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A clinical method for detecting bronchial reversibility using a breath sound spectrum analysis in infants

*Mayumi Enseki, Mariko Nukaga, Hideyuki Tabata, Kota Hirai, Shinichi Matsuda, Hiroyuki Mochizuki**

Department of Pediatrics, Tokai University School of Medicine, Shimokasuya 143, Isehara, Kanagawa 259-1193, Japan

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ABSTRACT

Background: Using a breath sound analyzer, we investigated clinical parameters for detecting bronchial reversibility in infants.

Methods: A total of 59 infants (4–39 months, mean age 7.8 months) were included. In *Study* 1, the intra- and inter-observer variability was measured in 23 of 59 infants. Breath sound parameters, the frequency at 99% of the maximum frequency (F_{99}), frequency at 25%, 50%, and 75% of the power spectrum (Q_{25}, Q_{50}, and Q_{75}), and highest frequency of inspiratory breath sounds (HFI), and parameters obtained using the ratio of parameters, i.e. spectrum curve indices, the ratio of the third and fourth area to total area (A_3/A_T and B_4/A_T, respectively) and ratio of power and frequency at F_{75} and F_{50} (RPF_{75} and RPF_{50}), were calculated. In *Study* 2, the relationship between parameters of breath sounds and age and stature were studied. In *Study* 3, breath sounds were studied before and after β_2 agonist inhalation.

Results: In *Study* 1, the data showed statistical intra- and inter-observer reliability in A_3/A_T ($p=0.042$ and 0.034, respectively) and RPF_{50} ($p=0.001$ and 0.001, respectively). In *Study* 2, there were no significant relationships between age, height, weight, and BMI. In *Study* 3, A_3/A_T and RPF_{50} significantly changed after β_2 agonist inhalation ($p=0.001$ and $p<0.001$, respectively).

Conclusions: Breath sound analysis can be performed in infants, as in older children, and the spectrum curve indices are not significantly affected by age-related factors. These sound parameters may play a role in the assessment of bronchial reversibility in infants.

Abbreviations: A_T, total area of the power spectrum; A_3/A_T, ratio of the third area to the total area; B_4/A_T, ratio of the fourth area to the total area; dB_{max}, power at the maximum point of the power spectrum; Q_{25}, frequency at 25% of the power spectrum; Q_{50}, frequency at 50% of the power spectrum; Q_{75}, frequency at 75% of the power spectrum; F_{50}, frequency at 50% of the maximum frequency; F_{75}, frequency at 75% of the maximum frequency; F_{99}, frequency at 99% of the maximum frequency; HFI, the highest frequency of inspiratory breath sounds; RPF_{50}, ratio of power and frequency at F_{50}; RPF_{75}, ratio of power and frequency at F_{75}

*Corresponding author. fax: +81 463 94 3426.
E-mail addresses: mayumi-k@is.icc.u-tokai.ac.jp (M. Enseki), hizamari0812@yahoo.co.jp (M. Nukaga), tabata204631@yahoo.co.jp (H. Tabata), bk063060@tsc.u-tokai.ac.jp (K. Hirai), matu0831@is.icc.u-tokai.ac.jp (S. Matsuda), mochihi@tokai-u.jp (H. Mochizuki).

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1. Introduction

The reversibility of the airway obstruction is a major criterion for the diagnosis of asthma [1] and the response to bronchoconstrictors or bronchodilators or both is routinely used in asthmatic pediatric patients in order to diagnose and evaluate asthma severity [2]. The reactions to bronchoconstrictors or bronchodilators or both are usually characterized by changes in forced expiratory flows and volumes in 1 s (FEV_1) from the baseline value [3]. Unfortunately, most infants and preschool children are unable to complete pulmonary function tests. For the assessment of airway changes in infants and younger children, a breath sound analysis is presumed to be a simple, safe, and effortless method [4].

Special attention is paid to lung sounds during the diagnosis of infantile asthma. It is well known that breath sounds are sensitive to airway changes [5]. Recent developments in signal processing methods have improved the potential of extracting physiologically and clinically relevant information from respiratory sounds [6]. Even in the absence of adventitious sounds, the breath sounds may show changes in frequency distribution when disorders of the respiratory system are present [7–9]. Previously, the highest frequency of inspiratory breath sounds (HFI) indicated airway narrowing in children [10,11]. However, the fact that breath sounds are strongly affected by the vital capacity [12] remains a problem, particularly in childhood breath sound analysis, as the airflow rate at the mouth (L/s) has a potent effect on the sound spectrum [13,14]. The airflow rate of breathing is affected by the tidal volume, FEV_1, and respiratory resistance, all of which are strongly affected by age and body size in children [15].

Recently, we evaluated some parameters from the sound spectrum curve that were not significantly affected by the airflow rate of breathing or the age, height, or pulmonary function in 4–16-year-old children [16]. The aim of the present study was to evaluate the reliability and reproducibility of our breath sound analysis in infants.

2. Patients and methods

2.1. Study subjects

This study included 59 pediatric outpatients (4–39 months of age, mean 7.8 months, boy to girl ratio=31:28) who agreed to participate. Thirty infants visited for a governmental health examination, including 13 children with allergic diseases, seven with congenital heart diseases, four with renal diseases, two with low birth weight, two with diseases of the nervous system, and one with endocrine disease, at the Tokai University Hospital from April 1, 2014 to December 28, 2015.

On the day of testing, none of the subjects had any respiratory symptoms. Written informed consent was obtained from the legal guardians of all children. The study protocol was approved by the institutional review board of Tokai University Hospital (No. 14R-133, approval date; Oct 29, 2014).

2.2. Study protocol

Generally, three sound samples from 10 tidal airflow breaths were taken from each subject while in a silent room (Fig. 1). It was confirmed that the breath sound samples included no crying, no wheezing, and no crackles according to the findings of the breath sound analyzer.

In *Study 1*, 23 of the 59 infants (boy to girl ratio=13:10, 4–26 months, mean age 6.7 months), who consented to the intra- and inter-observer experiment, underwent breath sound recording three times to examine the reliability of the parameters. One doctor recorded and analyzed the same subjects twice at an interval spanning a few minutes to determine the intra-observer variation. To examine the validity of the measurements, another doctor measured the parameters in the same subjects over an interval spanning a few minutes to determine the inter-observer variation [17]. To prepare the technique for clinical use, individual representative sound samples were conventionally prepared from a sample with a median value of three noise-free breaths [16].

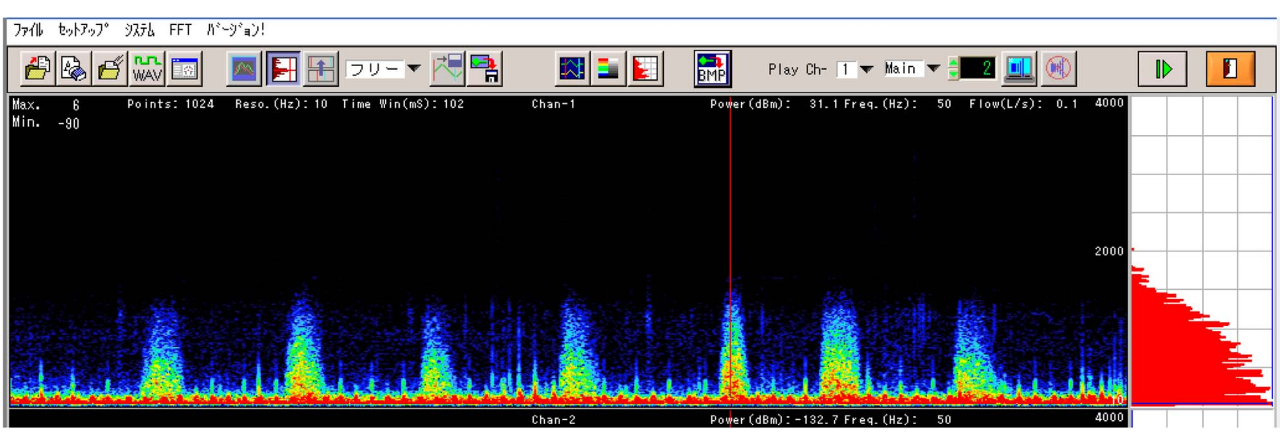

Fig. 1 – A sound spectrogram of an infant. The spectrogram of a 7-month-old healthy boy is shown after performing a Fourier analysis, with the vertical axis showing the frequency in Hz and the horizontal axis showing time. The sound intensity of the breath sounds is indicated using the color; high intensity was red, and low intensity was blue. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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