Classification of Velopharyngeal Dysfunction in Children with Cleft Palate using Cineradiographic Images

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Abstract—Cleft lip and palate is a commonly seen condition since birth. The treatment requires surgical correction in which the separated parts of lip and palate are sutured. After the surgery, the palate does not move adequately leading to a condition called velopharyngeal dysfunction (VPD). This leads to misarticulation, nasal emission of air during production of consonants and unclear speech. The present study evaluated four children with VPD using cineradiography technique. Different Kannada syllables uttered by these children are measured to identify the gap between soft palate and posterior pharyngeal wall. MATLAB program was used to analyse the image and to estimate the gap between soft palate and posterior pharyngeal wall across conditions.

Key words: Cleft lip and palate, Velopharyngeal dysfunction (VPD), Cineradiography

I. INTRODUCTION

Cleft lip and palate is a common congenital birth defect occurring due to incomplete closing of the lip and/or the palate in the early fetal growth during pregnancy. The treatment requires correction by plastic surgery. In most of the conditions, after the surgery, even though the structures appear to be normal, the function is reported to be inadequate leading to velopharyngeal dysfunction (VPD). Normal velopharyngeal closure is accomplished by the coordinated action of the soft palate, lateral pharyngeal walls and posterior pharyngeal wall [2]. These structures function as a valve that serves to close off the nasal cavity from the oral cavity during speech. During the velopharyngeal closure the posterior pharyngeal wall moves forward and this forward movement may be lesser than that of soft palate and lateral pharyngeal wall movements [3]. In individuals with velopharyngeal dysfunction, the incompletely closed velopharyngeal valve causes an inability to effectively manage the air stream for the production of speech. The speech characteristics include audible nasal air emission accompanying obstruct consonants, weak obstruct consonant production, substitution of nasal consonants for oral sounds, hypernasal resonance distortion [4],[5],[6].

There are various measures involved in the assessment of the speech in individuals with VPD. The assessment procedure provides the direct information by directly visualizing the velopharyngeal anatomy and the functions. The imaging techniques such as nasoendoscopy videofluoroscopy and cineradiography are widely used.

Cineradiography is a radiological technique that is used for evaluation of VPD. This procedure involves imaging of the movements of soft palate, posterior pharyngeal wall and tongue with several views (i.e., lateral, frontal, base, and townes view). Neely and Bradley (1964) developed a psychophysical rating scale to establish the standard procedures for the analysis of videofluoroscopic images. The variables that they included for rating are the approximation or the contact between the soft palate and the posterior pharyngeal wall, thickness of the soft palate, length of the soft palate, extent of the vertical contact between the soft palate and the posterior pharyngeal wall, location of velopharyngeal closure relative to the anterior most projection of the tubercle of the first cervical vertebra, location of the closure relative to the hard palate. In the present study MATLAB program was used to estimate the gap between soft palate and posterior pharyngeal wall using pixels.

II. SPEECH ANATOMY

Fig 1. shows the lateral view of face structures where each part is important in the functioning of normal speech.

A. Nose
Nose is used to produce nasal sounds like /n/, /m/, /ng/.

B. Tongue
During speech, all the vowels and most of the consonants require elevation, retraction and curling of tongue.

C. Hard Palate
The contact between the tongue and the hard palate is essential in the formation of speech sounds.

D. Soft Palate
To produce oral speech sounds, soft palate stretches and elevates to separate the oral cavity from the nasal cavity and touches the posterior pharyngeal wall. If this separation is incomplete, air escapes through the nose, causing speech to be perceived as nasal.

E. Alveolar Ridge
Alveolus is termed as a “reference point” where it comes in contact with tongue during speech sounds like /t/, /l/.
F. Lips
The closure and rounding of lips is essential for production of consonants and rounding of lips is important for vowel production.

G. Mandible
The mandible or lower jaw plays an active role in articulation of speech sounds. For speech, the mandible can be raised or lowered for changes in vowel articulation and resonance.

III. VELOPHARYNGEAL CLOSURE
Understanding the normal anatomy and physiology of the velopharyngeal mechanism is the first step in providing appropriate diagnosis and treatment for children with VPD. The velopharyngeal mechanism consists of a muscular valve that extends from the posterior surface of the hard palate (roof of mouth) to the posterior pharyngeal wall and includes the velum (soft palate), lateral pharyngeal walls (sides of the throat), and the posterior pharyngeal wall (back wall of the throat). The function of the velopharyngeal mechanism is to create a tight seal between the soft palate and pharyngeal walls to separate the oral and nasal cavities for various purposes, including speech. Velopharyngeal closure is accomplished through the contraction of several velopharyngeal muscles including the levator veli palatini, musculus uvulae, superior pharyngeal constrictor, palatopharyngeus, palatoglossus, and salpingopharyngeus. From the Fig 2, a normal soft palate closes off the nose from the mouth and helps to build-up the pressure needed for normal speech production especially oral consonants like /t/, /θ/, /k/, /g/. From the Fig 3, due to inadequate closure, air escapes through nose through velopharyngeal space and the speech production becomes weak and perceived as nasal.

One of the imaging techniques to assess the velopharyngeal closure is cineradiography, which provides the information about the structure and function of soft palate and posterior pharyngeal wall.

IV. CINERADIOGRAPHIC IMAGES
Fig 4. is the cineradiographic image of normal velopharyngeal closure and Fig 5. is the image of inadequate velopharyngeal closure during speech.

V. METHODOLOGY
The method to classify the velopharyngeal closure using cineradiographic images is explained in Fig 6.

The patients were seated comfortably in a normal upright position with the head held stable with the help of a head rest to obtain the x-ray image. The image was amplified by the electronic intensification, making it bright enough to be recorded in the video camera. Before starting this procedure a suspension of colloidal barium sulphate, a radio-opaque substance was instilled in the nasopharynx for better visualization of the contrast. The speech tasks considered were repetition of isolated vowels (/a/, /ɪ/, /u/) three times each and lateral view was recorded for clear observation of velar movements. The audio recording of the vowels was done simultaneously during the procedure.

A. Block Diagram

![Fig. 6: Block diagram](image_url)
From the Fig 6, the cineradiographic images of patients with VPD for different kannada syllables, before (pre-op) and after the surgery (post-op) are given as inputs in MATLAB. The space present between the soft palate and pharyngeal wall in the velopharyngeal closure is calculated. Comparing the values of both pre-op and post-op images, the severity of the velopharyngeal gap is classified as classified as mild, moderate or severe using reference database classification. The implementation is using MATLAB 7.8(2009a) tool.

### Method of Calculation in MATLAB

Using MATLAB, the length between the soft palate and pharyngeal wall is calculated. First, two reference points ‘A’ and ‘B’ are considered because of their less mobility during speech. ‘A’ is a point on the first cervical vertebra and ‘B’ is a point at the end of the hard palate or starting of the soft palate.

Point ‘C’ is taken at two - third of the length of the soft palate because approximately two - third of soft palate is the point of contact to the pharyngeal wall.

Using three points, three lines are drawn where the third line, ‘AC’, gives the length of velopharyngeal gap in pixels.

Similarly, the different images can be used to calculate the space present in velopharyngeal closure for different kannada syllables of different patients. From the Fig 7, three lines are drawn with points on the starting of the soft palate, two – third length of the soft palate and first cervical vertebra. The line AC gives the space present in the velopharyngeal closure in pixels.

### RESULTS

The images obtained by the cineradiography is analysed using MATLAB program. The distance between soft palate and posterior pharyngeal wall was calculated. The following table provides the gap between pre and post operation conditions in pixels.

<table>
<thead>
<tr>
<th>Case 1 12 year, F</th>
<th>Case 2 6 year, M</th>
<th>Case 3 9 year, M</th>
<th>Case 4 10 year, M</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-op (pixels)</td>
<td>Post-op (pixels)</td>
<td>Pre-op (pixels)</td>
</tr>
<tr>
<td>ka</td>
<td>53.09</td>
<td>58.35</td>
<td>65.98</td>
</tr>
<tr>
<td>ga</td>
<td>55.07</td>
<td>51.03</td>
<td>56.27</td>
</tr>
<tr>
<td>ta</td>
<td>55.05</td>
<td>53.89</td>
<td>57.79</td>
</tr>
<tr>
<td>da</td>
<td>56.06</td>
<td>55.56</td>
<td>62.04</td>
</tr>
<tr>
<td>tha</td>
<td>54.28</td>
<td>53.41</td>
<td>58.78</td>
</tr>
<tr>
<td>dha</td>
<td>55.79</td>
<td>53.19</td>
<td>56.23</td>
</tr>
<tr>
<td>pa</td>
<td>54.63</td>
<td>54.34</td>
<td>63.72</td>
</tr>
<tr>
<td>ba</td>
<td>55.15</td>
<td>54.63</td>
<td>55.03</td>
</tr>
</tbody>
</table>

Table 1: The Values Calculated Of Velopharyngeal Gap

<table>
<thead>
<tr>
<th>Range in pixels</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 30</td>
<td>Mild</td>
</tr>
<tr>
<td>31 - 70</td>
<td>Moderate</td>
</tr>
<tr>
<td>Above 70</td>
<td>Severe</td>
</tr>
</tbody>
</table>

Table 2: Classification Of Severity

Using Table II and the post - op values from Table I, the severity of Case 1, Case 2 and Case 3 are classified as moderate and Case 4 is classified as mild.

### CONCLUSION

Cleft lip and cleft palate are usually caused by a combination of genes or when the mother comes in contact with the environment or what the mother eats or drinks during pregnancy. The cleft lip and palate in India is estimated approximately one in 781 births [1]. With proper diagnosis of children in the right time, speech disorder for the cleft lip and palate children can be reduced. The MATLAB software is used to find the velopharyngeal gap and correlated with perception of nasality by speech language pathology and result helps to decide the line of treatment. The presence of significant difference can be analysed using descriptive statistics.
REFERENCES


