Role of MRI in Detection of Repaired Cleft Palate Muscles and Correlation to Speech

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ABSTRACT

Background: Cleft palate is a birth defect when the roof of the mouth contains an opening into the nose. It occurs in about 1:2 per 1000 births. These disorders can result in speech disorders, feeding problems and frequent ear infections. It is the result of tissues of the face not joining properly during development. Speech therapy and dental care may also be needed. Approximately 30 percent of patients having undergone cleft palate repair require secondary surgery for velopharyngeal dysfunction. Magnetic resonance imaging (MRI) is one of the common used tests in variable fields of medicine and surgery. Now trials are done for use of MRI in the postpalatoplasty velopharyngeal dysfunction patients. **Objective**: This study aims to detect static craniofacial and velopharyngeal measures of repaired cleft palate patients specially repaired muscle state (levator veli palatini muscle) by using MRI and correlate these data to speech state.

Patients and Methods: this prospective study conducted in AlAzhar and Beni-suef University Hospitals in the period of February 2018 till November 2018. It is conducted on twenty children who complained of post-palatoplasty velopharyngeal dysfunction and examined by nasendoscopy and speech analysis then MRI palate was done using 1.5 T MRI; to correlate MRI data to speech data. **Results**: our statistical results revealed significant decrease in the velopharyngeal variants than normal ranges. That prove that static MRI is a valid procedure for diagnosis of anatomical abnormality. But after correlation with speech data it showed that it should be accompanied with dynamic procedure (e.g. Nasendoscopy) especially in patients with normal ranged anatomy.

Conclusion: this study was done in variant range of children who suffer from post-palatoplasty speech abnormality, scanned by MRI palate and correlate these data by speech data. Static MRI is efficient technique to demonstrate structural defects in these patients.

Keywords: - MRI, Speech, Velopharyngeal Dysfunction, Cleft Palate.

INTRODUCTION

Cleft palate is a birth defect when the roof of the mouth contains an opening into the nose. It occurs in about 1:2 per 1000 births. These disorders can result in speech disorders, feeding problems and frequent ear infections [1]. It is the result of tissues of the face not joining properly during development. Speech therapy and dental care may also be needed. Approximately 30 percent of patients having undergone cleft palate repair require secondary surgery for velopharyngeal dysfunction [2, 3].

The basic morphology of the face is established between the 4th and 10th weeks of human development. The face is formed as a result of fusion of the midline frontonasal prominence and three paired prominences; the maxillary, lateral nasal, and mandibular prominences. Each of these prominences is filled with cranial neural crest cells that originated at different positions along the neural tube. Disruptions in the rate, the timing, or the extent of outgrowth of the facial prominences can all result in facial clefting [4].

Normal speech is dependent upon the functional and structural integrity of the velopharynx. Normal velopharyngeal closure is accomplished by the coordinated action of the velum, the lateral pharyngeal walls, and the posterior pharyngeal wall. These structures function as a valve that serves to close off the nasal cavity from the oral cavity during speech, whistling and swallowing. The velopharyngeal valve regulates and directs the transmission of sound energy and airflow in the oral and nasal cavities. The valve opens for nasal breathing and production of nasal sounds. Dysfunction of the velopharyngeal valve may lead to hypernasality, nasal air emission and compensatory articulation errors [5].

The normal palate serves several important functions, the main aim for palate repair is normal speech and consideration of cleft palate surgery must balance developmental, dentofacial growth and otologic issues as well [6]. The primary goal of surgical management of VPI cases is to produce a

Received:5/9/2018
Accepted:24/9/2018

competent velopharyngeal mechanism while avoiding the complications [7]. The surgeon should elicit a thorough history, carefully assessing each patient for prior surgery on the palate, velopharynx, tonsils and adenoids. In addition to the perceptual speech evaluation, careful physical examination should be performed in all patients who may be candidates for surgical management of the velopharynx [8].While surgery is the preferred treatment option for most cases of VPD, Behavioral speech treatment may be appropriate for a select set of patients for whom surgery is not possible or not desired [7].

Magnetic resonance imaging (MRI) is one of the common used tests in variable fields of medicine and surgery [9]. Two factors arise with regard to the reconstructed musculature for speech purposes following primary palatal surgery; the sufficient muscle mass to provide adequate velar elevation, assuming that the musculature is properly repositioned across the midline and if the repositioned musculature remain in its new position without drifting to a less favorable position [10]. Midsagittal image plane was determined as the image most clearly depicting the velar midline as noted by the presence of the anterior nasal spine, posterior nasal spine, maximum velar length [11]. The oblique coronal image plane used for measurements was determined by rotating the oblique slice, placing the slice through the bulk of the velar eminence and in the plane which shows the levator muscle from origin to insertion [11]. Craniofacial measures obtained included cranial breadth (used as a covariate), face width, face height (nasion to menton), nasion to sella, sella to basion, nasion-sella-basion angle, palate height, and palate width [12]. Velopharyngeal measures included effective velar length, pharyngeal depth, length of the levator muscle, distance between levator muscle origins, angles of origin, sagittal angle, velar length, velar thickness, and midline adenoid size (anterior-to-posterior depth) [12].

AIM OF THE STUDY

This study aims to detect static craniofacial and velopharyngeal measures of repaired cleft palate patients specially repaired muscle state (levator veli palatini muscle) by using MRI and correlate these data to speech state.

PATIENTS AND METHODS

This study conducted in Egypt at Al Azhar and Beni-Suef University Hospitals, starting in February 2018 to November 2018 which included 20 cases who were suffering from post-palatoplasty velopharyngeal dysfunction.

Inclusion criteria: subject with repaired cleft soft palate or repaired submucous cleft palate, and aged at least 3 years old.

Exclusion Criteria: - Age less than 3 years old, velopharyngeal incompetency e.g.: (motor neuron disease, myotonias)**,** mentally retarded uncooperative patients**,** and non-VPD patients i.e.:- oro nasal fistula.

METHODS

All patients who suffer from post-operative speech deformity were evaluated by: - Subject and parents interview, MRI imaging, speech analysis which included (simple tests, auditory perceptual speech analysis and nasoendoscopy). **The study was approved by the Ethics Board of Al-Azhar University.**

MRI

MRI procedures were conducted at Al Azhar University Hospitals. Sedation was given to children who were uncooperative.1.5 T MRI imaging system was used to perform the procedure. A commercially available head coil was used to acquire more accurate images. Each patient was placed in the standard supine position with his/ her head perpendicular to the table. T2 weighted sagittal scan images were initially included to confirm the field of oblique coronal images and accurate analysis of measurements from sagittal plane. T2 weighted oblique coronal images were done with angle perpendicular to the velar plane obtained from sagittal images to view levator veli palatini muscle measurements. T2 weighted coronal scan images finally were done to view coronal measurements.

MRI Image analysis

MRI images were analyzed to obtain following measures as described in **Ruotolo et al., 2006 [13] and Perry et al., 2018 [12].**

1- **Sagittal measures :- A-Cranial measures:- (** Face Height, Anterior cranial base angle, Nasion to sella, Sella to basion and Sagittal angle) **B-Velar measures:- (**Hard Palate Length, Velar Length, Velar Thickness, Osseous Pharyngeal Depth, Pharyngeal Depth, Effective velar length and Adenoid Thickness)
2- **Coronal measures:- A-Cranial measures:- (**Maximum Head Diameter, Face Width, Palate Width and Palate Height) **B-Velar Measures:- (**Length Of levator veli palatini

muscle, Thickness of levator veli palatini muscle, Angle of origin and Distance between origin to origin).

Speech evaluation

A-Simple clinical tests:-Gutzman's (A-I) test and Czermark's (cold mirror) test [5].

B-**Auditory perceptual speech assessment**

It should be documented by high fidelity audio recording and analyzed as following:

Table 1: Auditory perceptual speech assessment scale [5]

Degree of open nasality	0	1	2	3	4
Imprecision of consonants	0	1	2	3	4
Compensatory glottal articulation	0	1	2	3	4
Pharyngealization of fricatives	0	1	2	3	4
Audible nasal emission of air	0	1	2	3	4
Overall intelligibility	0	1	2	3	4
Nasal grimace	0	1	2	3	4

C-Visual assessment of vocal tract by nasopharyngeal video-fibroscopy

It is useful method to visualize vocal tract and record important findings and analyze them as following:

Table 2: nasopharyngeal video-fibroscopy scale (5)

Velar morphology					
Degree of velar movement	0	1	2	3	4
Right Pharyngeal wall movement	0	1	2	3	4
Left pharyngeal wall movement	0	1	2	3	4
Posterior Pharyngeal wall movement	Present		Absent		
Adenoids	Present		Absent		
Velopharyngeal gap shape	Coronal	Circular	Sagittal	Others	

Statistical analysis

Analysis of data was performed using SPSS v. 22 (Statistical Package for Social science) for Windows.

Description of variables was presented as follows: Description of quantitative variables was in the form of mean, standard deviation (SD), minimum and maximum; Description of qualitative variables was in the form of numbers (No.) and percent's (%).

One sample t-test was used to detect difference between the normal parameters and patient parameters; Pearson correlation was used to correlate between scale data and (r) correlation coefficient was either positive (+) or negative (-) and ranged from 0 to 1

RESULTS

Patients' age was 5.45±1.76 years ranged from 3 years to 9 years with median equal 5 years .This study included 9 (45%) males and 11(55%) females

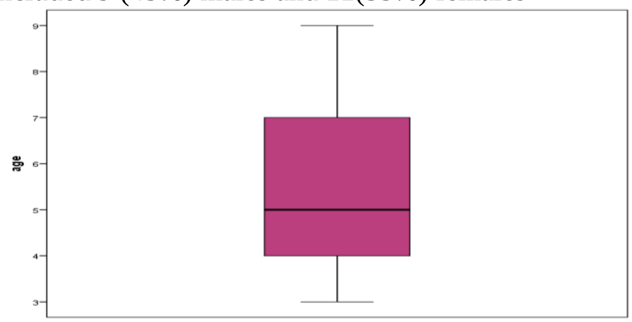


Fig 1 Box plot describes patients' age

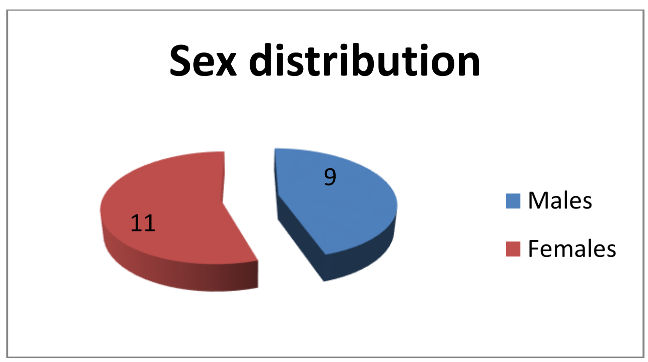


Fig 2 Sex distribution of patients under the study

Table 3 illustrates that patients in the study were significantly lower than normal values in all parameters except face height, nasion to sella, ossified pharyngeal depth¸ pharyngeal depth, adenoid thickness, face width, palate width and angle of origin; they weren't different significantly from normal values (P-value>0.05).

Table 3: showed the description of MRI data for patients in the study as (mean, standard deviation, minimum and maximum).

MRI parameters	Mean	Std. Deviation	Min.	Max.
Face height	97.56	10.8	76	120
Anterior cranial base angle (ACBA)	110.9	8.8	97	130
Nasion to sella	62.6	4.6	52	70
Sella to basion	41.9	1.8	40	45
Sagittal angle	48.7	12.9	0	65
Hard Palate Length	38.7	4.9	26.3	47.5
Velar length	16.4	6.1	0	29
Velar thickness	5.6	2.3	0	10
Osseous Pharyngeal depth	37	8.3	22	52.7
pharyngeal depth	20.9	5.6	9	32.2
effective velar length	7.9	3.4	0	13
adenoid thickness	8.8	3.5	0	14.8
Maximum head diame	135.6	18.2	97	168
face width	109.7	18.9	65	145
palate width	35.9	9.5	18.5	54.3
palate height	8.7	2.4	5	12.5
Levator muscle length	36.4	5.2	25	46
Right levator muscle thickness	3.2	0.79	2	5
Left Levator muscle thickness	3.2	0.87	1.5	5
Centre levator muscle thickness	1.2	1.4	0	4.5
Centre defect	4.2	4.9	0	16
Angle of origin	57.8	4.6	50	70
origin to origin	52.6	4.9	45	66

Table 4 demonstrated that most of patients under the study had symmetrical muscle limbs 14 (70%), 3 (15%) had larger right limb and 3 (15%) had larger left limb.

Table 4: Muscle slings state

Muscle symmetry	**Frequency 20**	**Percent 100%**
Both limbs of muscle are symmetrical	14	70
The right limb is larger	3	15
The left limb is larger	3	15

Table 8 showed that there were 9 patients (45%) had intact muscle and 11 patients (55%) defective muscle.

Table 5: Muscle defect description

Muscle defect	**Frequency**	**Percent**
Defective muscle	11	55
Intact muscle	9	45
Intact muscle parameters 9 (45%)		
Mean	2.6	
SD	0.8	
Range (min-max)	(2-4.5)	

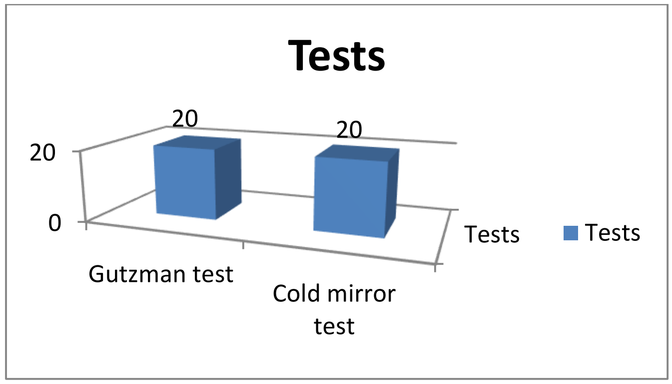


Fig 3: Gutzman test and cold mirror test

All cases under the study had positive Gutzman's test and cold mirror test 20 (100%).

Table 6: Description of speech parameters of patients under the study

Speech parameters	**Mean**	**Std. Deviation**	**Min.**	**Max**
Degree of open nasality	2.95	1.099	1	4
Imprecision of consonants	2.00	1.124	0	4
Compensatory glottal articulation	1.65	1.226	0	3
Pharyngealization of fricatives	.15	.366	0	1
Audible nasal emission of air	.85	.813	0	2
Overall intelligibility	1.90	1.165	0	3
Nasal grimace	1.45	1.356	0	4

Table 7: Description of flexible nasoendoscopic parameters of patients under the study

Flexible nasoendoscopic	Mean	Std. Deviation	Min.	Max
Degree of velar movement	1.60	.883	0	3
Right pharyngeal wall movement	1.55	.605	0	2
Left pharyngeal wall movement	1.65	.489	1	2

Table 8 showed the statistically significant correlation criteria between MRI data and speech analysis and nasoendoscopy data and shows that the **velar length** had a significant strong positive linear correlation with degree of velar movement (P-value<0.001); **velar thickness** had a significant moderate positive linear correlation with degree of velar movement and the overall intelligibility (P-value<0.05); and significant linear moderate negative correlation between degree of velar movement with the **effective velar length**, but moderate **negative** correlation between the **effective velar length** and degree of open nasality.

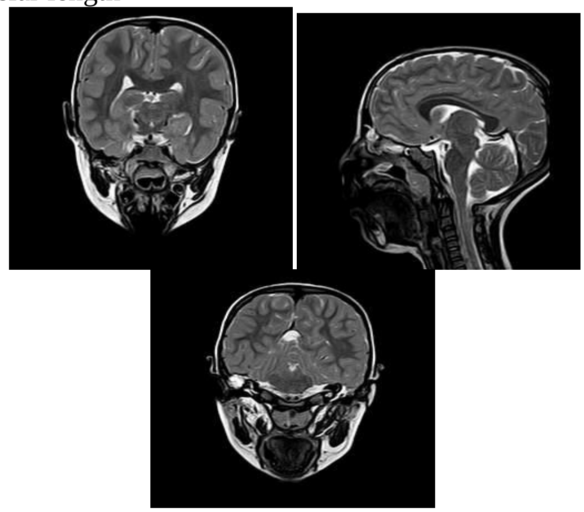
It showed that there was no significant linear correlation between the **pharyngeal depth** and speech or nasoendoscopic parameters (P-value>0.05). It showed that there was no significant linear correlation between the **levator muscle length and thickness** and speech or nasoendoscopic parameters (P-value>0.05). It showed that there was no significant linear correlation between the **LVP center defect** and speech or nasoendoscopic

Table 8 showing statistically significant correlation criteria between MRI data and speech analysis and nasoendoscopy data

		Velar Thick.	Velar Length	Effective Velar Length
Degree of open nasality	(r)	-0.289	-0.386	-0.489
	P-value	0.216	0.092	0.029
Overall intelligibility	(r)	0.459	0.437	0.270
	P-value	0.042	0.054	0.249
Degree of velar movement	(r)	0.515	0.741	0.552
	P-value	0.020	<0.001	0.018
Right pharyngeal wall movement	(r)	0.377	0.485	0.182
	P-value	0.101	0.030	0.444

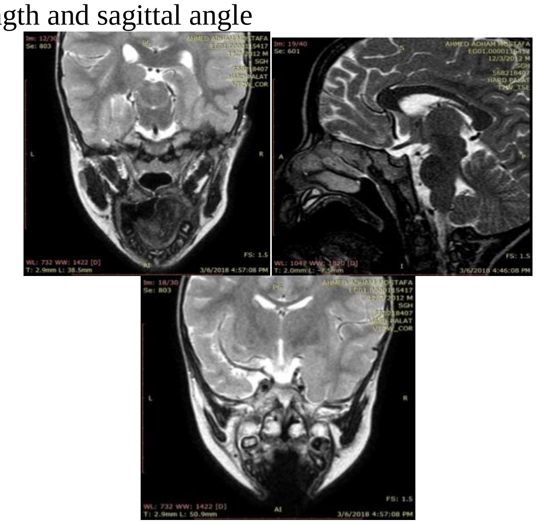
CASE 1

7 years old child with post-palatoplasty speech abnormality, his MRI showed intact muscle repair, short velum and decreased sagittal angle and effective velar length



CASE 2

5 years old child with post-palatoplasty speech abnormality his MRI showed disconnected muscle repair, short velum and decreased effective velar length and sagittal angle



DISCUSSION

This study was conducted on 20 patients complaining of speech abnormalities after palate reconstruction surgery (post-palatoplasty) to correlate between the speech abnormalities parameters and the anatomical defects measured by MRI. This study was conducted from February 2018 to November 2018 at Al Azhar and Beni-Suef University Hospitals

The patients' age was 5.45±1.76 years; ranged from 3 years to 9 years with median equal 5 years. The study included 9 (45%) males and 11(55%) females. approximately same sex percent of patients. It illustrates that patients under the study were significantly lower than normal values (P-value is significant) in all parameters except face height, nasion to sella, ossified pharyngeal depth¸ pharyngeal depth, adenoid thickness, face width, palate width and angle of origin; they didn't differ significantly from normal values (P-value>0.05); it means that static MRI is a significant tool in detecting deficient anatomical structures. It demonstrates that most of patients under the study had symmetrical muscle limbs 14 patients (70%), 3 patients (15%) had larger right limb and 3 patients (15%) had larger left limb; it means that patient may have symmetrical muscle slings but he has speech abnormality so dynamic procedures is mandatory in these cases. All cases under the study had positive Gutzman's test and cold mirror test 20 (100%) i.e.:- all cases suffer from hypernasal speech abnormality. It shows that most of patients had bad speech scores (scales) as **degree of open nasality** 8 (40%) patients had grade 4, **imprecision of consonants** 8 (40%) patients had grade 2 and **glottal articulation** 7(35%) patients had grade 3 but **the overall intelligibility** was of score 3 in 9 (45%) of patients. It shows that **most of patients** had **concave velar morphology** 10 (50%), **absent posterior pharyngeal wall movement** 15 (75%) and **circular velopharyngeal gap** shape 13 (65%). So that means static MRI can't detect various data detected by speech analysis and nasoendoscopy.

In correlation between MRI parameters and nasendoscopy and speech analysis parameters it was found that: **- The velar length** had a significant strong positive linear correlation with degree of velar movement (P-value<0.001), it means that increasing velar length will increase velar movement.

Velar thickness had a significant moderate positive linear correlation with degree of velar movement and the overall intelligibility (P-value<0.05); it means that increasing velar thickness will increase velar mobility.

There was a significant linear moderate negative correlation between the HPL and right pharyngeal wall movement (P-value=0.006), There was a significant linear moderate negative correlation with palate width (P-value=0.012); it means that optimal palatal dimensions is important in lateral wall mobility. There was a significant linear moderate negative correlation between sagittal angle and right pharyngeal wall movement, and there was a significant linear moderate negative correlation between degree of velar movement with the effective velar length, it means that accurate position of the muscle is an important factor in speech articulation.

CONCLUSION

This study proved that static MRI is an important radiological tool in diagnosis of structural VPD disorders specially it is magnetic noninvasive tool but needs to be integrated by nasoendoscopy in specific cases to view dynamic movement of velopharyngeal valve.

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