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Spectral & Aerodynamic Analysis of Cries in Infants with Cleft Lip and Palate.

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국 문 초 록

구순구개열 환아의 crying에 대한 음향학적 및 공기역학적 분석

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언어 발달의 조기 단계를 이해하기 위한 일환으로 crying은 언어전 발달의 기초 단계로서 여러 학문적 분야에서 많은 연구가 있어왔다. 그러나 구순구개열(CLP) 환아의 경우는 cry-producing/control mechanism에 variation이 많은 이유로 이 분야의 연구는 거의 없는 실정이다. 이에 본 연구에서는 다음과 같은 의문점을 가지고 CLP 환아의 cry feature에 대한 분석을 하였다. 첫째, 정상아와 CLP 환아의 cry에 전형적인 차이가 있는가? 둘째, CLP 환아의 술전, 술후 cry feature에 변화가 있는가? 셋째, cry 분석이 CLP 환아의 이후 speech disorder에 대한 언어전 평가로서의 가치가 있는가? 넷째, 특정 parameter가 언어전 평가에 적절한 도구로 작용할 수 있는가?

생후 15개월 이내의 CLP 환아 3명과 유사한 나이대의 정상아 8명의 cry에 대한 공기역학 및 음향음성학적 분석을 통해 CLP 환아와 정상아, CLP 환아의 술전, 술후 cry 특성을 비교 분석하였다.

결과는 다음과 같다.

1. 공기역학적 분석

1) airflow는 CLP 환아의 경우 정상아보다 약간 높았고 술후 약간 증가하였다.

2) 폐활량을 나타내는 volume에서는 정상아보다 술전 CLP 환자의 경우 보상적으로 더 큰 수치를 보였고 술후 약간 증가하였다.

3) 강도를 나타내는 parameter(SPL)에서는 정상아보다 술전 CLP 환자의 계측치가 약간 작았으나 술후 증가하는 양상을 보였다.

2. 음향음성학적 분석

1) 기저 주파수 분석시 정상아에 비해 술전 CLP 환자의 경우 계측치가 약간 낮았으나 술후 증가하여 정상군의 계측치에 근접하였다.

2) 강도를 나타내는 energy 측정시 정상아에 비해 술전 CLP 계측치가 보상성으로 약간 큰 수치를 나타내었고 술후 약간 더 증가하였다.

3) Shimmer 에서는 CLP 환자의 술후 계측치가 술전에 비해 현저히 감소하여 정상군의 수치에 근접하였다.

Keywords: aerodynamic analysis, sound spectral analysis, prespeech vocalization, cry parameter

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I. Introduction

Neonatal cry is a reflexive and reasonably patterned vocal behavior considered to have innate biological function.[1] Research on infant cries has been ongoing since the last century and can be dealt with from many different perspectives, such as anatomical, physiological, psychological, phonetic, or pediatric. It was shown that cry is an essential stage of prespeech development.[2]

Since the several studies have been done, some studies confirmed that the infants cry reflects control mechanism of the brain and the first maturational steps of the auditive-vocal system.

Disturbances within these prespeech processes not only affect prespeech vocalization but may produce later speech and language disorders. Combined with their value to analyze the prespeech developmental stages, cry parameters have been proven to be capable of indicating certain neuromuscular and cerebral dysfunctions.[3]

Abnormal cry features were found in infants with chromosomal abnormalities, metabolic disorders, asphyxia, meningitis, cleft palate, laryngitis, unilateral vocal cord paralysis, sudden infant death syndrome(SIDS), as well as immature.[1] A variety of studies have been documented that cry parameters are suitable to reflect control disturbances and may be used to determine the at-risk status of the infant for neuromuscular development. In comparison with healthy infants, the cries of children with the above-mentioned diseases area altered primarily in terms of frequency characteristics.

In particular, fundamental frequency and its related parameters area changed because of disturbances in laryngeal coordination caused by cerebral dysfunction. Especially high values of fundamental frequency are often an indicator for cerebral and neuromuscular dysfunctions and duration of cries may be prolonged or extremely shortened, especially in cases of severe mental retardation and SIDS. A prolonged cry was found to be typical in infants with hearing disorders.

In contrast to the remarkable number of studies reporting on cry characteristics in infants with developmental disorders, few investigations have been performed to analyze the cry features of patients with cleft lip and palate for several reasons. First, anatomical deviations of the vocal tract, especially prior to palatal repair. Second, most patients with CLP may be limited in their hearing capability because of recurrent serious otitis media before paracentesis and drainage of the middle ear. Third, some patient with CLP might also suffer from brain dysfunctions in case of a specific syndrome. For these reasons, there is an extraordinary degree of variability in cry-producing mechanisms and cry-control mechanisms of infants with CLP. Despite these problems, diagnosis of voice disturbances within the prespeech development of patients with CLP is helpful to start treatment as early as possible.[3]

Herein, we focus on the several questions about prespeech development of patients with CLP. First, are there any typical differences between the cries of patients with CLP and normal infants? Second, are there any cry changes between the CLP infant before/after surgery? Third, can cry analysis serve as a prespeech assessment of later speech disorders in children with CLP? Fourth, can cry analysis become a suitable tool for assessment of the prespeech development in patients with CLP? Thus, the purpose of this present study was to investigate the acoustic and aerodynamic findings based on the analysis of the infant cries with CLP and finally evaluate the differences in cry characteristics 1)between CLP group and normal infant group and 2)CLP group before and after surgery.

II. Materials and methods

1. Subjects

1.1. CLP infants group

A total 3 CLP infants participated in this study.

All the data was classified into two groups ; CLP infants before and after operation group.

A. 4-month-old male patient with unilateral complete cleft lip, lip repair was performed at the 4 months of age(according to the surgical routine of the Cleft Palate Clinic. This routine includes: surgical repair of the lip is around 4-5 months and palate is between 12-18 months).

B. 11-month-old male patient with incomplete cleft palate : palatal repair was performed at the 11 months of age. In case of palatal repair, Wardill V-Y pushback modification method was used.

C. 6-month-old male patient with unilateral incomplete cleft lip, primary cheiloplasty was performed at 6 months of age. The subjects were normal in all aspects otherwise.

1.2. Normal infants group

The normal sample consisted of 8 full-term, healthy infants from 3 months to 9 months of age. The pregnancy and delivery were without any complications and postnatal development was without any sign of developmental disorders. All samples were considered normal in all respects except three subjects; 3 subjects were suffered from common colds.

2. Cry recordings and data analysis

2.1. Spectral analysis

Traditionally, speech evaluation for the patients with articulation disorders have been based on perceptual judgement by speech pathologists. Recently various computerized speech analysis systems have been developed and commonly used in clinical settings to obtain the objective and quantitative data and specific treatment strategies.

In our study, spectral or acoustic analysis was performed with a CSL-Computerized Speech Lab of Kay Elemetircs. Spectrograms were produced for all recorded cries. To avoid artifacts because of errors in pitch determination of noisy segments, the data of the cry samples were calculated only for harmonic signals. And three stable cry samples were selected for each subjects to check reliability. Preoperative cry samples were obtained 7-10 days before operation and postoperative samples were 7-10 days after operation. All cry vocalizations were uttered spontaneously and unforced. A set of 9 voice parameters were obtained from cries recorded form each subject.

The followings cry parameters were analyzed.

① minimum frequency(mF ; Hz)
② maximum frequency(MF ; Hz)
③ maximum frequency - minimum frequency(M-m; Hz)
④ mean fundamental frequency(mF_0; Hz)
⑤ jitter(%)
⑥ minimum energy(mE ; dB)
⑦ maximum energy(ME ; dB)
⑧ mean energy(dB)
⑨ shimmer(dB) : amplitude of perturbation.

2.2. Aerodynamic analysis

Aerodynamic analysis was performed with a Aerophone II-model 6800 voice function analyzer(AP II) of Kay Elemetrics. A set of 8 voice parameters were obtained from cries from each subject.

The followings cry parameters were analyzed.

① maximum flow rate(MFR ; l/sec)
② volume(V : litre)
③ duration(sec)
④ phonatory flow rate(PFR ; l/sec)
⑤ maximum sound pressure level(MSPL ; dB)
⑥ phonatory sound pressure level(PSPL ; dB)
⑦ average pitch(AP ; Hz)

Since all of the parameters of the entire cry-sample were normally distributed, we calculated mean values

and standard deviations(SD).

III. Result

1. Spectral analysis by CSL

1.1. Control group

Table 1. shows the minimum frequency(mF), maximum frequency(MF), maximum frequency - minimum frequency(M-m), mean fundamental frequency(mF_0), jitter, minimum energy(mE), maximum energy(ME), mean energy(me) and shimmer for the control subjects. The mean mF for all subjects was 100.636 Hz(SD=55.632). The mean mF range was 51.042 to 200.455 Hz. Mean MF for all subjects was 285.142 Hz(SD=21.248). Mean MF ranged from 239.674 to 297.973 Hz. M-m for all subjects was 184.480 Hz(SD=68.415). Mean M-m ranged from 39.219 to 246.694 Hz.

The mF_0 for all subjects of normal infants was 223.460 Hz(SD=18.428). Mean mF_0 ranged from 193.265 to 245.354 Hz. The mean mF for all subjects was 79.982 Hz(SD=72.545) and 109.255 Hz(SD=54.723); preop and postop data, respectively. Mean jitter for all subjects was 5.056 %(SD=4.423), with a mean jitter range of 0.703 to 9.506 %. Mean mE for all subjects was 55.634 dB(SD=2.810), with a mE range of 51.19 to 59.998 dB.

The ME for all subjects was 75.263 dB(SD=4.061) and the mean ME ranged from 69.375 to 81.87 dB. The mean me was 67.157 dB(SD=4.946) with a mean me range of 56.877 to 72.944 dB. Mean shimmer for all subjects was 0.561 dB(SD=0.239), with a mean shimmer range of 0.409 to 1.133 dB.

1.2. CLP group

Table 2. shows the minimum frequency(mF), maximum frequency(MF), maximum frequency - minimum frequency(M-m), mean fundamental frequency(mF_0), jitter, minimum energy(mE), maximum energy(ME), mean energy(me) and shimmer for the subjects with CLP before and after surgery.

Mean MF for all subjects was 297.973 Hz(SD=0) and 297.973 Hz(SD=0). Mean M-m for all subjects was 198.576 Hz(SD=81.013) and 188.721 Hz(SD=54.723). The mF_0 for all subjects of CLP infants was 208.989 Hz(SD=17.150) and 227.764 Hz(SD=19.984). Mean jitter for all subjects was 2.142 %(SD=1.112) and 2.937 %(SD=0.718). Mean mE for all subjects was 54.995 dB(SD=6.168) and 56.68 dB(SD=2.283)

The ME for all subjects was 78.744 dB(SD=4.983) and 76.548 dB(SD=4.844). The mean me was 70.186 dB(SD=1.230) and 71.263 dB(SD=4.621). Mean shimmer for all subjects was 1.598 dB(SD=0.082) and 0.827 dB(SD=0.257).

1.3. Comparision of 1) control group with pre-op CLP group & 2) pre-op with post-op CLP group

1) mF(Hz) : Value of preoperative CLP subjects(79.982) were lower than that of normal subjects(100.636) and increased after operation(109.255)
2) MF(Hz) : The result shows higher levels of subjects with CLP(297.973) compared to normal subjects(285.142) and it had the same post-op values.
3) MF-mF(Hz) : The result shows the wide range of MF-mF in normal subjects compared to the values of pre-op CLP infants.
4) Mean F_0(Hz) : The value of normal infant(223.460) was higher than that of CLP infant(208.990). Post-op value of CLP group(227.764) was higher than that of preoperative data.
5) Jitter(%) : The result shows that higher values of normal subjects than pre-op CLP jitter levels. It was contrary to the previous findings. And we could also find increased tendency after operation

in CLP infants.

6) ME(dB) : The results suggest ME of preoperative CLP subjects(70.186) was higher than that of normal subjects(67.157). Post-op value of ME(71.263) was slightly increased.

7) Shimmer(dB) : Shimmer of pre-op CLP group(1.598) was higher than normal group(0.561) and substantially decreased after operation(0.827).

2. Aerodynamic analysis by Aerophone II voice function analyzer

2.1. Control group

Table 4. shows the maximum flow rate(MFR), volume, duration, phonatory flow rate(PFR), maximum SPL(MSPL), phonatory SPL(PSPL), average pitch(AP) for the control subjects. The mean MFR for all subjects was 0.392 l/sec(SD=0.085). The mean MFR range was 0.261 l/sec to 0.537 l/sec. Mean volume for all subjects was 0.115 litre(SD=0.057). Mean volume ranged from 0.034 to 0.196 litre. Mean duration for all subjects was 1.114 sec(SD=0.510). Mean duration ranged from 0.344 to 1.887 sec.

The PFR for all subjects of normal infants was 0.154 l/sec(SD=0.036). Mean PFR ranged from 0.098 to 0.204 l/sec. Mean MSPL for all subjects was 93.608 dB(SD=5.765). The mean MSPL range was 80.8 to 99.7 dB. Mean PSPL for all subjects was 91.429 dB (SD=5.128). Mean PSPL ranged from 80.8 to 97.83 dB.

The mean AP was 407.125 Hz(SD=92.788) with a mean AP range of 275 to 577.7 Hz.

2.2. CLP group

Table 5. shows the maximum flow rate(MFR), volume, duration, phonatory flow rate(PFR), maximum SPL(MSPL), phonatory SPL, average pitch(AP) for the subjects with CLP before and after surgery.

The mean MFR for all subjects was 0.389 l/sec(SD=0.132) and 0.41(SD=0.211); preop and postop value, respectively. Mean volume for all subjects was 0.161 litre(SD=0.151) and 0.217 litre(SD=0.112). Mean duration was 1.094 sec(SD=0.856) and 1.614 sec(SD=0.543).

The PFR for all subjects of CLP infants was 0.206 l/sec(SD=0.108) and 0.292 l/sec(SD=0.185). Mean MSPL was 88.134 dB(SD=12.790) and 97.867

Table 1. Results of a spectral analysis of normal subjects.

	mF(Hz)	MF(Hz)	MF-mF (Hz)	jitter(%)	mE(dB)	ME(dB)	me(dB)	shimmer (dB)
1	56.538	268.602	212.364	9.506	54.053	69.375	65.408	0.452
2	97.566	279.973	200.407	1.886	56.259	81.870	69.339	0.445
3	51.042	297.973	246.931	5.604	52.917	71.460	64.608	0.448
4	145.066	297.973	152.907	5.267	56.313	74.734	67.944	1.133
5	139.557	297.973	158.416	2.429	56.459	79.198	72.944	0.409
6	51.279	297.973	246.694	13.550	51.190	73.024	56.877	0.598
7	63.728	282.692	218.904	2.045	59.998	76.059	69.790	0.476
8	200.455	239.674	39.219	0.703	57.884	76.379	70.348	0.523
mean	100.654	285.142	184.480	5.056	55.634	75.262	67.157	0.561
SD	55.632	21.248	68.415	4.423	2.810	4.061	4.946	0.239

Table 2. Results of a spectral analysis of CLP subjects.

		A	B	C	Mean	SD
min F(Hz)	preop	82.895	6.025	151.027	79.982	72.545
	postop	108.088	55.125	164.552	109.255	54.723
max F(Hz)	preop	297.973	297.973	297.973	893.919	0.0000
	postop	297.973	297.973	297.973	297.973	0.0000
max-min (Hz)	preop	156.835	291.948	146.946	198.576	81.013
	postop	189.895	242.848	133.421	188.721	54.723
mean F(Hz)	preop	224.697	211.572	190.691	626.960	17.150
	postop	230.470	206.564	246.257	227.764	19.984
jitter(%)	preop	2.928	3.024	1.356	2.436	0.937
	postop	2.429	14.464	3.444	6.779	6.675
min E(dB)	preop	52.175	50.741	62.068	54.995	6.168
	postop	54.787	59.216	56.037	56.680	2.283
max E(dB)	preop	76.957	84.375	74.902	78.745	4.983
	postop	76.309	81.508	71.828	76.548	4.844
mean E(dB)	preop	68.774	70.766	71.019	70.186	1.230
	postop	70.715	76.134	66.941	71.263	4.621
shimmer (dB)	preop	0.448	0.611	0.539	1.598	0.082
	postop	0.534	1.014	0.933	0.827	0.257

dB(SD=1.660). Mean PSPL for all subjects was 88.017 dB(SD=8.570) and 95.3 dB(SD=1.992).

The mean AP was 307.767 Hz(SD=38.722) and 376.567 Hz(SD=38.001).

2.3. Comparision of 1) control group with pre-op CLP group & 2) pre-op with post-op CLP group

1) MFR(1/sec) : The results suggest MFR of preoperative CLP subjects(0.389) are lower than that of normal subjects(0.392) and increased after operation(0.410)

2) Volume(litre) : The result shows greater volume levels of subjects with CLP(0.161) compared to normal subjects(0.115). And it increased after operation(0.217).

3) Duration(sec) : Cry duration of normal infant(1.114) are longer than that of preoperative CLP infant(1.094). Postoperative value of cry duration with CLP infant(1.614) is higher than that of preoperative values.

Table 3. Comparision of 1) control group with pre-op CLP group & 2) pre-op with post-op CLP group by spectral analysis

		Normal	CLP	
			preop	postop
min F(Hz)			82.895	108.088
			6.025	55.125
			151.027	164.552
	Mean	100.636	79.982	109.255
	SD	55.632	72.545	54.723
max F(Hz)			297.973	297.973
			297.973	297.973
			297.973	297.973
	Mean	285.142	297.973	297.973
	SD	21.248	0.000	0.000
max-min(Hz)			156.835	189.895
			291.948	242.848
			146.946	133.421
	Mean	184.480	198.576	188.721
	SD	68.415	81.013	54.723
mean F(Hz)			224.697	230.470
			211.572	206.564
			190.691	246.257
	Mean	223.460	208.990	227.764
	SD	18.428	17.150	19.984
jitter(%)			2.928	2.429
			undefined	undefined
			1.356	3.444
	Mean	5.056	2.142	2.937
	SD	4.423	1.112	0.718
min E(dB)			52.175	54.787
			50.741	59.216
			62.068	56.037
	Mean	55.634	54.995	56.680
	SD	2.810	60.168	2.283
max E(dB)			76.957	76.309
			84.375	81.508
			74.902	71.828
	Mean	75.262	78.745	76.548
	SD	4.061	4.983	4.844
mean E(dB)			68.774	70.715
			70.766	76.134
			71.019	66.941
	Mean	67.157	70.186	71.263
	SD	4.946	1.230	4.621
shimmer(dB)			0.448	0.534
			0.611	1.014
			0.539	0.933
	Mean	0.561	1.598	0.827
	SD	0.239	0.082	0.257

4) PFR(1/sec) : Higher levels of PFR in CLP infant(0.206) compared to those of normal infant(0.154) suggest that compensatory articulations in individuals with VPI may be applied to the prespeech vocalizations in infants with CLP infants. Postoperative PFR of CLP group(0.292) is higher than that of preoperative data.

5) MSPL, PSPL(dB) : The result show that intensity levels of normal subjects are greater than preoperative CLP intensity levels. And we could also find increased tendency of intensity level(MSPL, PSPL) after operation in CLP infants.

6) AP(Hz) : The results suggest AP of pre-op CLP

Table 4. Results of a aerodynamic analysis of normal subjects.

		1	2	3	4	5	6	7	8	mean	SD
MFR (1/sec)		0.304	0.180	0.372	0.616	0.388	0.236	0.324	0.244		
		0.452	0.996	0.296	0.480	0.476	0.296		0.296		
		0.548	0.436	0.580	0.204	0.312	0.252		0.468		
	mean	0.435	0.537	0.416	0.433	0.392	0.261	0.324	0.336	0.392	0.085
Volume (litre)		0.060	0.056	0.254	0.161	0.194	0.063	0.034	0.070		
		0.077	0.208	0.193	0.146	0.152	0.086		0.080		
		0.143	0.307	0.141	0.009	0.085	0.071		0.110		
	mean	0.093	0.190	0.196	0.105	0.144	0.073	0.034	0.087	0.115	0.057
Duration (sec)		0.750	1.360	2.580	0.940	1.300	2.100	0.034	0.756		
		0.670	0.820	1.860	1.180	0.740	1.820		0.756		
		0.970	1.900	1.220	0.710	1.030	1.220		1.030		
	mean	0.797	1.360	1.887	0.943	1.023	1.713	0.034	0.847	1.114	0.510
PFR (1/sec)		0.095	0.043	0.179	0.299	0.160	0.105	0.165	0.121		
		0.130	0.280	0.108	0.258	0.238	0.063		0.133		
		0.151	0.252	0.170	0.056	0.109	0.126		0.131		
	mean	0.125	0.192	0.152	0.204	0.169	0.098	0.165	0.128	0.154	0.036
MSPL (dB)		100.4	87.000	97.200	100.2	95.000	92.200	80.800	91.000		
		97.200	99.999	92.000	100.2	97.000	97.800		90.800		
		92.800	97.200	97.600	98.800	93.400	97.400		90.000		
	mean	96.800	94.400	95.600	99.733	95.133	95.800	80.800	90.600	93.608	5.764
PSPL (dB)		98.100	84.900	95.600	98.500	91.600	89.100	80.800	88.400		
		95.900	95.300	89.800	98.500	93.600	92.600		88.800		
		90.700	95.300	95.800	96.500	90.900	95.100		86.900		
	mean	94.900	91.833	93.733	97.833	92.033	92.267	80.800	88.033	91.429	5.128
MAP (cmH_2O)		0.020	0.440	0.300	0.840	0.020	0.0000	0.050	0.320		
		0.040	2.400	0.400	0.930	0.170	0.0000		0.360		
		0.070	2.480	0.520	0.950	0.260	0.0000		0.500		
	mean	0.043	1.773	0.407	0.907	0.150	0.0000	0.050	0.393	0.465	0.607
AP (Hz)		660	314	354	387	455	252	429	447		
		586	224	388	339	472	326		454		
		487	287	368	384	450	408		442		
	mean	577.67	275.00	370.00	370.00	459.00	328.67	429.00	447.67	407.13	92.788

Table 5. Results of a aerodynamic analysis of CLP subjects.

		A(preop)	A(postop)	B(preop)	B(postop)	C(preop)	C(postop)
MFR (l/sec)		0.184	0.378	0.484	0.432	0.400	0.560
		0.480	0.226	0.584	0.552	0.482	0.552
		0.080	0.230	0.460	0.464	0.496	0.992
	mean	0.248	0.278	0.509	0.483	0.459	0.701
Volume (litre)		0.010	0.144	0.331	0.345	0.123	0.227
		0.012	0.094	0.361	0.357	0.191	0.155
		0.002	0.095	0.237	0.301	0.185	0.238
	mean	0.008	0.111	0.310	0.334	0.166	0.207
Duration (sec)		0.110	2.360	1.940	2.830	1.560	1.360
		0.120	1.600	1.660	1.070	1.500	0.740
		0.056	1.760	1.260	1.940	1.640	0.860
	mean	0.095	1.907	1.620	1.947	1.567	0.987
PFR (l/sec)		undefined	undefined	0.289	0.264	undefined	0.269
		0.157	undefined	0.371	0.378	0.174	0.280
		undefined	0.100	undefined	0.280	0.089	0.860
	mean	0.157	0.100	0.330	0.307	0.132	0.470
MSPL (dB)		59.400	98.600	99.600	96.800	90.800	99.600
		81.400	99.400	99.400	97.800	95.600	96.200
		82.000	100.200	99.400	93.800	85.600	98.400
	mean	74.267	99.400	99.467	96.100	90.667	98.070
PSPL (dB)		undefined	undefined	97.600	94.400		93.200
		80.000	undefined	96.500	96.200	90.800	93.600
		undefined	97.600	undefined	91.600	83.200	95.800
	mean	80.000	97.600	97.050	94.100	87.000	94.200
MAP (cmH_2O)		0.070	0.020	undefined	0.050	0.030	0.070
		0.090	0.030	undefined	0.070	0.050	0.080
		0.030	0.020	undefined	0.060	0.040	0.120
	mean	0.063	0.023		0.060	0.040	0.090
AP (Hz)		159.000	372.000	255.000	341.000	344.000	434.000
		340.000	374.000	284.000	340.000	362.000	392.000
		375.000	383.000	301.000	335.000	350.000	418.000
	mean	291.333	376.333	280.000	338.700	352.000	414.700

subjects(307.767) is lower than that of normal subjects(407.125). Postoperative value of AP(376.567) is greater than that of pre-op value.

IV. Discussion

1. Aerodynamic Analysis

Individuals with VPI may attempt to regulate actively vocal tract resistances as a compensation.[4] Increased glottal resistance during vowel production, for example, would decrease flow rate and facilitate regulation of subglottal pressure required to sustain phonation. Therefore, attempts to regulate respiratory and laryngeal aerodynamic and neuromuscular processes when

Table 6. Comparision of 1) control group with pre-op CLP group & 2) pre-op with post-op CLP group by aerodynamic analysis

		Normal	CLP	
			preop	postop
MFR(l/sec)			0.248	0.278
			0.509	0.483
			0.409	0.701
	Mean	0.392	0.389	0.410
	SD	0.085	0.132	0.212
Volume (litre)			0.008	0.111
			0.310	0.334
			0.166	0.207
	Mean	0.115	0.161	0.217
	SD	0.057	0.151	0.112
Duration (sec)			0.095	1.907
			1.620	1.947
			1.567	0.987
	Mean	1.114	1.094	1.614
	SD	0.510	0.866	0.543
PFR(l/sec)			0.157	0.100
			0.330	0.307
			0.132	0.470
	Mean	0.154	0.206	0.292
	SD	0.036	0.108	0.185
MSPL(dB)			74.267	99.400
			99.467	96.100
			90.667	98.070
	Mean	93.608	88.134	97.857
	SD	5.765	12.790	1.660
PSPL(dB)			80.000	97.600
			97.050	94.100
			87.000	94.200
	Mean	91.429	88.017	95.300
	SD	5.128	8.570	1.992
AP(Hz)			291.300	376.300
			280.000	338.700
			352.000	414.700
	Mean	407.125	307.767	376.567
	SD	92.788	38.722	38.001

inappropriate oronasal coupling exists may contribute to increased vocal perturbations.[5]

Generally, in the previous studies, airflow of CLP patients in phonation and articulation is higher than that of control group and increased after operation. In our presented studies, mean airflow rate of pre-op CLP group(PFR) is higher than that of control group and increased after operation. It could be explained as a compensatory articulation in speech of CLP patients and this relation is a consensus of existing opinion.

Lung volume and mean airflow in spontaneous cries are increased after operation and it coincided with previous studies of those of CLP in phonation and articulation. Warren reported that speakers with VPI

expend twice the normal volume of air during speech production[6] and have further suggested that individuals with VPI may increase respiratory effort as a way to develop adequate intraoral air pressure.[7]

Generally CLP patients speak with incomplete oronasal closure therefore results lower oronasal air pressure. In our study, the SPL of CLP group in spontaneous cries before operation is about 3 dB lower than the control group(PSPL).

Air pressure of CLP infants during crying is lower than that of control groups. In general, the SPL of CLP increased after operation.

Average pitch of CLP infants during crying is increased after operation. It can be regarded as a increased laryngeal muscle activity after operation.

2. Spectral Analysis

Crying in the human infant is a complex phenomenon occuring during the expiratory phase of respiration, and includes the production of sound of the vocal folds. The cry sound is produced by vibrations of the vocal folds in the larynx.[2]

Based on the findings of many cry studies, conceptual models were developed to describe the anatomic and physiologic basis for the production and neurological control of the infant's cry. In particular, the neurological integrity of the infants was related to the stability of laryngeal coordination. Laryngeal coordination is characterized by the variability of the fundamental frequency(F_0) and related parameters: the number of times the sound wave repeats itself during a second is the fundamental frequency(cycles per second, Hz), and is what we hear as voice pitch.[2] The fundamental frequency is primarily determined by the vocal fold tension from the intrinsic muscles of the larynx. These muscles are controlled by the vagus, the tenth cranial nerve. The most striking difference between the cries from healthy infants and infants suffering from certain CNS-disorders is the fundamental frequency. The majority of previous cry studies have described an abnormal high mean F_0 as a distinguishing feature for pathological conditions.[2,8,9]

Some studies described a developmental increase in mean F_0,[10,11,12] others decreasing trend.[13,14] The age-related F_0 values of infant cries yielded in these studies could simply reflect a temporarily high variability characteristic for certain developmental phases. Additionally, the mean F_0 of the spontaneous cries was highly variable between individuals as well as within individuals of the same age.[8] Prior investigations in patients without cleft showed that F_0 parameters reflects the regularity of vocal cord oscillations are well suited to characterize laryngeal developmental processes, including voice control mechanisms.[3,15] Because of the upper vocal tract is still immature in young infants, these parameters are especially capable of describing sound characteristics. Therefore, in this preliminary study, we could identify the possible deviations of these cry parameters in infants with CLP.[1]

It is known that some amount of voice perturbation is normal and may reflect random aerodynamic and neuromuscular events.[15]

The results of the present study shows that mean F_0 of CLP infants before operation is lower than that of normal subjects in two infants and it increased after operation toward the value of normal subjects. With respect to fundamental frequencies, two prior studies were existed.

Muhler found a lower F_0 in patients with CLP(414 Hz), compared with the control group(438.5 Hz).[16]

Michelsson et al. (1975) reported lower minimum and maximum values of F_0 during the third to fifth day of life and between the second and fourth week, the F_0 of the CLP infants was slightly higher than that of the control group.[17]

In our presented study, minimum frequency of CLP infant is lower than that of normal subjects in two infants and increased after opeation in all CLP subjects.

In contrast to the minimum frequency, maximum frequency is not changed after operation.

Mean maximum frequency(MF) - minimum frequency(mF) for normal subjects was 184.480 Hz and mean MF-mF ranged from 39.219 to 246.694 Hz. In CLP infant, mean MF-mF was 198.576 Hz and ranged from 146.946 Hz to 291.948 Hz before operation and mean value was 188.721 Hz with a range from 133.421 Hz to 189.895 Hz after operation. This data revealed wide range of MF-mF in normal group and it coincided with the prior study about CLP patients.

Differences in intensity levels among the children may have affected jitter and shimmer. Zajac and Linville, for example, reported increased jitter for adult speakers when phonating at greater than normal loudness levels.[5] However, Glaze reported that acoustically derived voice perturbations of children decreased with increased loudness.[18] These findings may be attributable to differences in laryngeal anatomy between children and adults. Generally, the increased jitter levels of the children with VPI suggest that laryngeal aerodynamic and/or neuromuscular processes may be altered as a result of oronasal coupling. The explanations for this require further experimental study. Also, it is possible that other mechanism may account for the present findings or that the above explanations are not mutually exclusive.[5]

Unfortunately, in our study, because some subjects of the normal group had a common colds, the mean jitter values exceeded 5% and its SD was also high(>4%). It was contrary to the previous studies.

Based on the results of other previous studies, jitter values that exceed 1% may identify the CLP patients.

Shimmer value of CLP group before operation was higher than normal group and substantially decreased after opeartion.

Postoperative CLP data was check only one time in post-op 7-10 days thus these data was transitory. Indeed, following F/U is necessary for further evaluation.

V. Conclusion

The results of the present investigation indicate possible positive relationship between the former studies about the speech of CLP patients and cries in infants with CLP through the aerodynamic and acoustic analysis.

1) Airflow rate of pre-op CLP group(PFR) was higher than that of control group and increased after operation. It could be explained as a compensatory articulation in speech of CLP patients and this relation is a consensus of existing opinion.
2) Air pressure of pre-op CLP group was lower than that of control groups. In general, the SPL of CLP increased after operation.
3) Mean F_0 of pre-op CLP group was lower than that of normal subjects in two infants and increased after operation toward the value of normal subjects.
4) Shimmer of pre-op CLP group was higher than normal group and substantially decreased after operation.

The high variability of each parameters in infants cries with CLP is a limiting factor to develop cry analysis but cry analysis is a non-invasive tool for the prediction of the status for later speech and language acquisition in infants with CLP. Therefore we could reduce the possible communitive disorders.

Finally, as the present study utilized a small sample of infants within a restricted age range, additional longitudinal research is required to confirm the present findings.

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