The study on the acoustic features of congenital velopharyngeal insufficiency

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Purpose: To study the acoustic features of the patients with congenital velopharyngeal insufficiency (CVPI).

Materials and Methods: The acoustic features of 28 patients with CVPI were analyzed with the computer speech lab, and compared with the features of 20 controls.

Results: It was not the same on each syllable; from phonetic images, F1, F2 and F3 of the controls were clearer than those of the patients, the other districts of the controls were lighter than those of the patients. F1 of the patients was darker and broader, their F2 and F3 were lower, weaker and broader. Among F1, F2 and F3 of the patients, there were some extra formants. Erected stripes and fills before the vowel of the patients were fewer than those of the controls.

Conclusion: There were apparent distinctions in F2, B2, F3 and B3 between the patients and the controls, and there was significant difference in phonetic images between the two groups, especially in Formants, and consonants. **(Int Chin J Dent 2003; 3: 105-110.)**

Clinical Significance: The results of the current study demonstrate that the patients with CVPI have the significant differences with the normal in speech, which will help to determine the status of the patient before and after surgery.

Key Words: acoustic features, congenital velopharyngeal insufficiency, misarticulation.

Introduction

Congenital velopharyngeal insufficiency (CVPI), also called Sedlackova syndrome, Shprintzen syndrome and Velocardiofacial syndrome in the literature, is a special entity among velopharyngeal insufficiencies. It is featured by hypernasality without overt oropharyngeal anatomical anomalies, therefore often overlooked clinically. In this study, computer speech lab (CSL) was used to quantitatively analyze the misarticulation in patients with CVPI, to clarify the particular Chinese formant, the time of vocalism and the phonetic images, in order to provide a basis for speech therapy of these patients.

Materials and Methods

Twenty-eight cases with CVPI were selected from the Department of Oral and Maxillofacial Surgery, Ninth People's Hospital, Shanghai Second Medical University between June 1999 and January 2001. Among them, 13 were male, 15 were female. Their age ranged from six to 25 years with an average of 13.33 years. All the included patients were with normal mentality and audition. They were also proficient in Mandarin Chinese without any speech therapy before. During recording, no patients had common cold, inflammation of oropharynx and nose, which could affect articulation.

Twenty students from the primary and middle schools of Shanghai served as the control group. Of them, 10 were male and 10 were female. The age range was from six to 19 years with an average of 12.35 years. No disorders that could influence articulation were found while recording.

The recording room was soundproof room in accordance with the standard of International Acoustics Association. CSL4300B was produced by KAY Company, USA. Word Test Table of Phonetics Intelligibility for Mandarin Chinese was developed by us and accepted nationally.

The patients were in sitting position and relaxed naturally 5 cm away from the microphones. The following sensitive aspirates /zi/, /ci/, /si/, /ji/, /qi/, /xi/ were practiced five times, and then input into CSL4300B. The samples collected were 10,000 Hz in frequency, 300 Hz in strip width and 12 in LPC order. The Pitch, Formant of F1, F2, F3 and Band were measured and averaged. Analysis of variance (ANOVA) was performed using SPSS10.0 software.

The experiment flow was as follows: 1) the subjects, 2) microphone, 3) CSL, 4) preservation of the collected sound samples, 5) imaging of the tested aspirates, 6) detection, and 7) evaluation.

Results

The acoustic parameters of the selected sounds were shown in Table 1. The comparison of the acoustic parameters between the control group and CVPI patients was shown in Table 2. The normal sonagram in human and the sonagram in CVPI patients were shown in Figs. 1 to 4.

From Table 1 and Table 2, it was noted that the differences between the patients group and the control group were principally in F2, B2, F3, and B3 ($p<0.05$). F2, F3 and VOT in the control group were significantly greater than those in the patients group, while B2 and B3 was significantly lower than those in the patients group. For each aspirate, there was still difference between the two groups.

From Figs. 1 to 4, it could be seen that F1, F2 and F3 in the control group were distinct with fewer darkness and intensive power. The erected stripes and fills were remarkable, and the time of consonants phonation was longer. In the patients group, F1 was darker and broader; F2 and F3 were unclear, lower, weaker and broader. Some darker power concentrations were present among formant, resulting in extra formants. Erected stripes and fills before the vowels of the patients were fewer than those in the controls.

Discussion

Clinical Features of CVPI

CVPI is one kind of velopharyngeal insufficiencies. The clinical manifestations of CVPI are complex, often accompanying congenital systemic malformations such as inherited cardiovascular disorders.[1]

Patients usually had aponea1 with the IQ ranging from 55 to 87.[2] Most CVPI patients were with an idiosyncratic countenance including eye extenuation, hypercanthus, and bilateral flat suborbit. Fifteen patients in this report had a typical appearance. Patients with typical countenance resemble each other and seem to have sibship. In 1970s, it was determined to be autosomal dominant heredity with mutation in 22q11. In this series, two patients had congenital cardiovascular diseases concomitantly. The IQ in this series was between 44 and 109 with an average of 67, slightly lower than the normal.

Table 1. Acoustic parameters of selected sound.

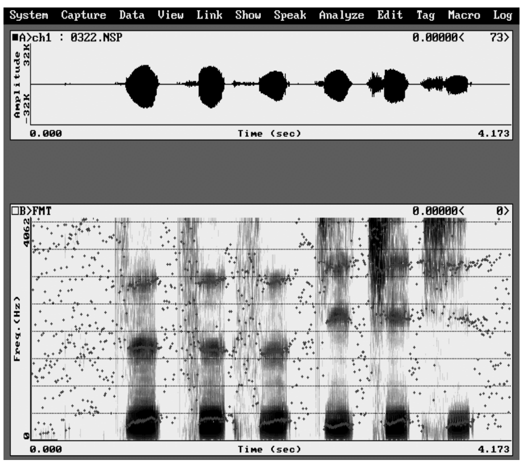
Sound	Sex		No.		Age (y)	F1 (Hz)	B1 (Hz)	F2 (Hz)	B2 (Hz)	F3 (Hz)	B3 (Hz)	Pitch (Hz)
/zi/	M	Normal	10	Mean	12.95	319.85	59.27	1,529.12	60.88	2,636.46	76.58	160.46
				SD	1.55	32.77	13.85	91.60	18.74	306.54	21.91	22.91
		CVPI	13	Mean	13.79	303.86	51.79	1,485.29	128.14**	2,136.07*	112.64 *	192.86
				SD	5.74	25.47	18.79	418.83	63.11	205.17	38.26	61.72
	F	Normal	10	Mean	11.37	329.68	60.58	1,743.61	99.55	1,911.82	82.18	251.50
				SD	1.83	32.57	24.37	106.53	44.29	227.71	25.70	38.37
		CVPI	15	Mean	11.86	385.50	81.18	1,343.18**	155.79**	2,186.93*	115.43*	245.50
				SD	4.24	89.58	30.91	439.47	49.54	220.74	36.02	50.36
/ci/	M	Normal	10	Mean	12.95	347.42	64.08	1,510.50	65.65	2,682.69	85.50	156.77
				SD	1.55	42.57	12.11	86.88	12.70	185.45	19.55	23.30
		CVPI	13	Mean	13.79	326.93	67.14	1,576.29	117.50*	1,923.50**	122.50*	205.50
				SD	5.74	62.80	21.07	445.74	39.84	159.11	43.23	63.51
	F	Normal	10	Mean	11.37	360.53	71.55	1,758.89	113.45	2,059.00	89.58	254.47
				SD	1.83	42.98	26.13	90.15	40.65	403.97	24.08	31.91
		CVPI	15	Mean	11.86	384.57	81.50	1,534.57*	143.29*	2,215.36	116.50	248.50
				SD	4.24	89.04	37.48	385.95	43.14	301.66	34.29	41.06
/si/	M	Normal	10	Mean	12.95	323.88	63.50	1,500.85	78.69	2,748.27	99.85	155.92
				SD	1.56	32.90	11.75	83.08	11.92	137.97	23.75	20.29
		CVPI	13	Mean	13.79	332.36	63.36	1,531.64	128.79**	2,079.21	120.43	186.42
				SD	5.75	83.46	19.30	427.60	32.95	329.50	32.51	58.21
	F	Normal	10	Mean	11.37	355.79	66.89	1,732.53	119.13	2,097.97	95.50	241.37
				SD	1.84	58.02	25.89	98.81	37.19	400.15	33.90	43.64
		CVPI	15	Mean	11.86	372.93	79.89	1,421.29**	145.29 *	2,189.71	113.93	248.89
				SD	4.25	81.46	39.08	395.51	41.87	345.57	39.34	41.50
/ji/	M	Normal	10	Mean	12.95	272.04	47.00	2,140.88	66.85	2,953.27	92.08	157.81
				SD	1.56	18.71	10.58	140.35	21.30	214.35	15.97	21.51
		CVPI	13	Mean	13.79	286.00**	44.57**	1,414.64**	163.21**	2,756.79**	116.75	258.21
				SD	5.75	25.50	19.05	606.47	44.44	369.47	35.77	27.97
	F	Normal	10	Mean	11.37	301.37	43.13	2,142.47	114.63	2,582.00	90.21	253.89
				SD	1.84	25.16	21.37	512.34	47.94	232.00	25.85	32.06
		CVPI	15	Mean	11.86	343.93**	59.43**	1,546.68**	162.14	2,490.07	114.57	228.07
				SD	4.25	58.20	21.15	491.53	38.45	365.46	26.04	66.68
/qi/	M	Normal	10	Mean	12.95	293.35	51.46	2,071.81	85.58	2,918.50	88.19	156.23
				SD	1.56	29.88	11.60	174.95	19.34	204.71	10.46	21.85
		CVPI	13	Mean	13.79	290.00	48.43	1,350.36**	170.64 **	2,536.57*	130.79**	229.21**
				SD	5.75	26.42	19.89	626.67	50.62	330.75	44.50	66.70
	F	Normal	10	Mean	11.37	310.24	46.53	2,075.63	127.58	2,775.95	93.13	252.53
				SD	1.84	28.53	23.09	538.23	37.54	335.22	24.55	33.44
		CVPI	15	Mean	11.86	353.89*	67.93	1,441.71**	152.21	2,792.29	126.82	258.11
				SD	4.25	67.57	30.50	557.94	41.07	278.64	37.69	23.33
/xi/	M	Normal	10	Mean	12.95	306.00	52.04	2,095.08	96.23	2,931.65	94.27	154.73
				SD	1.56	87.81	11.05	123.21	26.81	190.18	13.07	20.94
		CVPI	13	Mean	13.79	287.86	45.86	1,333.07**	164.50**	2,710.29*	135.43*	206.14*
				SD	5.75	26.38	22.03	606.94	44.33	298.42	35.67	66.33
	F	Normal	10	Mean	11.37	321.03	54.66	2,095.15	145.13	2,723.71	106.79	256.82
				SD	1.84	32.59	26.34	369.86	71.69	300.12	22.35	28.37
		CVPI	15	Mean	11.86	345.32	63.68	1,425.64**	144.04	2,803.39	126.96	245.29
				SD	4.25	61.40	28.18	504.31	44.36	302.57	28.45	38.08

Note: * means, p<0.05; ** means; p<0.01.

Table 2. Comparison of acoustic parameter between the control and CVPI.

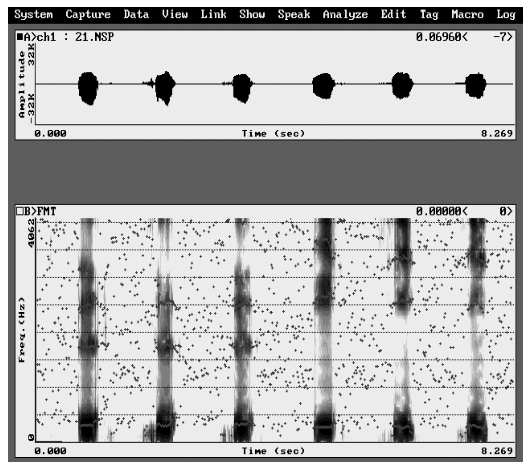
Syllable	Male							Female						
	F1	B1	F2	B2	F3	B3	Pitch	F1	B1	F2	B2	F3	B3	Pitch
/zi/				L	S	L				S	L	L	L	
/ci/				L	S	L				S	L			
/si/				L						S	L			
/ji/	L	L	S	L	S	L	L	L	L	S				
/qi/			S	L	S	L	L	L		S				
/xi/			S	L	S	L	L			S				

Note: L; The CVPI were larger than the control apparently. S; The CVPI were smaller than the control apparently.



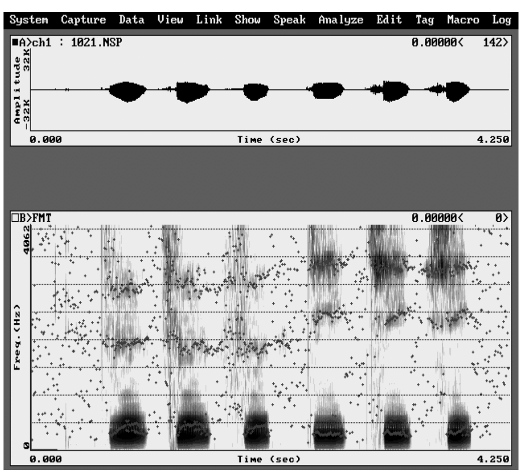
/zi/ /ci/ /si/ /ji/ /qi/ /xi/

Fig. 1. Spectrum of normal male.



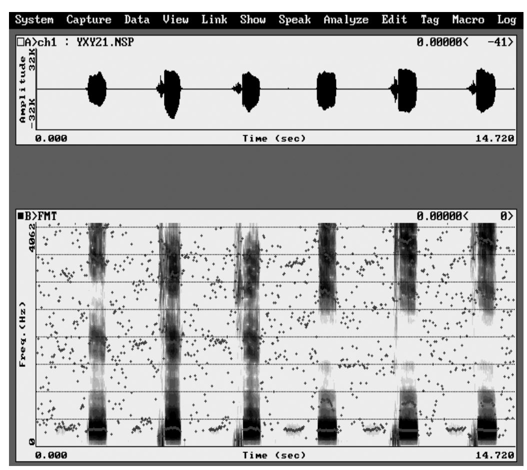
/zi/ /ci/ /si/ /ji/ /qi/ /xi/

Fig. 2. Spectrum of CVPI male.



/zi/ /ci/ /si/ /ji/ /qi/ /xi/

Fig. 3. Spectrum of normal female.



/zi/ /ci/ /si/ /ji/ /qi/ /xi/

Fig. 4. Spectrum of CVPI female.

CVPI was greatly less common than cleft lip and palate with an incidence of 1/8,000 to 1/5,000.[3,4] This anomaly is often overlooked clinically, or delayed for appropriate treatment, owing to lack of history of cleft lip and palate repair, injury of palate, surgery of jaw bones and palatopharyngeal tumor resection. The main complaints of patients are abnormal vox, mainly hypernasality and hypointelligibility. Many were misdiagnosed as abnormal articulation caused by poor phonation habits or short lingual frenum, thus receiving unsuitable managements.

The misarticulation in CVPI patients resulted from too large resonance space during consonant, or too weak muscle motilities of the soft palate and parapharynx. The conventional examinations for VPI were almost always compliant to CVPI, and the treatment of CVPI was similar to VPI, too.

The Acoustic Features of CVPI

Everyone has his own characteristic voice, which attributes to the different width, thickness and length of the vocal cords, and the variable frequencies. In daily living, the voice between man and woman is significantly different, because woman has shorter and thinner vocal cords than man, which causes the higher and sharper voice. In addition, man has a sound tract of different length from woman, which leads to the different formant frequencies. In 1948, Joos reported that woman has a higher English vocal formant frequency by 17% than man. In Mandarin Chinese vowels, the formant of woman was 1.25 times as man. To avoid the bias in the result caused by the above-stated factors, the subjects were divided into groups by sex to prevent from the interference from sex.

Acoustic analysis extracts major parameters from the sound waves conducted by air from the outside of sound tract, using appliances to measure and record the phonic acoustics characters, such as clang, pitch, sound power and length, with synthetical study of these parameters. It is a supplement to physiologic analysis. The test subjects are a serial of phenomenon of the voices sounding that could reflect the position and method of vocalization.

Clang is decided by the nature of materials and vibratory mode. The distinguishing of clang can be made by some physical quantities with acoustics characters of voice, such as waveform, the frequency and bandwidth of formant. The bandwidth of formant is defined by that under 3dB of formant. The broader the bandwidth, and the bigger the amplitude, the lower the formant power. Compared to the control, great differences exist both in vowels and consonants in CVPI patients due to nasal leakage and sound compensation. In view of the acoustic features in vowels, extra formants were found in most sonagrams of CVPI patients. The mycterophonia formant was superimposed with F1, which was darker and broader. More extra formants were noted among F1, F2 and F3, making F2 and F3 weaker, broader slurred and with less capacity. The formant frequency of F2 and F3 decreased because of retrusion of the tongue and insufficient elevation of the soft palate during phonation.

In view of the acoustic features of consonants, because of the palatopharyngeal cleft in CVPI patients during phonation, the stripes and fills in sonagrams decreased significantly, or even missing in some patients. The onset duration of consonants reflecting articulation aspirates also reduced remarkably or disappeared, presenting weakness or defluxion of the consonants. For example, only /i/, /i/, and /i/ were heard during phonation of /ji/, /qi/ and /xi/. Pitch is a supersound that could help to distinguish sounds. The size of tone (namely pitch) was a sense of human being to frequencies of sound signals. It is a subjective measurement for hearing. The values of pitch were expressed by fundamental frequency of sound, which is thought to be relevant to the length, healthy status and tensity of the vocal cord. CVPI patients usually had healthy phonation organs; therefore, there was not difference in pitch compares with the control.

The differences of acoustic features in CVPI patients were correlated with varied velopharyngeal closure on one hand, and diverse demands of phonation for velopharyngeal closure on the other hand. This was supported by the different results from different subjects in this study. The acoustic features of CVPI patients were fundamentally similar to VPI patients after cleft palate repair, due to approximate sound disturbance.

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