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A Suggestive Diagnostic Technique For Early Identification Of Acyanotic Heart Disorders From Infant's Cry

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Abstract - Congenital Heart Defects (CHD) are the critical heart disorders that can be observed at the birth stage of the infants. These are classified mainly into two, Cyanotic and Acyanotic. The present paper concentrates on the Acyanotic heart disorders. Acyanotic heart disorder cannot be observed on external checkup, whereas bluish skin is the indication for the infant affected with Cyanotic disorder. Acyanotic heart disorder can only be diagnosed using chest X-Ray, ECG, Echocardiogram, Cardiac Catheterization and MRI of the Heart. The present work aims at estimating the fundamental frequency (pitch) and the vocal tract resonant frequencies (formants) from the cry signal of the infants. The pitch frequency and formant frequencies are estimated using frequency domain (Cepstrum) and Linear Prediction Code (LPC) methods. The results show that the fundamental frequency of the cry signal was between 600Hz-800Hz for the infants with Acyanotic heart disorders. This fundamental frequency helps in identifying Acyanotic heart disorders at an early stage.

Keywords*- Infant cry; Acyanotic heart disorder; Fundamental frequency; Formant Frequency;*

1. INTRODUCTION

A. *Infant Cry*

The infant cry is mainly produced by the human voice-production system and it is a combination of three important components i.e. voiced sound, resonances and radiation. The voiced sound is generated from the vibrating vocal cords. The generated sound contains the fundamental frequency and its harmonics. The fundamental frequency ($F0$) is the lowest frequency component of the spectrum. The loudness and pitch of the cry depends on the expiration speed of the air from the lungs and the tightness of the vocal cords[1]. Investigations dealing with the infant cry can be classified into three main categories: Investigation of 1.Reason of crying, 2.Development of crying, 3.Connection between disease and cry. During crying, volume, pitch (fundamental frequency) and tone color changes [2] .This could lead to the diagnosis of some diseases and abnormalities. Investigations of cry have been done on different medical problems like oropharyngeal anomalies, asphyxia, neonatorum, symptomless Low birth weight, herpes encephalitis, congenital hypothyroidism, hyperbilurubinemia, bacterial meningitis, Hydrocephalus, bradycardia, various forms of brain damage, malnutrition, genetic defects and sudden infant death syndrome (SIDS) [3-17]. Cry signals of hunger, pleasure and at the time of birth were analyzed by Wasz-Hockert [18]. In hunger cry the average fundamental frequency was about 550 Hz-390 Hz. Birth cry signal's fundamental frequency range from 550 Hz to 450 Hz. Pleasure cries have been reported to a fundamental frequency range of 650 Hz-360 Hz. Pain cry of healthy term infants is characterized by a fundamental frequency range of 650 Hz-400 Hz. Infants with Down's syndrome were tested by Lind [19] and was found its range as 510 Hz- 270 Hz. The cry of infants with hypothyroidism has been investigated by Michelsson and Sirvio [20]. The range of fundamental frequency values as 470 Hz-270 Hz. Wasz-Hockert [21] studied cries of infants with metabolic disturbances, particularly cries of infants with high hyperbilurubinemia. The findings included fundamental frequency range of 2120 Hz-960 Hz, respectively. Thoden and Michelsson [22] studied cries of infants of diabetic mothers. They found fundamental frequency of 1480 Hz. The fundamental frequency was even higher (1520 Hz) in infants suffering from hypoglycemia and even higher (1790 Hz) in infants with hyperbilurubinemia. Infants who suffered from both hypoglycemia and hyperbilurubinemia displayed a fundamental frequency of 1980 Hz. [22].This proposes the idea of a diagnostic system based on the infant's cry. In this study, infants with Acyanotic heart disorders were analyzed and FO, F1, F2, F3 parameters were estimated. Main goal of this project is to bring knowledge about the infant cry and connections with CHDs.

B. Acyanotic Heart Disorder:

Any defect or abnormality in the heart structure that is present at birth is called Congenital Heart Defect (CHD). Bluish skin of the infant is one of the symptoms for Cyanotic heart disorder. Acyanotic heart problems can be detected by the presence of a heart murmur heard with a stethoscope. Further evaluations are likely to include a chest X-ray, electrocardiogram, and echocardiogram. When surgery is contemplated, cardiac catheterization may be necessary. The types of Acyanotic heart disorders are Patent Ductus Arteriosus (PDA), **Coarctation of the Aorta (CA), Atrial Septal Defect (ASD), Ventricular Septal Defect (VSD), Atrioventricular Septal Defect (AVSD), Aortic Stenosis (AS), Pulmonary Stenosis (PS). This may be caused by an associated genetic abnormality by an illness that** affected the mother during fetal heart development, by some medication taken by the mother during pregnancy. Acyanotic disorder affected baby may not gain weight normally, the baby's breathing may be rapid and distressed and the baby may have difficulty in eating [23].

II. SUBJECTS

A. Data Collection

The Cry signals of around 40 infants (1-12 months old) having Acyanotic heart disorder, (confirmed through medical examination) were recorded at Innova Children's Heart Hospital, Hyderabad. The length of the cry signal was 40-60 sec. The author used a digital camera (CANON-A3100 IS) in order to recognize the infant and the circumstances of crying. The sampling frequency of the cry signal is 44,100 Hz. The distance between the microphone and the mouth of the infant was 200 cm.

B. Database

The recorded infant cries (.avi) were transferred into a PC and converted into .wav files. The infant's database contains the following information.

- **Details of the Infant:** Name, Date of birth, Gender, Address and Telephone number of the Parents

- **Medical Observations**: Type of heart disorder, other diseases existing

Details about the cry record: Date of recording, Place of recording, Length of cry signal, Sampling frequency, Type of recording device, File name of the cry signal samples of cry signals of infants affected with Acyanotic heart disorder were taken for the examination.

III. METHOD

The author used MATLAB software for Preprocessing and estimation of fundamental frequency and formant frequencies of infant's cry signal. The Fig. 1 shows the cry signal of infant affected with Acyanotic heart disorder. 40

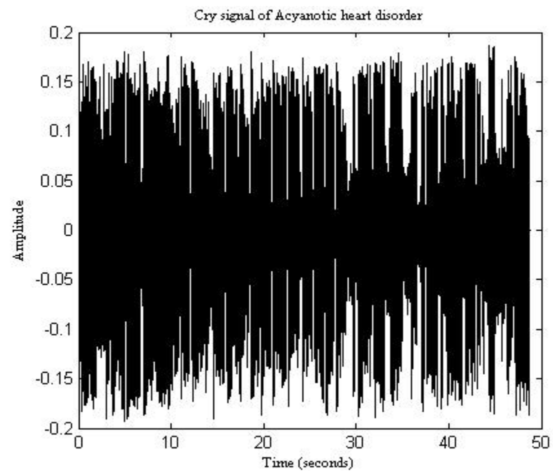

Figure. 1 Cry signal of Acyanotic heart disorder

A. Data Preprocessing

The infant cry signal is preprocessed before estimating the fundamental and formant frequencies. In the preprocessing stage, the cry signals were pass band filtered in the range of 200Hz-5,500Hz and resampled at 11,025Hz. In the next step for each cry signal the first five cry units were segmented in frames of 25ms and the four parameters (F0, F1, F2 and F3) extracted from each frame. This procedure was applied for all Cry signals.

B. Estimation of Fundamental Frequency

The Fundamental Frequency (F0) detection is an important part of investigation. The fundamental frequency is the lowest useful frequency component in the spectrum. Cepstrum analysis is used to calculate F0. Cepstrum analysis is a form of spectral analysis where the output is the Fourier transform of the log of the magnitude spectrum of the input waveform [24]. The cry signal was divided into 5 successive units which were in 25ms size. The Cepstrum analysis was applied for each unit. Fig. 2 shows the stages in the Cepstrum analysis algorithm.

C. Estimation of Formant Frequencies

The Formant Frequencies are vocal tract natural resonance frequencies. Formants are frequency ranges that characteristically contain a concentration of the acoustic energy. The author used linear prediction code method to estimate first three formant frequencies (F1, F2, and F3) [25]. The Linear prediction Code method was applied for each unit. Fig. 3 shows the formant frequency estimation.

Signal	Parameter	Unit1	Unit2	Unit3	Unit4	Unit5	Mean
Cry4	**FO**	1000	423.631	440.559	916.84	1000	756.206
	F1	876.1	851.6	874.2	940.3	853.9	879.22
	F2	1517.1	1520.5	1589.9	1831.5	1466.6	1585.12
	F3	2598.5	2691.2	2758.3	2489.9	2695.4	2646.66
Cry11	**FO**	733.777	407.956	733.777	550.562	1000	685.2144
	F1	1018.1	948	1039.5	972.4	952.5	986.1
	F2	1426.8	1174	1372.2	1368.5	1496.8	1367.66
	F3	2250.1	1951.9	2379.1	2293.3	2640.1	2302.9
Cry14	**FO**	647.577	846.449	611.65	846.449	579.501	706.3252
	F1	454.7	669.6	991.3	1307.2	1062.4	897.04
	F2	1155.9	1484	2189.4	2223.5	2169.1	1844.38
	F3	2286.1	2358.7	2743.6	3178.5	2620.8	2637.54
Cry21	**FO**	686.493	1000	555.812	555.812	1000	759.6234
	F1	863.4	821.8	1078.5	963.7	893.49	924.178
	F2	1453.4	986.7	1675.4	1428.4	858.6	1280.5
	F3	2438.4	1849.5	2718.2	2856.8	1784.6	2329.5
Cry27	**FO**	1000	358.364	858.465	858.465	417.389	698.5366
	F1	792.3	736.5	758.5	592.9	826.3	741.3
	F2	1031.4	2108.4	1789.4	1625.4	1693.5	1649.62
	F3	2183.4	2374.5	2242.3	2258.2	2482.3	2308.14
Cry31	**FO**	744.826	418.395	744.826	536.496	1000	688.9086
	F1	1028.1	958.4	1048.6	983.5	962.4	996.2
	F2	1432.5	1184.2	1368.4	1359.4	1482.8	1365.46
	F3	2235.2	1963.4	2384.2	2279.3	2618.4	2296.1
Cry36	**FO**	1000	458.153	1000	753.359	763.1	794.9224
	F1	724.5	812.4	812.4	678	763.5	758.16
	F2	1405.8	1069.5	842.7	1117.2	783.5	1043.74
	F3	2168.2	2321.4	2139.5	2078.1	2021.4	2145.72
Cry37	**FO**	1000	887.63	653.456	653.456	653.456	769.5996
	F1	583.1	1142.9	869.4	546.5	821.6	792.7
	F2	1521.7	2432.7	1218.4	963.4	979.5	1423.14
	F3	2289.8	2673.4	2276	2273	2425.3	2387.5
Cry38	**FO**	623.78	623.78	425.635	826.334	512.534	602.4126
	F1	831.7	865.2	756.4	789.5	836.3	815.82
	F2	1735.3	1765.3	1764.7	1558.3	1789.5	1722.62
	F3	2156.8	2287.1	2358.4	2212.5	2248.5	2252.66

TABLE-1 Cry unit's Mean fundamental frequencies and Formant frequencies

F0: Fundamental frequency (Hz); F1: First Formant frequency (Hz); F2: Second Formant frequency (Hz)

F3: Third Formant frequency (Hz);

TABLE-II Mean and Standard deviation of each cry signal

Signal	**FO**	**F1**	**F2**	**F3**
Cry1	848.1732	741.86	959.84	2134.56
Cry2	843.705	747.64	960.84	2133.9
Cry3	834.095	755.86	1036.74	2146.66
Cry4	794.9224	758.16	1043.74	2145.72
Cry5	782.9286	792.6	1689.1	2430.84
Cry6	773.354	802.58	1681.82	2400.18
Cry7	771.9142	784.86	1434.78	2399.04
Cry8	769.5996	792.7	1423.14	2387.5
Cry9	768.165	627.24	1649.62	2308.14
Cry10	761.5738	890.18	1590.6	2637.06
Cry11	761.1828	616.74	1455.02	2330.28
Cry12	759.6234	924.178	1280.5	2329.5
Cry13	758.2832	831.82	1719.6	2876.02
Cry14	756.206	879.22	1585.12	2646.66
Cry15	753.7984	698.24	1574.54	2308.3
Cry16	749.5352	833.96	1720.58	2886.6
Cry17	745.7654	693.28	1576.68	2316.16
Cry18	739.2658	917.58	1287.64	2330.58
Cry19	717.7834	899.62	1834.22	2628.44
Cry20	713.603	972.78	1414.68	2375.72
Cry21	706.3252	897.04	1844.38	2637.54
Cry22	701.5936	710.42	1576.48	2504.32
Cry23	701.2038	693.64	1572.62	2502.92
Cry24	698.5366	741.3	1649.62	2308.14
Cry25	698.3008	961.2	1404.98	2366.76
Cry26	689.0232	733.76	1645.92	2307.3
Cry27	688.9086	996.2	1365.46	2296.1
Cry28	685.2144	986.1	1367.66	2302.9
Cry29	682.8448	986.5	1372.22	2638.94
Cry30	676.8258	727.8	1694.48	2336.56
Cry31	676.0108	723.54	1692.3	2339.72
Cry32	674.9152	985.42	1383.48	2648.88
Cry33	644.3716	985.34	1669.14	2298.8
Cry34	642.894	1021.12	1889.26	2597.18
Cry35	634.6622	1019.8	1904.5	2627.88
Cry36	633.9072	977.1	1678.96	2306.9
Cry37	630.2666	889.8	1447.92	2298.584
Cry38	627.1726	886.58	1467.86	2291.2
Cry39	602.4126	815.82	1722.62	2252.66
Cry40	602.1752	816.88	1733.02	2257.24
Mean	717.5261	837.9114	1525.042	2406.81
SD	63.6825	115.2904	238.8924	186.5996

F0: Fundamental frequency (Hz);

F1: First Formant frequency (Hz);

F2: Second Formant frequency (Hz)

F3: Third Formant frequency (Hz);

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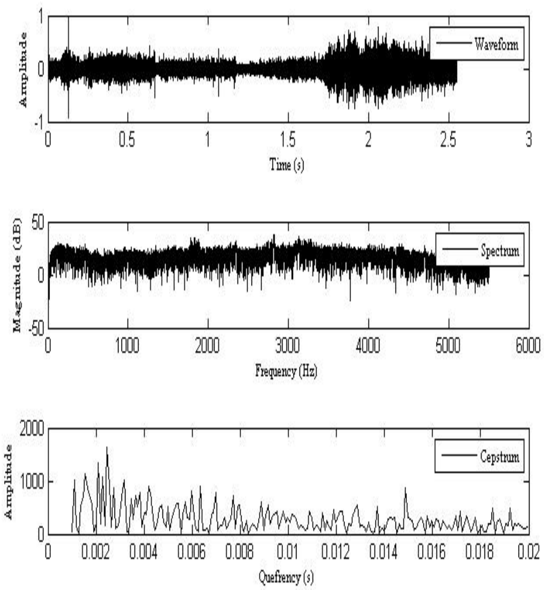

Figure 2. Cepstrum Analysis

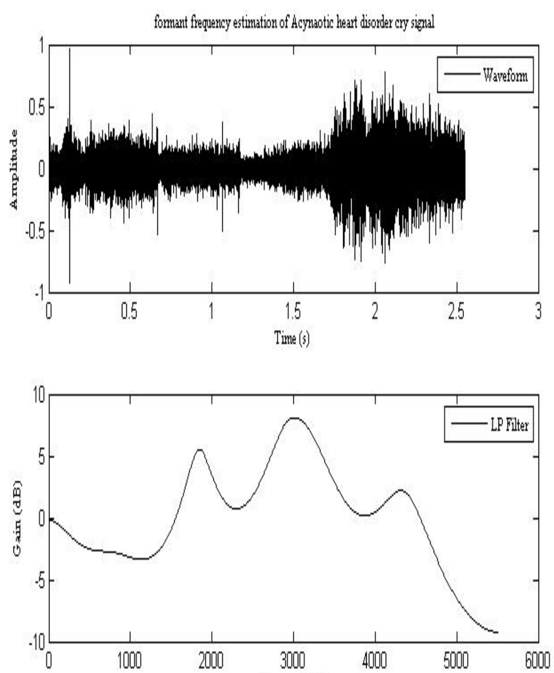

Figure 3. Formant Frequency estimation

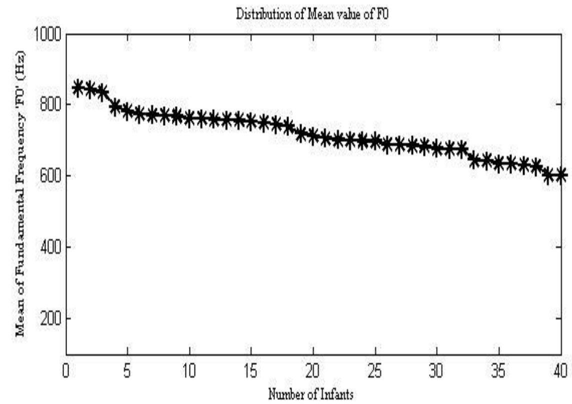

Figure 4. Distribution of Mean value of FO

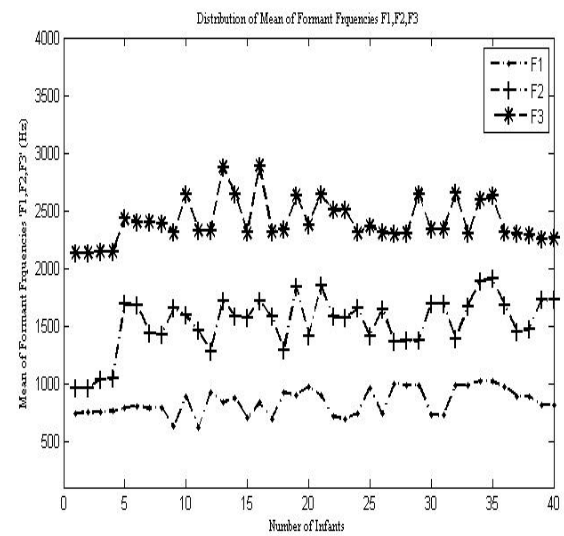

Figure 5. Distribution of Mean of Formant frequencies F1, F2, F3

unit of cry are also shown. This shows only 9 samples of cry signals out of 40.

TABLE-II shows the mean values of fundamental and formant frequencies of 40 cry signals. In the bottom of the table mean and standard deviation, for each parameters were also shown

V. DISCUSSION AND CONCLUSION

The fundamental frequency (FO) is the most important feature in cry research. The Fundamental frequency plays an important role in the several medical problems. This paper investigated the average fundamental frequency of 40 infants with Acyanotic heart disorder. TABLE-II shows that the average fundamental frequency was 717Hz with a standard deviation of 63.6825.The distribution of mean value of FO was shown in Fig. 4. In this Figure 98% of the mean values of Fundamental frequencies are between 600Hz-800Hz.In this paper author estimated the three Formant Frequencies (F1, F2, F3). Fig. 5 shows the distribution of mean of three Formant frequencies. From this Figure the author concluded that the first formant frequency (F1) is in the range of 616Hz-1021Hz.The second Formant frequency (F2) is in the range of 959Hz-1904Hz.The Third fundamental frequency (F3) is in the range of 2133Hz-2886Hz.This paper investigated Fundamental and Three Formant frequencies of Acyanotic Heart disordered infant cries.

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