The infant’s cry in health and disease

MUKEISH AGRAWAL

INTRODUCTION

An infant’s cry is a reflection of the child’s physiological state and emotional well-being. It differs in different situations and an experienced person can draw useful inferences from it. Crying activity has been studied as an index of neonatal well-being at birth, as a mode of infant–mother communication, and for monitoring sick infants to obtain a ‘quick diagnosis’ or to estimate the prognosis. Many studies have also explored the correlation between early vocal behaviour and later development of speech and intelligence. The auditory interpretations of an infant’s cry are subjective and depend on the clinical experience and alertness of the listener. Marked variations exist in the ability of medical and paramedical personnel to differentiate between the cries of different infants, and of the same infant in different situations. Mothers, however, are adept at identifying the cry of their own infants and its cause. Though there is ample evidence that training can improve the perceptual capability of a listener, such training based simply on individual auditory impressions is difficult. Furthermore, these impressions are subject to individual bias.

The invention of sound spectrographic techniques in the 1940s has made it possible to objectively analyse infantile vocalizations. These techniques present a graphic record of sound at any given instant or of the entire sound pattern heard over a period of time. This has helped to study the ‘cry sounds’ of normal and sick infants in detail. This article reviews various aspects of infants’ cries and the basis of sound spectrographic analysis.

PHYSIOLOGY OF THE CRY

Crying is a complex neurophysiological act. It results from the intense expulsion of air from the lungs under pressure, causing the approximated vocal cords to perform rhythmic oscillations. The alternate condensation and rarefaction of the stream of air particles leads to the formation of sound waves. The anatomical cavities above and below the cords act as resonators. The acoustic characteristics of a cry depend on the intensity of air expulsion; the tension, length, thickness and shape of the vocal cords; and the shape, length and tension of the resonators. The peripheral phonatory organs are neurologically controlled by cranial nerve nuclei, the caudal periaqueductal region, the adjacent segment and the subcortical structures of the amygdala, and the hypothalamus. An infant’s cry is likely to be altered by structural or functional changes in these areas, in the interneurones connecting these regions or in the peripheral phonatory organs themselves.

Depending on the quality of sounds and status of the peripheral phonatory organs, Truby and Lind categorize three different types of sounds, namely phonation, hyperphonation and dysphonation. Phonation is the result of simple periodic oscillations and adequate amplification by the resonators. Hyperphonation represents an extremely high-pitched cry caused by excitation of the constrained vocal cord and/or constrained activity of the resonating chambers. Dysphonation is a raucous cry and may result from alterations in basic glottic oscillations accompanied by simultaneous supraglottic excitation.

THE CRY IN A NORMAL INFANT

Although not usually recognized, an infant can cry in utero if asphyxiated or if the membranes are ruptured. The first postnatal cry is an important measure of the general physiological status of the newborn. It helps clear the air passage, the switch-over from foetal to neonatal circulation, and the maintenance of body temperature. A feeble or delayed first cry may be an early indication of birth asphyxia. Marked variations in the amount of crying have been demonstrated between neonates and in the same neonate at different ages and in different rearing conditions. Preterm infants and those in whom the cord is clamped late usually cry less than full-term infants and those in whom the cord is clamped early. The first child in the family cries more than the subsequent ones. Infants cry more frequently in the evening and in hospitals than at home. The amount of crying increases after birth and reaches a maximum at four to six weeks, followed by a gradual decline. Early stimulation, increased supplementary carrying and better nursing care of the infant in early life is also known to reduce crying.

CAUSES OF AN INFANT’S CRY

Crying activity in a neonate or young infant is virtually the sole mode of vocal response to a wide variety of stimuli (Table I). In very young infants, the cause is often unidentified or non-specific, and shifts to specific factors with age. The cry in early infancy is a reflex activity, but with maturation of the brain it becomes a form of communication and expression of emotion.
TABLE I. Common causes of crying in infancy.24,29-32

<table>
<thead>
<tr>
<th>Internal disturbances</th>
<th>External disturbances</th>
<th>Emotional factors</th>
<th>Idiopathic</th>
<th>Infective ('Paroxysmal fussing') periods</th>
<th>Mythological concepts</th>
<th>Sick infants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hunger, thirst, wind, colic, pain, sleepiness, constipation</td>
<td>Excessively hot or cold environment, uncomfortable positions, unpleasant noise, light, smell or taste, soiled diapers, itching, flies and mosquitoes, partial or total immobilization, restraining of body</td>
<td>Loneliness, fear, nightmare, jealousy, pleasure, boredom, ego-affections</td>
<td>'Idiopathic'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In response to cry of another infant in neighbourhood</td>
<td>'Infective' cry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SPECTROGRAPHIC ANALYSIS OF AN INFANT’S CRY

Although various instruments ranging from simple oscilloscopes to advanced cry analysers have been used, their basic principles remain the same. To study a cry, initial recordings are made on a sensitive tape recorder with the microphone held a few inches from the infant. To elicit a cry, a painful stimulus such as pinching the ears is applied. Spontaneous cries can also be recorded. Suitable zones or samples are selected from the recordings and transcribed by a spectrograph which prints a picture of the sound onto a continuously rotating kymograph drum. Frequency is depicted along the ordinate and time on the baseline. The relative intensity of markings on the paper gives a rough estimate of the amplitude.

Although more than 20 cry characteristics have been identified, some important and basic variables are discussed here and shown in Fig. 1. The duration between the pain stimulus and the onset of crying is called the ‘latent period’. Each vocalization after this period consists of an expiratory phase (phonation) and a much shorter, usually inaudible, inspiratory phase. The length of the audible expiratory phase from the time of the stimulus to the next inspiration is termed as the ‘duration of phonation’. The expiratory phase may be either continuous or interrupted. If interrupted, its parts are referred to as ‘signals’, with the longest signal being the main one. The time interval between the first and the second vocalizations or between the end of the first phonation and the following inspiration is known as the ‘pause time’.

During the phase of phonation, a single frequency sound, i.e. a pure tone, appears on the spectrograph as a horizontal line. The height of this line represents the ‘frequency’ of the tone. Pure tones are rare under natural conditions and generally appear as a series of parallel horizontal lines. The lowest line in the sonograph is called the ‘fundamental frequency’ (FF), and successively higher components the second, third, etc. harmonics. The pitch of the FF is also variable and the highest and the lowest voiced points in the FF represent, respectively, the ‘maximum and minimum pitch’. A sudden upward or downward movement in FF is known as a ‘shift’.

Phonation may be initiated or terminated with a shift, but a similar movement can also be located in the middle of phonation. The relation between the shift and course of phonation (whether it occurs in the beginning, middle or at the end) is important in some disorders. A marked shift exceeding 500 Hz is called a ‘glide’. Gradual changes in the FF during phonation also result in different ‘melody forms’, i.e. falling, rising, falling–rising, rising–falling, flat, etc. A double series of FF running simultaneously with different kinds of melody forms or pitch, e.g. one series going down and another rising, is termed 'biphonation'. When a simultaneous series of double harmonics have a similar melody form as the FF but of lower intensity, it is called a ‘double harmonic break’. A peculiar break in phonation when the FF suddenly splits into a series of weaker frequencies either at the beginning, middle or end of phonation is known as ‘furcation’. Sometimes a series of wave-like frequency variations appear on a sonogram. These represent the ‘vibrato’ form of cry. Besides these common characteristics, some workers have also recorded

![Sonagram schematic](image-url)

Fig. 1. Sonagram (schematic) showing important cry variables. A=Stimulus, B=latency, B-C=duration of phonation, 1=max. pitch of FF, 2=min. pitch of FF, 3=shift part, 4=biphonation, 5=furcation, 6=double harmonic break, 7=vibrato, melody form, I=FF, II and III= overtone frequencies
sound pressure levels, voice quality, noise concentration (audible high-energy peaks during phonation), duration of the crying period and the presence of glottal plosives and glottal rolls (phonation of low FF and low intensity below the normal pitch, often occurring at the end of phonation).

Acoustic theory predicts that any anatomical, functional or neurological abnormality in the phonation mechanism will be reflected in measurable acoustic variations in some or all of the above characteristics. Based on this hypothesis, various cry tests and representative sonographic patterns have been developed. Recently, Golub et al. have described a physio-acoustic model for cry production, which is used to measure subglottic pressure, laryngeal function and the functioning of the supraglottal vocal tract. Such models also help in the understanding of the origin of sounds and their distortions in abnormalities of the vocal tract. With these models it is also possible to retrace the origin of sonographic abnormalities.

CRY OF A HEALTHY INFANT

Crying in a healthy infant has been studied in four different conditions: birth, hunger, pain and pleasure.

Birth

Considerable variations exist in the acoustic characteristics of human birth cries mainly in the extent of non-harmonic distortion. In an analysis of birth cries in 338 normal infants, Bilnick et al. reported that duration of vocalizations in 43% were of approximately 0.7 seconds, with their FF ranging between 400 and 500 Hz. However, maximum frequencies reached 8000 Hz, with the dominant frequency (the strongest harmonic on the spectrograph) ranging between 1200 and 1500 Hz. Frequency modulations up to 50% were also present. Some variations in the intensity and character of the infant's cry could be attributed to the arousal state or mucus congestion in the vocal passage. Most infants began their cries at a high intensity and with marked harmonic distortion, i.e. loud, strong and spanning. The amplitude gradually decreased and the cry became more harmonic. The repetition rate of the cries was variable with the usual utterance rate being one per second. In a few normal babies, the cries lasted longer and were interspersed with a vibrato effect or longer bands of non-harmonic sounds. The inspiratory phase was mostly voiceless, but high squeaky inspirations were occasionally heard. Other workers have reported similar findings in a typical birth cry, but with a melody form which was flat or falling, and usually voiceless or tense.

Pain

Pain cries have been widely investigated in normal infants and the results have been variable. Even in sick babies, cry analysts have used a pain stimulus, e.g. pulling of hair, snapping the ears, pinching the biceps, striking the sole with a rubber band, etc. In general, pain cries are high pitched (FF 510 to 2750 Hz) with marked frequency variations, variable duration of phonation (2.6 to 5.2 seconds), have frequent shifts (16% to 38%), and have a falling or rising–falling melody form present in more than 75% of cases. Double harmonic breaks, glottal rolls and plosives, and vibrato occur more frequently during pain cries of normal infants. Also the variations of FF during phonation are greatest in the middle of the cry. The usual crying period of a normal infant is over 30 seconds and depends on the strength of the stimulus. The latent period ranges from 1.2 to 2.6 seconds; it decreases after repeated stimuli, but is unaffected by the strength of the stimulus.

Hunger

The characteristics of a hunger cry are a rising–falling melody form with relatively lower FF and frequently occurring glottal plosives. Fairbanks monitored hunger wails in his own child during the first nine months and reported a mean FF of 558 Hz over the entire period.

Pleasure

The pleasure cry is often a flat melodic type with a variable FF. It is similar to the spontaneous birth cry but is neither voiceless nor tense.

CRY OF A SICK INFANT

Paediatricians have long been aware of the characteristic shrill cry of kernicterus, the hoarse cry of laryngitis, the high-pitched piercing or staccato cry of raised intracranial pressure, the feeble cry of floppy infants, the hoarse gruff cry of cretinism, the grunting cry of pneumonia and the typical cries of the cri du chat and Down's syndromes. Though not extensively studied, sound spectrographic analyses have revealed that there are characteristic patterns of crying in sick infants.

Prematurity and intrauterine growth retardation

Characteristics of the cry are more dependent on gestational age than the birth weight of the newborn. Preterm infants have a shorter duration of cry with a higher FF and a glide occurs more often. The first phonation is usually longer than those that follow. Cries of full-term, low birth weight babies are almost similar to those of normal infants except for a higher shift. However, two studies on small-for-date newborns have reported exactly opposite results regarding duration and FF of the cries. No acoustic differences exist between the cries of newborn twins or quadruplets, and singletons.

Perinatal asphyxia

For asphyxiated newborns, cry analysis has a diagnostic as well as prognostic value. In a large series they were found to have high FFs with both the minimum and maximum pitches increased and biphonation occurring more frequently. The occurrence of melody forms other than falling or rising–falling was increased. In the same study (and in a subsequent one), a more pronounced abnormal cry was found in full-term asphyxiated newborns who either died later or were neurologically abnormal when compared to those who were healthy at follow up.

Infants born to mothers who were narcotic addicts also had characteristic cry abnormalities. In a study of such
infants by Blinick et al. the most characteristic abnormality was a high-pitched, squalling cry seen in 44%. It is questionable whether the abnormalities were the direct result of addiction as drug addicted mothers suffer from nutritional deficiencies and other problems which might affect the health of their offspring.

**Neonatal hyperbilirubinaemia**

The cries of infants with different kinds of hyperbilirubinaemia, mostly due to haemolytic disease of the newborn (RHHDN), have been extensively studied over the last 20 years. The most consistent abnormalities reported are shorter cry duration and latency period along with an increase in FF and maximum and minimum pitch. The frequent occurrence of furcation and biphonation have also been reported, but mainly in cases with neurological abnormalities.

A recent study constructed a cry score using 16 different acoustic characteristics and evaluated 100 healthy infants and 31 newborns with RHHDN. The results showed that the cry score and maximum pitch increased at an early stage of hyperbilirubinemia; as much as a day before the appearance of neurological signs. However, plasma bilirubin levels did not affect cry characteristics in the absence of neurological signs. Furcation, biphonation or a combination of both, occurred in most infants after the appearance of neurological signs—probably an early sign of kernicterus. A cry score of five or more at the time of discharge was consistently associated with abnormal neurological development during the first year of life. Corwin et al. suggested that the cry changes in jaundiced infants is an evidence of unstable glottal function, which might be an early manifestation of the neural toxicity of bilirubin.

**Intracranial infections**

A short high-pitched cry with biphonation, glide and abnormal melody forms is typical of bacterial meningitis, and infants with abnormal cries are more likely to develop long term neurological complications. Babies with Herpes simplex encephalitis have a most characteristic cry; they have noise concentration in addition to other features seen in meningitis.

**Hydrocephalus**

Michelsson et al. studied infants with different types of hydrocephalus and found more cry abnormalities in those with the congenital variety where FF was markedly increased while biphonation and abnormal melody forms occurred frequently.

**Diseases of the peripheral phonatory organs**

Characteristic features in infants with cleft palate include nasality, vibrato, tonal pit and instability of FF, and are distinct from those occurring in diseases of the larynx. In infectious laryngitis, cries are associated with loud inspiration, hoarseness and a long second pause time. Spectrographic cry analysis of infants with pertussis is useful in monitoring both the severity of symptoms and efficacy of treatment. Long horizontal bands with harmonics are seen and an upward trend occurs during whoops lasting for a second or more. Sometimes, laryngeal spasm caused by the whoop may lead to blank areas before the phase of expiration appears on the spectrogram.

**Chromosomal disorders**

Low-pitched monotonous cries are highly suggestive of chromosomal defects such as Down's syndrome and trisomy 13 or 18. These infants require stronger and prolonged stimuli to arouse crying and they have a longer cry latency and duration of phonation than healthy newborns. Typically, the cry has a low FF, flat melody forms, nasality and intermittent stuttering. Biphonation in every fourth cry is a characteristic of Mongolism. Cries of infants with abnormalities involving chromosome 4 or 5, the cri du chat syndrome, are usually high pitched with a flat melody form.

**Sudden infant death syndrome (SIDS)**

Two studies revealed that the pre-recorded cries of SIDS infants differed from those of normal newborns. However, in one study, the cry was shorter and weaker with a high FF, while in the other, the cry was longer, had a low FF and a greater sound pressure. The first study also recorded a higher frequency of shift and voiced inspiration. In the siblings of SIDS infants, Colton et al. documented similar differences, but to a lesser degree and suggested that these siblings had respiratory instability. Using the cry model, Golub et al. showed that these cries were the result of constriction in the vocal tract.

**Metabolic disorders**

The cries of children with protein energy malnutrition are similar to those with brain damage. They are characterized by a high FF, low amplitude, longer duration and longer latency period. The occurrence of biphonation and the flat melody form are more frequent compared to normal controls. These studies have also shown similarities between cries of malnourished (especially marasmic) infants and those with brain damage.

In hypoglycaemic infants, the cries suggest brain damage, and have a very high FF, abnormal melody forms, and vibrato and biphonation of unusual configurations. The hoarseness of the cry in infants with congenital hypothyroidism is typical. However, spectrographic analysis shows no major differences between a cretin’s and a normal infant’s cry except for a lower FF which increases gradually after treatment. The rare occurrence of shift parts and high frequency of glottal rolls at the end of phonation accentuates the auditive impression of a hoarse, low-pitched cry.

**SUMMARY**

The acoustic characteristics of an infant’s cry can yield valuable information. Recent research, involving sonographic studies of cry sounds produced by normal and sick infants under various conditions, indicate that cry characteristics might be used in the diagnosis and monitoring of sick infants. Physio-acoustic studies of their phonation may also improve our understanding of various changes...
occurring during the course of a disease.\textsuperscript{33,34}

So far, studies have included small numbers of infants and most have employed some kind of pain stimulus to induce crying. As pain cries themselves have certain diagnostic features, such stimuli may blur the characteristic cry pattern of the disease. Further studies involving larger samples are required to evaluate the role of cry analysis in clinical practice.

REFERENCES


