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ACOUSTIC ANALYSIS OF CRY SIGNAL TO DIFFERENTIATE HEALTHY AND CONGENITAL HEART DISORDER IN INFANTS

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ABSTRACT

The human body produces many signals that are related to different functions such as cardio logical and nervous systems. It is important that these biological signals be analysed for medical diagnosis and also for the study of various phenomena observed in the human body. The pathological conditions of the human body can be identified and explained through this analysis. Babies usually communicate their needs through crying, which is considered as a vocal signal. The variations in the cry can be related to different emotions such as hunger, pain, illness and discomfort. Research dealing with this relationship is termed as research in acoustic properties with the help of such research pathological states in infants, such as brain damage, cleft palate, hydrocephalus and sudden infant death syndrome (SIDS) were identified. The present work aims at estimating the jitter, shimmer, Signal to noise ratio, Noise to signal ratio, Autocorrelation and intensity from the cry signal of the infants with TOF, VSD, ASD, PDA (congenital) heart disorders by using PRATT software method and compared these results with normal cry signal of infants. Such parameters provide useful information in the early diagnosis of heart disorders in infants.

KEYWORDS: Infant Cry, Acyanotic Heart Disorder, Jitter, Shimmer

INTRODUCTION

Infant Cry

Crying is a vocal signal that alerts the environment about the needs and wants of the infant and alerting the listener to respond. Infant crying is a biosocial phenomenon. This biosocial signal helps parents to be better care givers as it provides information about the biological integrity of the infants [1]. In order to understand the different acoustic parameters of the infant, it is also important to comprehend the production of the cry. By nature, all systems are involved in the production of a cry and is influenced by its acoustics. It also gives its perceptual impression. In other words, the perceptual meaning of the cry is a affected not only by the systems that interfere with or participate in the emission of the sound but also by the infant's state which is the main reason behind the cry[2].

Though there is a general comprehension about cry physiology, there is still many problems related to neural mechanism that have to be solved. Crying involves delicate coordination of a number of muscles and neural events, including the laryngeal, supralaryngeal and respiratory muscle groups and the vagal neural complex. It is generally accepted that the cry of the new born is involuntary and reflexive [3].

The Cry Acoustics

Crying is a sound whereas cry analysis involves analysing sounds or acoustics. Sounds are composed of sound waves that vibrate at different frequencies. The science of acoustic involves in the breaking apart of sound waves into their component frequencies. The sound produced when the infant's vocal cords vibrate is what we hear as a cry. But the determination of sound of the cry is not just because of the vibration of the vocal cords [4]. The cry sound signal is very complex because it is not composed of single sin wave but of many waves vibrating at different frequencies. When the fundamental frequency is affected by its surroundings Complex sound waves are generated. The changes in the sound and its unique qualities or richness, is obtained by resonating chamber. These are called resonance frequencies or formants and they explain how the resonating chamber modifies, changes and filters the sound [5].

CHD Congenital Heart Disorder

Most of the infants effected by cardiac disease is congenital heart disease. Congenital heart disease involves a defect of the heart or the major blood vessels that is present at birth. This Congenital heart defect is found for one in every 120 babies. CHDs are classified into Cyanotic and Acyanotic heart disorders. The blueness of the infant's skin at birth is a primary symptom of cyanotic congenital heart disease. Tetralogy of Fallot (TOF) belongs to cyanotic heart disorder. When the skin does not turn blue it is called as Acyanotic heart disorder. This also includes Ventricular Septal Defect (VSD), Atrial Septal Defect (ASD) and Patent Ductus Arteriosus (PDA) [6].This congenital heart defect can be due to genetic abnormality and due to illness afflicting the mother during the baby's heart development due to. It can also be over medication taken by the mother during pregnancy. The symptoms of CHD affected infants is visible through shortness of breath, cyanosis, chest pain, syncope, sweating, heart murmur, respiratory infections, under-developing of limbs and muscles, poor feeding, or poor growth, build-up of blood and fluid in lungs, feet, ankles and legs. The diagnostic techniques to identify CHDs are heart murmur, Electrocardiogram (ECG), Chest X-Ray, Blood tests, Echocardiography (Cardiac ultrasound), Cardiac Catheterization [7].

MATERIALS AND METHODS

In this paper 200 congenital infant cry signals were taken and analytical test was done on this group. The results were compared with 50 healthy persons. PRATT software [8] was used for acoustic analysis. The following parameters were analysed: Jitter (Frequency perturbation local, %), Shimmer (amplitude perturbation-local, %), Harmonic to noise ratio (HNR-dB), Mean autocorrelation, Noise to harmonic ratio (NHR) and intensity [9].

Cry Recording

A total of 250 cry signals were analysed, out of which 200 infants(50 TOF,50 VSD,50 ASD, 50 PDA) having congenital heart disorder, (confirmed through medical examination) were recorded at Innova Children's Heart Hospital, Hyderabad and 50 Normal infant cry signals were recorded at hospitals and houses. The babies were 1-12 months old. The length of the cry signal was 40-60 sec. The author used a digital camera (CANON-A3100IS) in order to recognize the infant and the circumstances of crying. The sampling frequency of the cry signal was 44,100 Hz. The distance between the microphone and the mouth of the infant was 1m.

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

Feature Extraction

The various acoustic parameters like Jitter, Shimmer, Harmonic to noise ratio, Mean autocorrelation, Noise to harmonic ratio intensity [10, 11] of congenital heart disorder and healthy infant cries were extracted from the different cry signals by using PRATT software. The figure - 1 shows the flow chart of cry signal analysis

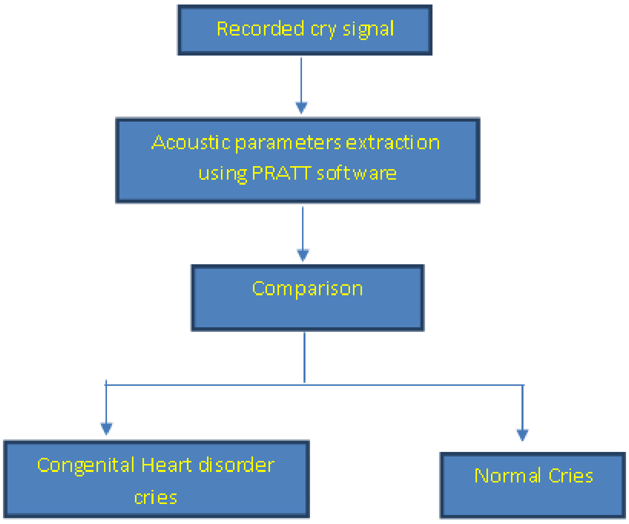

Figure 1: Flow Chart Showing Cry Signal Analysis

a) Jitter (Relative) is the average absolute difference between consecutive periods, divided by the average period. It is expressed as a percentage:

$$Jitter = \frac{1}{N-1}\sum_{i=1}^{N-1}|T_i - T_{i+1}|$$

b) Shimmer (Relative) is defined as the average absolute difference between the amplitudes of consecutive periods, divided by the average amplitude, expressed as a percentage:

$$Shimmer = \frac{1}{N-1}\sum_{i=1}^{N-1}\frac{1}{N-1}\sum_{i=1}^{N-1}\left|20\log\frac{A_{i+1}}{A_i}\right|$$

c) Harmonic to Noise Ratio (HNR) A Harmonicity object represents the degree of acoustic periodicity called as HNR. It is expressed in dB. It is used to measure for quality of the voice.

$$\text{HNR}=10*log_{10}\frac{AC_V(T)}{AC_V(0)-AC_V(T)}$$

d) Mean Autocorrelation: It calculates the degree of similarities between a given time series and a lagged version

$$\widehat{R(k)} = \frac{1}{(n-k)}\sum_{t=1}^{n-k}(X_t-\mu)(X_{t+k}-\mu)$$

RESULTS AND DISCUSSIONS

Congenitalcry signals (n = 200) and healthy cry signals (n = 50) were recorded and analysed by using PRATT software (Tables 1-6). Cries of infants were analysed and classified as per the type of disorder to establish possible differences in jitter, Shimmer, Harmonic to noise ratio, Noise to Harmonic ratio, Auto correlation and intensity. Table 1, 2 represented the mean of Jitter and shimmer, values of all groups. Table 3, 4 represented the mean of Noise to harmonic ratio and Auto correlation of all groups. Table 5 and 6 represented the mean of Harmonic to noise ratio and intensity of all groups

Table 1: Comparative Analysis of Jitter

S. No	Name of the Disorder	Mean of Jitter (Absolute)
1	TOF	3.67%
2	PDA	1.56%
3	ASD	2.13%
4	VSD	1.17%
5	Normal	0.98%

Table 2: Comparative Analysis of Shimmer

S. No	Name of the Disorder	Mean of Shimmer (Relative)
1	TOF	12.58%
2	PDA	9.88%
3	ASD	12.55%
4	VSD	12.35%
5	Normal	8.28%

Table 3: Comparative Analysis of Mean Noise to Harmonic Ratio (NHR)

S. No	Name of the Disorder	Noise to Harmonic Ratio (NHR)
1	TOF	0.32
2	PDA	0.13
3	ASD	0.21
4	VSD	0.08
5	Normal	0.11

Table 4: Comparative Analysis of Auto Correlation

S. No	Name of the Disorder	Mean Autocorrelation
1	TOF	0.79
2	PDA	0.90
3	ASD	0.85
4	VSD	0.92
5	Normal	0.93

Table 5: Comparative Analysis of Harmonic to Noise Ratio (HNR)

S. No	Name of the Disorder	Mean Harmonic to Noise Ratio (HNR)
1	TOF	7.50
2	PDA	12.23
3	ASD	9.71
4	VSD	11.84
5	Normal	21.67

Table 6: Comparative Analysis of Mean Intensity

S. No	Name of the Disorder	Mean Intensity
1	TOF	79.01
2	PDA	83.91
3	ASD	80.27
4	VSD	83.63
5	Normal	78.45

The analysis of mean of acoustic parameters like Jitter, Shimmer, Mean Auto correlation, HNR and NHR of different congenital and healthy persons are compared and presented in Figure 2-6. From the figures, TOF disorder infant cries findings showed the mean values of jitter, shimmer, Mean Auto correlation, NHR, HNR and intensity respectively 3.67%, 12.58%, 0.79, 0.32, 7.50, and 79.01 while, Infant cries with PDA disorder showed 1.56%, 9.88%, 0.90, 0.13, 12.23, and 83.91 for the same parameters. Infants who suffered from ASD were tested and the resultant parameters mean values obtained are 2.13%,12.55%, 0.85, 0.21.9.71 and 83.63.The findings of VSD disorder infant cries showed that the mean values of jitter, shimmer, Mean Auto correlation, NHR, HNR and intensity are 1.17%, 12.35%, 0.92, 0.08, 11.84 and 83.63.However, normal infant cries were also investigated and the mean values of jitter, shimmer, Mean Auto correlation, NHR, HNR and intensity are 0.98%, 8.28%, 0.93, 0.11, 21.67 and 78.45.

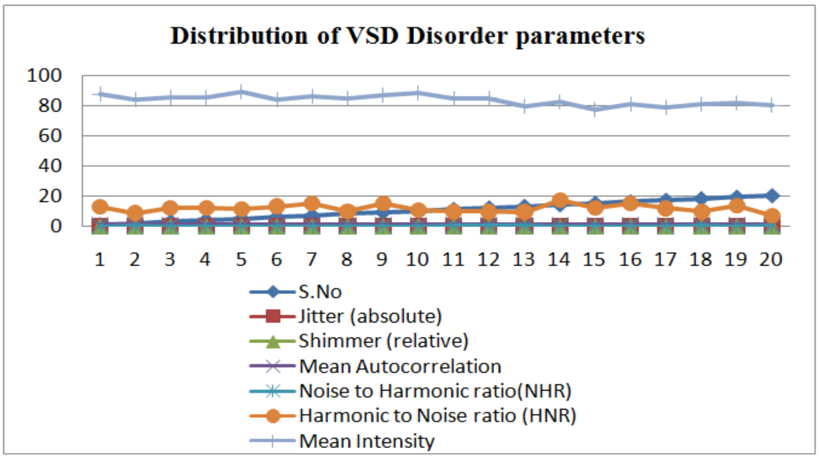

Figure 2: Distribution of VSD Disorder Parameters

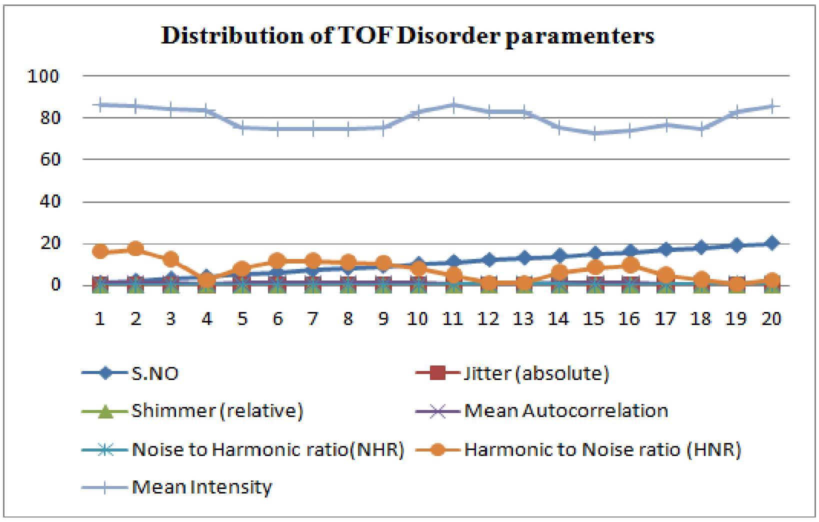

Figure 3: Distribution of TOF Disorder Parameters

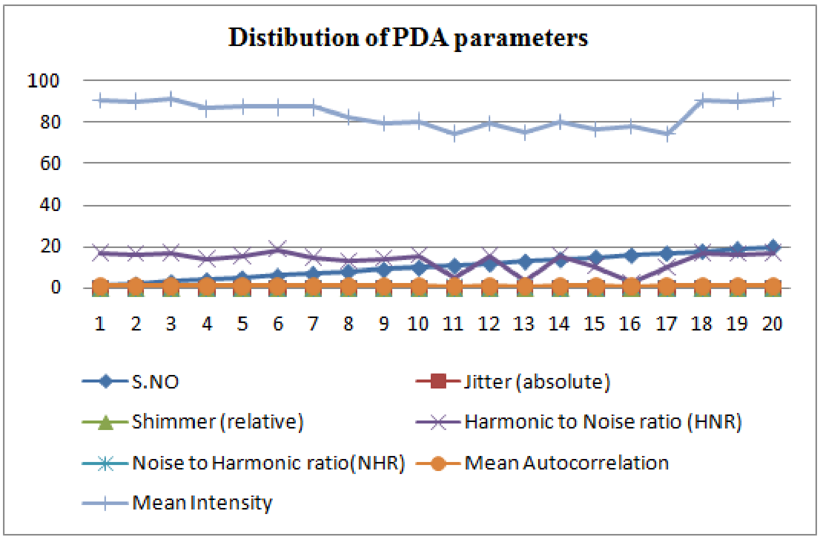

Figure 4: Distribution of PDA Disorder Parameters

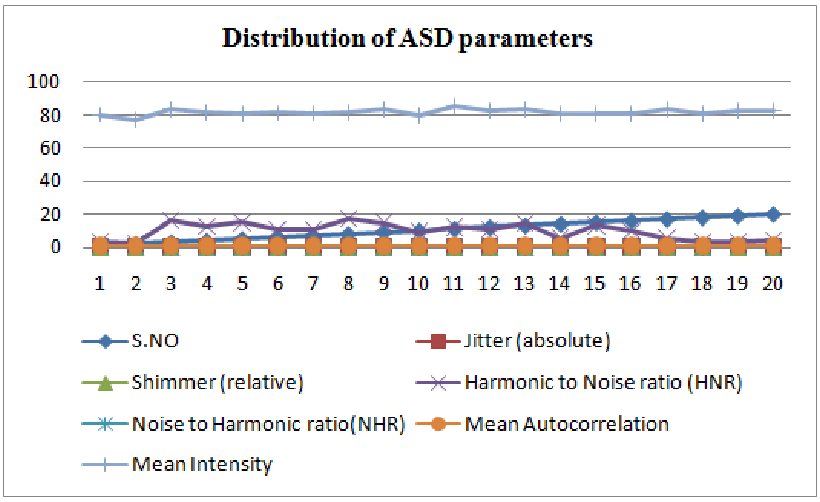

Figure 5: Distribution of ASD Disorder Parameters

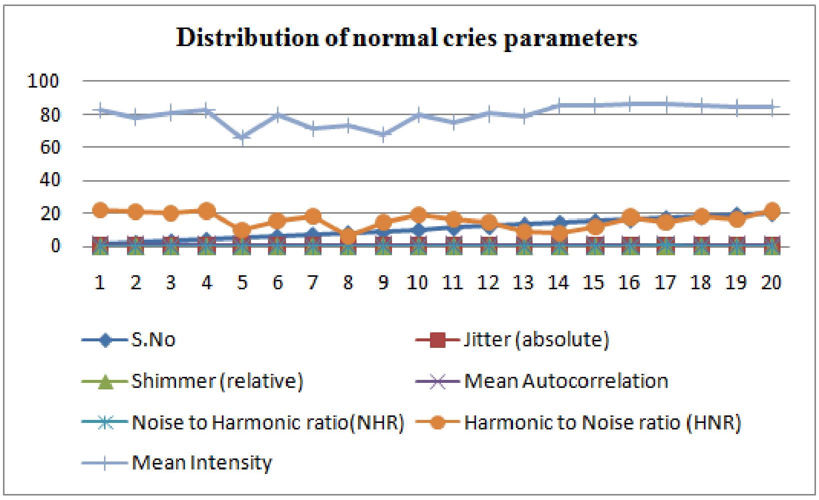

Figure 6: Distribution of Normal Cries Parameters

CONCLUSIONS

In this paper, acoustic analysis is used for the detection of congenital heart disorder. The main target of the investigation was to find the differences between the crying sounds of healthy infants and congenital heart disorder infants. The parameters of jitter, shimmer, Mean Auto correlation, NHR, HNR of Normal and Congenital heart disorder cries were investigated using PRATT software. It is evident from the results that the HNR value is very high for normal cries and low for TOF disorder infant cries and the value of NHR is low for normal cries. Further research is needed in this direction wherein these parameters might be useful to identify the pathological conditions of infants at an early stage.

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