change.

Correlations between variables are shown in Table 4. There was a statistically significant correlation between the two endoscopic scales and the symptom severity scale postoperatively ($P < 0.05$). Conversely, as described in Table 5, postoperative polysomnographic parameters did not correlate with any scale ($P > 0.05$).

MDO was not associated with fatal complications in our sample. Seventeen (44.73%) patients showed complications in the first 14 postoperative days. Of these, 10 (26.31%) patients had pneumonia requiring parenteral treatment, three (7.89%) presented with bleeding not requiring blood transfusion, one (2.63%) lost the distractor early, and one (2.63%) had cellulite. One patient had cardiopulmonary arrest during surgery, which was readily reversed, none required surgical reintervention.

4. Discussion

The use of MDO as a treatment for RS began in 1992 with McCarthy (Evans, 2006). Since then, several authors have reported a high success rate of this surgery in selected patients, as it resulted in decreased AHI levels measured by PSG postoperatively in patients without

tracheostomy (Monasterio, 2002) and in an increased chance of decannulation in those with tracheostomy (Greathouse et al., 2016; Preciado et al., 2004). In a recent meta-analysis, Ow & Cheung (2008) found a 91% prevention rate of tracheostomies among neonates who underwent MDO as an initial surgical procedure, and a 78% decannulation rate in pediatric and adult patients with tracheostomy who underwent surgery subsequently.

Regarding the airway patency of children with RS who underwent MDO, Olson et al. (2011) demonstrated an increase in the supraglottic space correlated with a clinical improvement in 16 patients. This measurement, however, was performed using direct laryngoscopy, a method that is not considered optimal for the assessment of glossoptosis because in this procedure the base of the tongue is supported by the laryngoscope. Furthermore, Izadi et al. (2013) used FFL to assess airway patency and reported a subjective postoperative improvement in glossoptosis in children with RS without the use of endoscopic grading scales. Preciado et al. (2004) described an improvement in airway patency in five children with cerebral palsy who underwent MDO using the percentage of airway obstruction, a method that we consider difficult to apply to the obstruction caused by the base of the tongue.

Regarding the assessment of obstructive sleep apnea (OSA) in patients with RS, Monasterio et al. (2004) and Genecov et al. (2009) showed an improvement in post-MDO polysomnographic parameters in 18 and 67 patients, respectively. The improvement in PSG found in the present study probably reflects a greater airway patency after MDO and its positive effect on the treatment of OSA (Cheng et al., 2001; Genecov et al., 2009; Monasterio et al., 2002).

However, MDO is still considered a controversial surgical treatment (Kirschner et al.,

2003; Schaefer et al., 2004). Advocates of other treatment modalities criticize the morbidity rate associated with this technique, its long-term effects on mandibular growth, the excessive caution with the position of distractors, the possible aesthetic sequelae, and even the efficacy of the procedure (Sahoo et al., 2016; Schaefer et al., 2004). Thus, further studies are required. The complications of MDO found in our study are inherent to a patient population with severe craniofacial abnormalities who underwent corrective surgery.

To our knowledge, no previous study had performed a clinical, polysomnographic and endoscopic assessment of children before and after MDO. Moreover, no study had used specific grading scales to measure the airway patency of these patients. In the present study, a significant improvement was found in all these assessments, as demonstrated by a decrease in airway obstruction and symptom severity, as well as by the mean variations in polysomnographic parameters (AHI: 12 points; TST: 94.6 points; ODN: 4 points; ODI: 13.8 points). This certainly represents a substantial reduction in the known effects of OSA on children's cardiovascular system, growth and intellectual development.

Furthermore, the correlation between symptom severity and endoscopic scales after MDO in patients with RS had not been assessed either. It should be noted, though, that such correlation had been previously proved to be significant at the baseline evaluation in a previous study (Manica, 2016). In the present study, there was a significant correlation between symptoms and endoscopic scores for glossoptosis, which shows that the available grading scales are also useful to evaluate children after surgery.

Preoperative polysomnographic parameters, however, did not significantly correlate with scores in the grading scales of Yellon (2006), Cole et al. (2008) and de Souza et al. (2003).

This was probably due to the small number of patients in the present study.

A limitation of the present study is that we could not assess swallowing in all patients due to restrictions of hospital resources. Furthermore, optimally, having a control group would allow us to measure the improvement caused simply by the child's growth.

5. Conclusion

MDO seems to be an effective surgical option for children, as shown by postoperative improvements in clinical symptoms, endoscopic grading scales, and polysomnographic parameters.

Comparative studies of different treatments must be conducted in order to define and establish the best option for the management of patients with RS. This should be done preferably through the assessment of clinical symptoms, polysomnographic parameters, and endoscopic grading scales for glossoptosis, so that children are thoroughly evaluated before and after surgery.

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Conflict of interest

None.

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Table 1
Characteristics of the population (n = 38)

Variable	Patients
Age (days)	45 (17-129)
Male	23 (60.5%)
Grading scale of Cole et al. (2008)	Grade 1: 11 (28.9%)
	Grade 2: 11 (28.9%)
	Grade 3: 16 (42.1%)
Genetic classification	Isolated RS: 15 (39.5%)
	RS-plus: 10 (26.3%)
	Syndromic RS: 13 (3.2%)
Nasogastric tube/gastrostomy	20 (52.6%)
Tracheostomy[a]	7 (18.9%)
Cleft palate	12 (31.6%)

[a] Of these, 2 patients underwent tracheostomy intraoperatively due to difficult airway.
Continuous variables are described as median and the 25th and 75th percentiles (in parentheses).
Categorical variables are described as number of patients (n) and percentage (%).
RS, Robin sequence.

Table 2
Comparison of endoscopic and clinical scores before and after MDO

Variable	Pre-MDO Mean	CI	Post-MDO Mean	CI	P-value
Endoscopic grading scale of Yellon (2006)	2.19	1.99-2.38	1.16	0.85-1.47	< 0.001
Endoscopic grading scale of de Sousa et al. (2003)	1.56	1.33-1.78	0.92	0.70-1.14	< 0.001
Symptom grading scale of Cole et al. (2008)	2.20	1.98-2.42	0.81	0.35-1.28	< 0.001

CI, confidence interval; MDO, mandibular distraction osteogenesis.

Table 3

Comparison of polysomnographic scores before and after MDO

Variable	Pre-MDO Median	IQR	Post-MDO Median	IQR	P-value
AHI	14.4	5.2-33.6	2.4	1.6-4.9	< 0.001
TST[a]	245.3	112.4	339.9	109.6	0.03
ODN	82	74.5-86.5	86	81.75-90.5	0.01
ODI	20.1	7.4-30.3	6.3	1.7-21.5	0.04
OSI	96.15	95.1-97	97	96-97	0.62

Data are expressed as median and interquartile range (IQR) because of their asymmetrical distribution.

[a] TST scores are expressed as mean and standard deviation.

AHI, apnea-hypopnea index; IQR, interquartile range; MDO, mandibular distraction osteogenesis; ODI, oxygen desaturation index; ODN, oxygen desaturation nadir; OSI, oxyhemoglobin saturation index; TST, total sleep time.

Table 4
Correlations between clinical and endoscopic scales after MDO

Variable 1	Variable 2	Correlation coefficient[a]	P-value
Grading scale of Yellon (2006)	Grading scale of Cole et al. (2008)	0.55	0.003
Grading scale of Sousa et al. (2003)	Grading scale of Cole et al. (2008)	0.45	0.01

[a] Spearman's correlation coefficient for ordinal values: grading scales of Yellon (2006), de Souza et al. (2003) and Cole et al. (2008).
MDO, mandibular distraction osteogenesis.

Table 5
Correlations between polysomnographic parameters and endoscopic and clinical grading scales

Variable 1	Variable 2	Correlation coefficient[a]	P-value
AHI	Grading scale of Sousa et al. (2003)	0.24	0.27
AHI	Grading scale of Yellon (2006)	0.25	0.25
ODI	Grading scale of Cole et al. (2008)	0.03	0.89
AHI	Grading scale of Cole et al. (2008)	0.23	0.35

[a] Spearman's correlation coefficient for ordinal values: grading scales of Yellon (2006), de Souza et al. (2003) and Cole et al. (2008).
AHI, apnea-hypopnea index; ODI, oxygen desaturation index.

CAPTIONS TO ILLUSTRATIONS

Fig. 1. Boxplot showing variations in polysomnographic parameters before and after mandibular distraction osteogenesis (MDO): A) Variation in apnea-hypopnea index (AHI); B) Variation in oxygen desaturation index (ODI); C) Variation in oxygen desaturation nadir (ODN); D) Variation in oxyhemoglobin saturation index (OSI); E) Variation in time spent under 90% oxygen saturation; F) Variation in total sleep time (TST).