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Original Research Article

Analysis of Cry of Infants with Asphyxia

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ABSTRACT

Cry samples of 160 infants, that is, 31 infants with asphyxia, 29 low birth weight infants with asphyxia and 100 normal infants were analyzed, using PRAAT software, to extract the acoustic, temporal and spectral parameters. Results showed significant differences between cries of infants with asphyxia and normal infants in terms of latency and flat melody type. Similarly, the cries of infants with asphyxia and low birth weight infants with asphyxia had significant differences in latency, the average duration of cry, number of shifts, and raising melody type. Significant differences between cries of low birth weight infants with asphyxia and normal infants were observed in number of voice breaks, and rising-falling melody type. It has been concluded that the acoustic, temporal and spectral parameters analyzed have been useful in differentiating the cries of infants with history of asphyxia and thus has clinical utility.

Keywords: Infants, cry, acoustic, asphyxia and low birth weight.

INTRODUCTION

Infant starts crying immediately after birth, that is when the infant's potential to cry due to the interaction of maturational ability and conditions of environment is understood. [1] The infant's first cry is very important for language acquisition. [2] A feeble or delayed first cry may be an early indication of birth asphyxia [3] this is considered as a high-risk factor as they have been found to cause brain damage [4] other neurological problems [5] and neurodevelopment disorders. [6,7]

The risk of having asphyxia has been reported to increase by 5.8 times in infants with low birth weight. [8-13] Incidence of asphyxia has been found to be 8% [14,15] and has also been reported to be high at birth. [16,17] One of the main reasons for the early neonatal mortality in India has been found to be the occurrence of birth asphyxia. According to the National Neonatal Perinatal Database [18] report on intramural births the incidence of birth asphyxia has been about 5% among the institutional birth and it has accounted for 24.3% of the neonatal deaths.

According to Manfredi et al. [19] crying may affect the respiratory flow and moreover, in infants with asphyxia crying has been found to involve high effort, which might lead to distress and even have an undesirable effect on blood oxygenation. Hence, acoustic analysis of infants' cry plays a vital role in identifying the abnormalities in the neurophysiological conditions of the infants. Physio-acoustic studies of the phonation (cry) have been reported to help in understanding of various changes occurring during a disease condition. [20]

Lederman et al., [1] have reported that the cry helps in the diagnosis, especially in case of infants who are at risk. That is, infants who have history of any trauma which are associated with motor and/or sensory disorder which develops later on. Even though most of the infants may develop normally, but considerable amount of them do not, still there are no means to identify the infants who might probably develop abnormalities, so that proper and early treatment can be planned to improve the condition. At-risk infants have been found to demonstrate a lot of individual variations in cry acoustics which differ from cry of normal infants and hence provides information regarding their prognosis. [2,3]

Michelsson [21] compared cry signals of 250 infants with asphyxia with 50 healthy full-term infants and 75 healthy preterm infants and reported that the cries of neonates with dominating peripheral respiratory distress differed considerably from the cries of normal infants in terms of the duration of cry and the maximum fundamental frequency. The cries of infants with mainly central respiratory problems were significantly different from the normal infants in terms of the duration of cry, minimum and maximum fundamental frequency. These changes in the cry characteristics were more marked in terms of severity as the duration of asphyxia increased.

The results of the follow-up study by Michelsson, Sirvio, & Wasz-Hockert [22] indicated that there were significant differences in the cries of the infants with asphyxia and normal infants in-terms of the maximum fundamental frequency, minimum fundamental frequency, biphonation, vibrato, double harmonic break, glottal roll, rising melody, falling-rising melody and flat types of melody. Follow-up assessment at around 2-8 years of age had revealed that the neurologically affected infants and infants who died had more abnormal cries during the neonatal period. Comparison of cry patterns, recorded at day one and day eight of birth had shown that the infants were more likely to improve without neurological sequel when the cries became normal within few days after asphyxia than when the cry characteristics remained abnormal during the hospitalization period.

Michelson, Tuppurainen, & Aula [23] reported that in cries of infants with asphyxia there was a high occurrence of biphonation, glides, rising and falling/rising type of melody. Lenti [24] studied cries of infants with asphyxia having evident lesions in MRI and normal infants. Results of spectrographic analysis of cry revealed that infants with brain lesions had more occurrence of vibrato compared to cries of infants in the control group. Especially, in two infants who were later diagnosed having spastic displegy which was followed by death, had more distinguished spectrographic findings. However, in infants with midbrain injuries the fundamental frequency parameters were decreased significantly.

Investigators have reported that jitter percent, number of voice breaks, degree of voice break, shimmer in dB, mean fundamental frequency (F0), maximum F0, pause duration, glide, furcation, tonal pit, and noise concentration were more in infants with asphyxia compared to normal infants and also infants with other high risk factors. [25-28] Verduzco-Mendoza et al. [29] analyzed the cries of 40 infants with various diseases such as asphyxia, breathing problems, deafness, and neurological disorders and reported that the infants did not differed significantly in terms of fundamental frequency.

From the review of literature, it can be viewed that asphyxia is one of the major causes of early infant mortality, especially in developing countries like India. Studies have shown that infant cry analysis can help differentiate infants with asphyxia from normal infants. However, the acoustic, temporal and spectral parameters that play an important role in early diagnosis are not conclusive. The present study is an attempt to identify acoustic, temporal and spectral parameters in the cries of infants with asphyxia and asphyxia with low birth weight.

AIM OF THE STUDY

The study aimed at analyzing the cries of infants with asphyxia, asphyxia with low birth weight and normal in terms of acoustic, temporal and spectral parameters and to determine the possible differences between these three groups of infants in terms of the parameters analyzed.

METHOD

Subjects - Based on the history that were collected from the mother of each infant and the medical records, 31 infants with asphyxia and 29 low birth weight infants with asphyxia and 100 normal infants were selected from different Hospitals for the study.

Procedure - After obtaining the consent from the mother of each infant, regarding the participation of the infant in the study, the data collection was carried out. The recording of the cry sample was carried out in a quiet room in the presence of the infant's mother. The mother of the infant was instructed not to comfort the infant or make any noise during the recording of the cry sample.

The pain cries were elicited by using procedure followed in the earlier studies [25,30-32] i.e., by flicking the sole of the infant's foot with the index finger. The cry was elicited and recorded only after the infant was fed fully. When the infant did not cry immediately or when the cry was not robust (strong and long) then the infant was stimulated again and the cry sample was recorded. The presentation of the pain stimulus was indicated by the investigator by saying 'now'. From the presentation of the stimulus to the end of the infant's cry was recorded using a digital recorder (Sony IC Recorder, ICD – P320) with the microphone held at a distance of five cm from the mouth of the infant. After the data collection, each recorded sample was transferred and saved on the hard disk of a laptop (with 64 bit and Windows 8 operating system).

PRAAT software (version 6.0.36) [33] was used to analyze the cry samples and to obtain acoustic, temporal and spectral parameters from each cry sample, which were saved on the hard disk of the laptop. To analyze parameters, the settings and the procedure that were described in the PRAAT manual [34] were used. "Each cry sample consisted of cry sequence of an infant which usually consisted of a series of relatively long expiratory cries separated by brief inspiratory intervals. This may contain many cry units, which is the sound that results during the passage of air past the vocal folds during a single inspiratory/ expiratory cycle. Each cry unit consists of one or more phonations. Phonation is a segment of cry unit that is periodic." [35] Each cry sample was displayed on the monitor of the laptop and was used for the analysis. By visual inspection, the investigator moved the cursor from the beginning of the word 'now' which was uttered by the investigator, to the end of the cry i.e. end of the waveform and listened to the same by playing the highlighted waveform. Once it was confirmed auditorily that the whole cry was highlighted then it was stored as a file. This was done for all the cry samples of all the groups of infants. The digitized cry samples of all the 160 infants (31 infants with asphyxia, 29 low birth weight infants with asphyxia and 100 normal infants) were used for the analysis of acoustic, temporal and spectral parameters.

For measuring Acoustic parameters, each of the cry sample was selected and the waveform and spectrogram of the same was displayed using PRAAT software. Each cry phonation was selected by highlighting and then selecting the ‘voice report’ option in the ‘pulses’ menu of the ‘Edit’ window. PRAAT software displayed the values of the following acoustic parameters (i) average fundamental frequency (F0), (ii) Minimum fundamental frequency, (iii) Maximum fundamental frequency, (iv) Standard deviation (SD) of fundamental frequency, (v) Jitter (Local), (vi) Jitter (Absolute), (vii) Jitter (Rap), (viii) Jitter (PPQ 5), (ix) Jitter (DDP), (x) Shimmer (Local), (xi) Shimmer (dB), (xii) Shimmer (APQ 3), (xiii)

Shimmer (APQ 5), (xiv) Shimmer (APQ 11), (xv) Shimmer (DDA), (xvi) Noise to Harmonic ratio, (xvii) Harmonic to Noise ratio, (xviii) Number of voice breaks, and (xix) Degree of voice breaks, as shown in the Figure 1. The values were noted. Similar procedure was used to analyze all the phonations of the cry sample. For each parameter, the values obtained from all the phonations were averaged to obtain mean values. Likewise, cry samples of all the infants were analyzed.

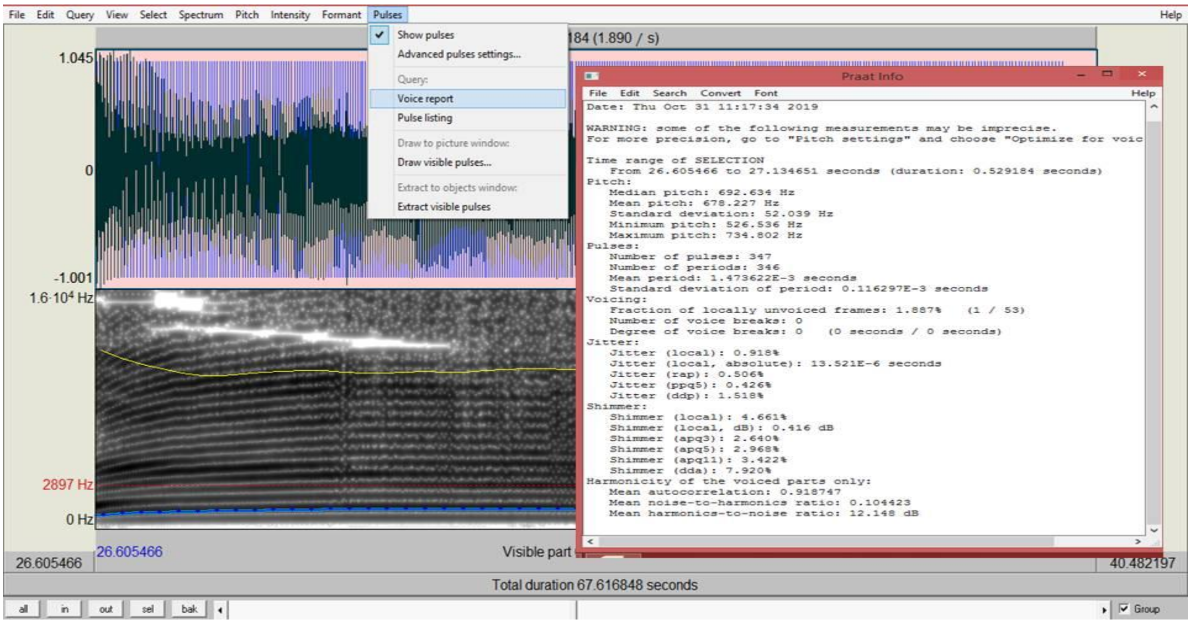

Figure 1: Shows the values of acoustic parameters as displayed by the PRAAT software.

To obtain the value of Formant 1, each phonation was highlighted by moving the cursor from starting to the end point of phonation by visual and auditory confirmation of the waveform and spectrogram, then "formant" option was selected from the menu and from the drop down menu "Get first formant" was clicked. The value displayed by the software was noted. Likewise, from the menu, "formant" option was selected and from the drop down menu "Get second formant" was clicked to obtain value of Formant 2. The value of Formant 2 was noted. Similar procedure was followed to obtain values of Formant 1 and Formant 2 for all the phonations of the cry sample. All the obtained values were averaged to get mean values of Formant 1 and Formant 2 of the cry sample. Using same procedure, the cry samples of all the infants were analyzed.

For analyzing Temporal parameters the following procedures were used. (i) To measure 'Latency', the cursor was placed at the end of the word 'now' which was uttered by the investigator during cry recording. Then, the cursor was moved to the starting of the cry sample. The duration of the highlighted portion was noted as the latency. (ii) To measure 'Total duration of the cry' the cursor was placed at the starting of the cry sample and then the cursor was moved to the end of the cry sample. The duration of the highlighted portion was noted as the Total duration of cry of the cry sample. (iii) 'Duration of phonation' was measured by placing the cursor at the starting and dragging to the end of each phonation. The highlighted portion displayed the duration of the phonation in seconds, and the value was noted. Similar procedure was carried out for all the phonations in the cry sample. The obtained values from all the phonations of the cry sample were averaged to get the mean value. (iv) The values of all the duration of phonation noted from the entire cry sample were compared with each other. The lowest value among all the duration of phonation was noted as 'Minimum duration of phonation' in the cry sample. (v) The highest value noted among all the duration of phonations was noted as 'Maximum duration of phonation' in the cry sample. (vi) To measure 'Pause duration' the cursor was placed at the end point of each phonation and was moved to the starting point of the following phonation. The duration of the highlighted portion was noted as Pause duration. All the obtained values were averaged to get the mean value of pause duration for the entire cry sample. (vii) 'Second pause' was measured by placing the cursor at the end of the first phonation and moving the cursor to the starting of the second phonation. The highlighted portion displayed the duration of second pause (viii) To measure 'Duration of cry' the cursor was placed at starting of each cry unit and was moved to the end of the cry unit. The duration of highlighted portion displayed was noted. All the obtained values of all the cry units of the entire cry sample were averaged to get the mean value. Similar procedures were carried out to analyze cry samples of all the infants.

The following spectral parameters were measured by analyzing the narrow band spectrogram displayed by identifying each of the following as per the definitions given in appendix- (i) Shift (ii) Glide (iii) Tonal pit (iv) Double Harmonic Break (v) Biphonation (vi) Vibrato (vii) Furcation (viii) Noise concentration (ix) Plosive (x) Glottal roll and (xi) the type of Melody (Raising-falling/ Falling-raising/ Raising/ Falling/ Flat/ fluctuating melody or No pitch). The total numbers of occurrences of each parameter were noted for each of the phonation in the cry sample. Then, the values were averaged to get the mean values. Similarly, cry samples of all the infants were analyzed.

Statistical analysis - The obtained values were then tabulated and subjected to statistical analysis using the Statistical Package for the Social Sciences (SPSS-Version 16). The mean and standard deviation of all the parameters for each group were calculated. The data were subjected to One-way ANOVA for comparing between the groups. To know the significance of difference, Scheffe's Post hoc test was carried out. 'p' value of < 0.05 was considered as significant.

RESULTS

Between each group comparisons for all the parameters were made using One-way ANOVA. Results indicated that there were statistically significant differences between groups in latency [$F(6,179)= 4.89$, $p= 0.001$], average duration of cry [$F(6,179)= 2.31$, $p= 0.036$], number of voice breaks [$F(6,179)= 3.18$, $p= 0.005$], number of shifts [$F(6,156)= 3.27$, $p= 0.005$], raising-falling melody type [$F(6,179)= 9.79$, $p= 0.001$], raising melody type [$F(6,67)= 3.69$, $p= 0.003$] and flat melody type [$F(6,172)= 9.35$, $p= 0.001$].

The mean and standard deviation values for the parameters which exhibited statistically significant differences between the infants with asphyxia, low birth weight infants with asphyxia and normal infants (Group 1, Group 2 and Group 3 respectively) are shown in Table 1. From Table 1 it can be seen that the mean value of latency was highest for infants with asphyxia, followed by normal infants and then for asphyxia with low birth weight infants. However, for average duration of cry, shifts and Raising Melody, the mean values were highest for asphyxia with low birth weight infants compared to normal infants and was least for infants with Asphyxia. The mean values of the flat melody were highest for infants with asphyxia, followed by asphyxia with low birth weight infants and least for normal infants. The mean values were highest for normal infants and lowest for asphyxia with low birth weight infants for rising-falling melody type. For number of voice breaks, the mean values were highest in low birth weight infants with asphyxia compared to infants with asphyxia and least in normal infants.

Table 1: Mean and standard deviation (SD) values for the parameters which exhibited significant difference across different groups.

Parameters	Group 1	Group 2	Group 3
Latency	2.89 (2.17)	1.08 (0.44)	1.49 (0.82)
Average Duration of cry.	1.49 (0.68)	2.92 (1.16)	2.05 (1.18)
Raising-Falling Melody.	29.12 (18.16)	22.34 (9.04)	48.77 (18.93)
Raising Melody.	4.1 (0.56)	26.15 (3.32)	10.70 (7.82)
Flat Melody.	58.2 (20.32)	44.76 (16.95)	31.81 (16)
Shift.	22.51 (13.45)	43.68 (11.02)	27.2 (14.58)
Number of voice break.	0.85 (0.42)	1.15 (0.62)	0.58 (0.46)

The parameters which exhibited a statistically significant difference in One-way ANOVA were subjected to the Post-Hoc Scheffe test. The comparisons between groups for the parameters which exhibited significant differences are depicted in the Table 2. Results revealed that there were significant differences between cries of infants with asphyxia and normal infants in latency, and flat melody type. Between cries of infants with asphyxia and low birth weight infants with asphyxia, there were significant differences in latency, the average duration of cry, number of shifts, and raising melody type. Significant differences between cries of normal infants and low birth weight infants with asphyxia were observed for number of voice breaks and rising-falling melody type.

Table 2: Showing comparisons between groups for parameters which exhibited significant differences.

Parameters	Group1 Vs Group2	Group2 Vs Group3	Group1 Vs Group3
Latency.	Longer in Group 1	-	Longer in Group 1
Average duration of cry.	Longer in Group 2	-	-
Raising- falling melody.	-	More in Group 3	-
Raising melody.	More in Group 2	-	-
Flat melody	-	-	More in Group 1.
Number of Shifts.	More in Group 2	-	-
Number of voice breaks.	-	More in Group 2	-

DISCUSSION

From the review of literature, none of the studies on acoustic analysis of cry of low birth weight infants with asphyxia were found by the investigator. Thus, the results of the statistical analysis are discussed using studies that have compared cries of infants with asphyxia and cries of normal infants. The results of the present study are in consonance with the following studies. Michelsson, Sirvio, & Wasz-Hockert [22] indicated that there is a significant difference between the cries of the infants with asphyxia and normal infants. In infants with asphyxia, usually flat melody type occurs. Partanen et al., [36] concluded that the painful cries of healthy infants were significantly different from the cries of infants with asphyxia. Sangeetha [26] reported that the number of voice breaks, shimmer in dB and maximum F0 was more in infants with asphyxia compared to normal infants. Nandyal [27] reported that infants with asphyxia have a high maximum fundamental frequency. Visalakshi [37] reported that maximum fundamental frequency, glides and the falling melody was higher in cries of infants with asphyxia than normal infants. Whereas, vibrato was a little less in infants with asphyxia compared to normal infants. There was no significant difference between cries of infants with asphyxia and normal infants in double harmonic break and shift.

Many investigators have reported that the differences in cries of infants with asphyxia and normal infants might be due to more effort involved in cry production by infants with asphyxia, which in turn is because of affected respiratory flow leading to an adverse effect on oxygenation of blood. [19] Also, as birth asphyxia leads to brain damage [38] and other neurological problems, [5] cry production in infants with asphyxia is affected. This is reflected in cry characteristics of infants with asphyxia and low birth weight infants with asphyxia. As the acoustic analysis of an infant's cry is associated with basic neurophysiological parameters. Thus, physio-acoustic studies of the phonation (cry) might also improve understanding of various differences in the cry of infants. [20]

CONCLUSIONS

From the present study, it can be inferred that latency, intensity, and flat melody type are important cry parameters that differentiate between infants with asphyxia and normal infants. However, latency, the average duration of cry, minimum intensity, number of shifts, and raising melody type are main cry parameters that differentiate between infants with asphyxia and low birth weight infants with asphyxia. The important parameters that help in differentiating cries of low birth weight infants with asphyxia and normal infants are intensity, minimum intensity, number of voice breaks, and rising-falling melody type.

From the study, it was observed that the cries of low birth weight infants with asphyxia were significantly different from cries of infants with asphyxia and normal infants. Therefore, low birth weight infants with asphyxia should be considered separately and their cries can be used to differentiate them from infants with asphyxia and normal infants. Hence, the differences in the acoustic, temporal and spectral parameters of cries of low birth weight infants with asphyxia, infants with asphyxia and normal infants will aid in early diagnosis, predicting prognosis and planning appropriate interventions.

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APPENDIX

Definitions of Spectral parameters are as follows:

(i) "Shift denotes an abrupt upward and downward movement of the fundamental frequency. The shift part has been included in the measurements when the signal exceeds 0.1 sec" (Sirvio and Michelsson, 1976). [39]

(ii) "Glide is as a very rapid up and/or down movement of the fundamental frequency, and its duration is generally very short. The change in the frequency of the fundamental tone must be at least 600 Hz in 0.1 seconds to be considered as gliding" (Sirvio and Michelsson, 1976). [39]

(iii) "Tonal pit refers to a rapid downward and upward movement in fundamental frequency. It is considered when the fall in pitch exceeds 30% and occurs in less than 0.4 sec." (Sirvio and Michelsson, 1976). [39]

(iv) "Double harmonic break or sub-harmonic break is defined as a parallel series of harmonics which have the same melody form as the fundamental frequency and occurs simultaneously with the fundamental. There may be a double or treble series of parallel harmonics." (Sirvio and Michelsson, 1976). [39]

(v) "Biphonation or diplophonation is a double series of fundamental frequencies. In biphonation the two or more series do not have a parallel melody form. One series can be falling, while the other can be simultaneously rising, unlike in double harmonic break" (Sirvio and Michelsson, 1976). [39]

(vi) "Vibrato is considered to occur when atleast four successive rapid up and down vibrations have been noticed. It is characterized by frequency vibrations that appear more clearly in the upper harmonics" (Sirvio and Michelsson, 1976). [39]

(vii) "Furcation is a term denoting a split in the fundament, where a relatively strong cry signal suddenly breaks into a series of weaker ones, with each of them having its own fundamental frequency." (Sirvio and Michelsson, 1976). [39]

(viii) "Noise concentration denotes a clearly audible, high energy peak of 2000-2500 Hz found both in voiced and voiceless parts of the signal. This is uncommon in the cries of healthy babies." (Sirvio and Michelsson, 1976). [39]

(ix) "Plosive- Glottal plosive is a sudden release of pressure at the vocal folds producing an impulsive expiratory sound" (Golub and Corwin, 1990). [35]

(x) "Glottal roll is a sound with very low pitched, voiced fundamental frequency and usually has a low intensity. Glottal roll occurs often at the end of the phonation." (Sirvio and Michelsson, 1976). [39]

(xi) Melody type is classified as raising-falling, falling-rising, raising, falling and flat. The criteria of classifying the type is that there should be at least 10 % change in pitch level during more than 10 % of the duration of cry (Golub and Corwin, 1990). [35]

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