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A Sound Spectrogram Analysis of Children's Crying after Painful Stimuli during the First Year of Life

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Key Words
Infant cries · Pain · Sound spectrogram · Vaccinations

Abstract

In a prospective study we tested the hypothesis that a cry from an infant can be used as part of an instrument to measure pain. Ten healthy newly born infants were subjected to painful stimuli on four occasions during their first year of life. The sound of the crying was analysed with regard to duration. With the help of a sound spectrogram, the fundamental frequencies of the first five crying sounds were analysed. The number of crying sounds decreased with age. There was a considerable difference between the 10 children, and also between the different pricking occasions for the respective children. We conclude that if crying is to be used as part of an instrument for measuring pain, the child's age has to be taken into account.

Introduction

In this study we investigated the influence of age on a child's crying, and whether or not the cry can be used as part of an instrument for measuring pain in children.

The children were followed during their first year of life. Their crying was taped and analysed, first when the children were subjected to a heel-prick for a blood sample for a phenylketonuria (PKU) test, and then on three later occasions when they were being vaccinated for diphtheria, tetanus, polio, whooping cough and haemophilic influenza type B (PENTAVAC).

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Table 1. Mean weight, SD and age for 10 children, 5 boys and 5 girls, when subjected to heel-prick and vaccinations during the first year of life

Parameters	PKU	Vac 1	Vac 2	Vac 3
Infants	10	10	10	10
Weight, g	3,619 (2,950–4,205) SD 358	6,065 (5,380–7,330) SD 681	7,701 (6,370–9,060) SD 954	10,371 (8,440–12,500) SD 1,112
Age, days	3 days 12 h (3 days 0 h–4 days 2 h)	100 (88–135)	174 (157–208)	373 (355–404)

We are not aware of any similar investigation that has followed the same child during the first year of its life with repeated observations while being subjected to painful stimuli without using any general or local anaesthesia.

Method

Children

Included in the study were 13 consecutive newborn infants, 8 boys and 5 girls. All deliveries were normal and without complication. The infants were full-term and their birth weights normal. At the routine postpartum examination by a paediatrician all were found to be healthy. None of the children were subjected to any operative intervention during the year studied. During the study 2 children emigrated and the guardians of 1 child refused further participation. These 3 were excluded from the study. The means of the weights and ages of the 10 remaining children (5 boys and 5 girls), on the four occasions for the investigations, are summarized in table 1.

The children's cries were taped on four occasions during the first year of their lives. First, when the infants were between 3 and 5 days old, a PKU screening was performed. This procedure involves taking a blood sample by a heel-prick. During the first five cries the foot was neither stroked nor squeezed.

When the children were 3, 6 and 12 months of age they each received the routine vaccinations against diphtheria, tetanus, whooping cough, polio and diseases caused by *Haemophilus influenzae* type b (Hib, PENTAVAC). At a routine examination by the general practitioner who gave the vaccinations, all the children were found to be healthy.

At the time for the heel-prick all the infants had been breast-fed by their mothers at least 30 min prior to the test. The infants were awake and quiet (eyes open, no facial movement, Prechtl [1] state 3) before the prick. Their feet were pre-warmed with warm water or socks until they felt warm and seemed to have good circulation. Before the heel-pricks, the heels were cleaned with disinfected swabs. A Microtainer Brand Safety Flow Lancet (Becton Dickinson, Meylan Cedex, France) was used to make the heel-pricks.

The PENTAVAC (Aventis Pasteur MSD) was given as an intramuscular injection with a 0.60 × 25 mm disposable injection needle (Sterican, Braun Melsungen, Germany) in the upper part of the infants' thighs (anterolateral). Before the pricks the skin was disinfected with a swab.

We subjected the infants only to blood sampling and vaccinations, which is routine for all newborn infants in Sweden. At the time of the blood sampling or the vaccinations there were no alternative methods available in the department where the study was undertaken. No routine local or general anaesthesia was used prior to the prick at the time of the study. At least 1 parent, and sometimes both, were informed and had approved participation in the study.

The Ethics Committee of the Faculty of Medicine, Lund University, approved the study. This research work was performed without any obligations.

Table 2. Summary of the latency time, total crying time and time for the first five crying sounds for 10 children when subjected to heel-prick and vaccinations during the first year of life

Parameters	PKU	Vac 1	Vac 2	Vac 3	
Latency time, s Range and SD between the prick and the first cry sound[a]	1.4 (0.5–5.1) SD 1.4	1.3 (0.6–2.7) SD 0.6	0.9 (0.4–1.4) SD 0.3	1.2 (0.6–3.1) SD 0.6	no significant differences
Total crying time[a], s	107.6 (0–235) SD 85.8	43.5 (14–104) SD 34.8	15.8 (0–58) SD 17.5	31.8 (0–94) SD 32.7	significant differences p = 0.001 PKU and Vac 1, Vac 2, Vac 3
Time cry sound 1[a], s	1.0 (0–3.4) SD 0.9	2.1 (0–3.4) SD 1.9	2.2 (0–5.7) SD 2.4	3.5 (0–6.3) SD 3.4	significant differences p = 0.006 between PKU and Vac 3
Time cry sound 2[b], s	0.9 (0–3.9) SD 1.0	1.3 (0.1–6.7) SD 2.1	1.1 (0–3.8) SD 1.5	1.2 (0–2.6) SD 1.0	no significant differences
Time cry sound 3[c], s	1.3 (0–4.7) SD 1.5	1.4 (0.4–3.6) SD 1.2	1.5 (0–6.2) SD 1.9	0.7 (0–2.7) SD 0.9	no significant differences
Time cry sound 4[d], s	1.4 (0–3.4) SD 1.1	0.6 (0.1–1.1) SD 0.4	0.4 (0–0.9) SD 0.5	0.6 (0–2.4) SD 0.8	no significant differences
Time cry sound 5 [e], s	0.7 (0–2.7) SD 0.8	0.8 (0.2–2.0) SD 0.5	0.3 (0–1.1) SD 0.4	0.4 (0–0.2) SD 0.7	no significant differences

Mean value, range and SD are given.
[a] Numbers of children with no cry: PKU, n = 1; Vac 2, n = 3; Vac 3, n = 2.
[b] Numbers of children with less than two cry sounds: PKU, n = 1; Vac 2, n = 3; Vac 3, n = 3.
[c] Numbers of children with less than three cry sounds: PKU, n = 2; Vac 2, n = 3; Vac 3, n = 4.
[d] Numbers of children with less than four cry sounds: PKU, n = 2; Vac 2, 5; n = Vac 3, n = 5.
[e] Numbers of children with less than five cry sounds: PKU, n = 2; Vac 2, n = 5; Vac 3, n = 6. Older children had fewer cry sounds than newborn infants (p = 0.37).

Recording

The cries were recorded on a Panasonic RX-2700 standard tape recorder with a built-in microphone (Matsushita ElectricTrading Co., Ltd., Osaka, Japan). The tape recorder and the microphone had a frequency response in the range of 40–13,000 Hz. A Maxell MD tape was used. The microphone was held about 10 cm from the infant's mouth. The recording began before the infant had been subjected to the pricking, and continued until sampling had been completed or vaccination given and the infant had stopped crying.

Analysis

The children's cries were analysed acoustically with the assistance of a computer program specially designed for this purpose (Innomess Elektronik, Berlin, Germany). The sound spectrogram is a visual diagram of the sound signal. Time is recorded on the horizontal scale, frequency on the vertical. The curve of the lowest harmonic on the spectrogram gives the fundamental frequency, and the upper lines the harmonic overtone multiples of the fundamental frequency. We chose the sound spectrogram, since it is a well-tested and also a time-honoured method for analysing crying [2, 3]. Furthermore, an objectively measurable curve is obtained. The computer program uses a sampling frequency of 128 kHz. Signals of up to 2 s can be analysed.

We measured the time between the pricking and the first cry (the latency time), the duration of the first five cry signals after the prick, and the total crying time. The times were measured by means of the spectrogram and by listening to the tape. The fundamental frequencies for the first five cries were analysed. If these values were found to differ between those obtained from the

Table 3. Summary of the mean fundamental frequency for the first five crying sounds for 10 children when subjected to heel-prick and vaccinations during the first year of life

Parameters	PKU	Vac 1	Vac 2	Vac 3	
Fundamental frequency cry 1[a], Hz	462 (259–599) SD 103	543 (360–1001) SD 181	326 (110–547) SD 135	507 (250–632) SD 116	significant differences p = 0.049 between Vac 1, Vac 3 and Vac 2
Fundamental frequency cry 2[b], Hz	538 (410–640) SD 81	502 (395–766) SD 115	458 (250–520) SD 160	525 (250–691) SD 158	no significant differences
Fundamental frequency cry 3[c], Hz	587 (422–720) SD 96	523 (300–672) SD 105	407 (250–592) SD 155	455 (384–553) SD 74	significant differences p = 0.009 between PKU, Vac 1 and Vac 2, Vac 3
Fundamental frequency cry 4[d], Hz	622 (480–992) SD 172	529 (250–1204) SD 262	494 (295–602) SD 120	445 (400–500) SD 36	no significant differences
Fundamental frequency cry 5[e], Hz	556 (457–757) SD 116	530 (307–1075) SD 204	523 (470–600) SD 57	435 (300–500) SD 93	no significant differences

Mean value, range and SD are given.
[a] Numbers of children with no cry: PKU, n = 1; Vac 2, n = 3; Vac 3, n = 2.
[b] Numbers of children with less than two cry sounds: PKU, n= 1; Vac 2, n = 3; Vac 3, n = 3.
[c] Numbers of children with less than three cry sounds: PKU, n = 2; Vac 2, n = 3; Vac 3, n = 4.
[d] Numbers of children with less than four cry sounds: PKU, n = 2; Vac 2, n = 5; Vac 3, n = 5.
[e] Numbers of children with less than five cry sounds: PKU, n = 2; Vac 2 n = 5; Vac 3, n = 6.

spectrogram and those obtained from the computer program, we chose the values from the spectrogram. The method has been described and used in several investigations [2–5].

We have chosen to analyse the cries according to the following criteria. The fundamental frequency, shown by the bottom-most curve on the spectrogram, is the number of wave movements in 1 s, expressed as cycles per second, or Hertz. The greater the number of movements, the higher the fundamental frequency of the sound. One cry is the duration of the vocalization during a single expiration. Crying time is the time the infant cries following one prick. Latency time is the time between the prick and the first cry [6].

Statistical Analysis

The significance was calculated with the ANOVA test, the chi-square test and Fisher's test.

Results

The results showed no differences in the total crying time or in the number of children who did not cry when subjected to a prick for the three different vaccinations. The first crying sound when heel-pricked for the PKU was shorter compared with that at the prick during the third vaccination. The older the children the fewer the number of crying sounds. The crying sound numbers 2, 3, 4 and 5 were similar in length (table 2).

The fundamental frequency of the first and third crying sound was decreased during vaccination 2 and 3 compared with when being heel-pricked for PKU and vaccination 1. There were no significant differences between the fundamental frequencies of crying numbers 2, 4 and 5 (table 3).

There was a considerable inter- and intra-individual variation of the crying parameters measured on the four different pricking occasions. The latency time range was from 0.4 to 5.1 s, the total crying time for the children who were crying between 11 and 235 s, the time for each crying sound between 0.1 and 11.1 s and the fundamental frequency between 110 and 1,204 Hz.

Discussion

The results show that the time from the prick to the first crying sound, i.e. the latency time, was the same after the heel-prick as after the pricks at the vaccinations. This means that the time for the central nervous system to interpret the pain stimulus is the same, regardless of age and type of pain stimulus.

Our results show that when subjecting the newly born baby to a heel-prick the total crying time is longer and the first crying sound is shorter compared to when the child is subjected to the prick at the vaccinations. The reason can be that the pain experienced from a heel-prick differed from that from a vaccination prick.

When subjected to the heel-prick the children were smaller and younger and may have another way of crying than when being vaccinated. The newborn child has other, or no other, pain experiences compared with the older child. This can influence the cry. The first crying sound of the newborn child was shorter when subjected to a heel-prick and this may have been on account of a different type of stimuli and a different type of pain from the heel-prick.

The decreasing frequency of the crying sound in tune with the child's increasing age may have been an effect of longer vocal cords or just due to less pain.

Lind and Wermke [7] analysed the fundamental frequency of spontaneous cries of 1 male infant during the first 3 months of life. They found no significant decreasing or increasing trend of the mean fundamental frequency. Our results show that the crying sound frequency decreases with increasing age. However, there are large individual differences between the children as well as between the pricking of the same child on different occasions. This is known from our previous study [6].

Craig et al. [8] commented on the results from a number of studies and stated that 'listeners and signal processing analyses of cry suggest qualitative difference between cry triggered by pain and by other sources, but these qualities are not firmly established and their clinical or practical value has not been proven'. This supports our results, demonstrating the difficulties of only using cries when analysing pain in children.

The question if a cry can be used as a measure of pain has been studied before [9] and found to be a reliable and valid method. A comparison of the results from the different pricking occasions of a single child reveals a great difference. This is also seen when comparing different children on the same pricking occasion. If crying is to be used as a parameter to measure pain, these differences are to be taken into account.

In a previous study [6] the results showed that an analysis of crying in a newborn could be used as part of an instrument for measuring experienced pain by children only if the cause of the pain was known. Our present findings do not contradict these results.

Summary

The results show that the children cried for a longer time and with a higher frequency when subjected to a heel-prick compared with the vaccination pricks carried out at different ages. The first crying sound was shorter when the child was subjected to a heel-prick. When subjected to a painful stimulus, the number of crying sounds decreases with increasing age. There was a considerable difference between the children and also between the different pricks for one and the same child.

If the cry is to be used as a parameter for measuring pain, the child's age has to be taken into account.

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