Frequency Spectra of Normal Breath Sounds in Childhood*

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Clinicians who auscultate the chest of normal children note that the frequency content of their breath sounds appears to vary with age. Because these changes have not been systematically documented before, we recorded and analyzed inspiratory breath sounds in 35 children (0 to 13 years) and five adults (34 to 43 years). Our objective was to determine if the frequency content of normal breath sounds differed with age. Using a Fast Fourier Transform program, we calculated an average amplitude frequency spectrum from the inspiratory portion of the breath sounds of each subject (n = 10 breaths), and we compared the shape of the AFS and the values of selected frequency parameters. We found that the shape of the AFS of the youngest children differed most from the AFS of adults. Three of four selected frequency parameters (F25, F50, F95) differed significantly between children and adults (p<0.05), and one parameter (F75) did not (p = 0.11). The F25, F50, and F75 parameters of children (but not F95) were correlated (p<0.001) with increasing height and age. These results suggest that differences in the frequency content of the normal breath sounds of children and adults contribute to the differences that clinicians detect during clinical auscultation.

(Chest 1991; 100:999-1002)

**AFS = amplitude-frequency spectrum (or spectra); F25, F50, F75, and F95 = frequencies limiting 25, 50, 75, and 95% of the energy of the AFS, respectively; RLL = right lower lobe**

Chest auscultation is an important part of patient assessment for the detection of respiratory disease. In clinical practice, lung disease may be diagnosed when adventitious sounds are present, or when an individual's breath sounds are perceived as having a frequency content and intensity that differ from normal. This latter process is critically dependent on the listener's knowledge of the range of frequencies and intensities that can be found in normal breath sounds. Thus, clinicians need to have a clear perception of what these normal ranges of frequency and intensity are to avoid systematic errors in auscultation. This may be one reason why agreement on auscultatory signs of lung disease among different observers is reported to be modest.1-3

The frequency range of normal lung sounds in adults extends from 50 to 75 Hz to 400 to 500 Hz, and the shape of the linear AFS of these sounds follows an exponential decay pattern.4 The studies of normal breath sounds in children have been more limited but suggest that the frequency content of their breath sounds differs from that of adults.5-8 However, to our knowledge, there are no published cross-sectional or longitudinal studies exploring the frequency content of normal breath sounds of children from infancy to adolescence, the period of life when the largest postnatal lung growth occurs.9 To document what the frequency content of normal breath sounds is in subjects of different ages, we recorded and analyzed RLL inspiratory breath sounds in a group of normal children ranging in age from a few weeks to 13 years and in a group of adults.

**Materials and Methods**

**Population**

The subjects of this study were 35 children and 5 nonsmoking adults free of disease or recent respiratory illnesses. The children (18 boys and 17 girls) varied in age from 0 to 13 years, with 8 to 11 children in each of the following age groups: 0 to 3, 3 to 6, 6 to 9, 9 to 13 years. The five adult subjects (three men and two women) ranged in age from 34 to 43 years. Written consent was obtained in all cases from the subjects or their guardians.

**Breath Sound Recordings**

Children breathed spontaneously and adults at an increased depth and rate while breath sounds were recorded; all subjects were erect inside a double-walled acoustic chamber. A microphone was air-coupled to the chest wall over the RLL at a distance of 0.7 cm. The sound was preamplified (5,000 X) and high-pass filtered (5-pole elliptical filter, cutoff frequency 100 Hz, minimum stopband loss of 60 dB at 50 Hz). Thoracic impedance was measured by two electrodes and differentiated with respect to time to obtain an estimate of flow. The sound and impedance signals were recorded on magnetic tape (tape speed 15 in/s) using two FM channels. The measured amplitude-frequency response of our preamplifier-filter-tape recorder was flat (±1.3 percent) from 100 to 1,000 Hz.

**Data Analysis**

The analog signals were low-pass filtered at 2,000 Hz, and digitized at a rate of 4,096 samples/s with a 12-bit resolution analog-to-digital converter. The sound, impedance, and d(impedance)/dt signals were displayed, and ten artifact-free inspiratory time segments of up to 1 s each in duration were selected. The beginning and end of inspiration were defined as the points where d(impedance)/dt = 0. In children, the total inspiratory time analyzed

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Comparison of the AFS of Children vs Adults

Visual examination of all the AFS obtained (data not shown) indicated that the AFS of the youngest children and adults were most different. Figure 1 shows a comparison of the AFS of children grouped by age to the averaged AFS of five adult subjects. As reported by Gavriely et al., after the cutoff frequency, the adult AFS followed an exponential decay pattern (dotted lines in Fig 1). However, the shape of the AFS of children varied from the adult AFS pattern according to the age of the child. As shown in Figure 1, the averaged AFS of the youngest group of children (0 to 3 years) differed most from those of adults, while the average AFS of the oldest group of children (9 to 13 years) differed the least.

When we compared selected frequency parameters from the AFS of the children and adults (Table 1), we found that F25, F50, and F95 were significantly different (p<0.05), while F75 was not (p = 0.11). If the frequency parameters of the children grouped by age were compared to the frequency parameters of adults (Fig 2), as suggested by the examination of the shape of the AFS, the largest number and most pronounced differences occurred between the parameters of the youngest group of children (0 to 3 years of age) and the adults (different for F25, F50, F75, p<0.005 for all three variables, F95>0.05). In contrast, the parameters of the oldest group of children (>9 years) and the adults were very similar (different only for F95,

Table 1—Comparison of Frequency Parameters of Children and Adults

<table>
<thead>
<tr>
<th>Frequency Parameter, Hz</th>
<th>n</th>
<th>F25</th>
<th>F50</th>
<th>F75</th>
<th>F95</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults</td>
<td>5</td>
<td>125 ± 6</td>
<td>160 ± 14</td>
<td>252 ± 19</td>
<td>527 ± 52</td>
</tr>
<tr>
<td>Median</td>
<td>126</td>
<td>166</td>
<td>245</td>
<td>524</td>
<td></td>
</tr>
<tr>
<td>Children</td>
<td>35</td>
<td>139 ± 15</td>
<td>194 ± 26</td>
<td>277 ± 34</td>
<td>467 ± 45</td>
</tr>
<tr>
<td>Median</td>
<td>136</td>
<td>195</td>
<td>275</td>
<td>459</td>
<td></td>
</tr>
<tr>
<td>p-Value: adult vs children*</td>
<td>.02</td>
<td>.03</td>
<td>.11</td>
<td>.02</td>
<td></td>
</tr>
</tbody>
</table>

*Comparisons between the frequency parameters of children and adults were done using the Wilcoxon rank-sum test.

Normal Breath Sounds in Childhood (Hidalgo, Wegmann, Werling)

was 8.9 ± 1.3 s per subject (range 4.47 s in a three-week old to 10 s), and 30/35 samples were >8 s in duration. In all adults, the amount of inspiratory time analyzed was 10 s. The inspiratory segments were transformed from the time to the frequency domain with a 4,096 point Fast Fourier Transform program, as has been described. This system had a frequency resolution of 1 Hz. The ten AFS from each subject were averaged, smoothed with a seven point moving average, and used to calculate the frequencies limiting 25, 50 (median), 75, and 95 percent of the total spectral energy. To compare AFS between subjects or groups of subjects, the AFS were normalized to the total area of the spectrum. Groups were compared with the Wilcoxon rank-sum test or an unpaired Student's t-test, as appropriate; linear regressions were by the least-squares method; and one-way analysis of variance was done with the Kruskal-Wallis test. Statistical significance was assumed at a level of p < 0.05.
Correlation of Frequency Parameters of Children with Age and Height

Figure 3 shows that there was a significant decrease (p<0.001) in F25, F50, and F75 associated with increasing age or height in children. In general, the values for these parameters in the older children approached those of adults. In contrast, the relationship of F95 to age was not significant with age or height (p>0.05), and in fact, when an average value for F95 was calculated in the children grouped by age
(Fig 2), this parameter decreased from zero to three to six to nine years, and then increased.

**DISCUSSION**

The purpose of this cross-sectional study was to determine if the frequency content of normal inspiratory breath sounds varied among subjects of different ages. In general, the differences in spectral shape and selected frequency parameters were most pronounced between the youngest children and the adults; however, these differences disappeared when the oldest children were compared to the adults. In addition, decreases in the frequency parameters F25, F50, and F75 (but not F95) were correlated with increasing age and height in children.

Studies of the breath sounds of children during spontaneous breathing are limited by technical problems, such as low sound intensity; however, it is the frequency content of tidal breath sounds that is most relevant for clinical auscultation because many children cannot cooperate with ventilatory maneuvers. Amplification and filtering of breath sounds is often necessary to reduce heart, muscle, and motion artifacts; unfortunately, filtering causes loss of the breath sound signal outside the pass-band range. Our data do not address what the shape of the AFS of children and adults is below the lower cutoff frequency used (100 Hz), but the data do show that above this cutoff frequency, the shapes of the AFS of RLL inspiratory breath sounds of the youngest children differ from those of adults. These findings are limited to breath sounds recorded over the RLL because normal breath sounds at other lung sites may differ in intensity and frequency content.

The intensity and frequency content of a sound determine the properties that the listener ascribes to that sound. The breath sounds of young children appear different from those of adults, and experienced observers describe them as higher pitched. Our data indicate that this perception is rooted, at least in part, on the different frequency content of these sounds. In this study of RLL breath sounds, we showed that it is the younger children's breath sounds that are most different from adult sounds and that older children have breath sound AFS that are very similar to those of adults. These data help us understand how the breath sounds of young children are fundamentally different from those of adults and may be useful in the design of automated methods for detection of normal and abnormal breath sounds in children.

**REFERENCES**