Allergology International 66 (2017) 132–138

Contents lists available at ScienceDirect

Allergology International

journal homepage: http://www.elsevier.com/locate/alit

Original article

Peripheral bronchial obstruction evaluation in patients with asthma by lung sound analysis and impulse oscillometry

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ARTICLE INFO

Article history:
Received 4 February 2016
Received in revised form
23 May 2016
Accepted 20 June 2016
Available online 8 August 2016

Keywords:
Airway obstruction
Bronchial asthma
E/I LF
Impulse oscillometry
Lung sound analysis

Abbreviations:
LSA, lung sound analysis; FeNO, fractional exhaled nitric oxide; $FEV_{1.0}$, forced expiratory volume in one second; FVC, forced vital capacity; and, maximal expiratory flow at 50% and 25%; E/I LF, the expiration-to-inspiration sound power ratio in a low-frequency range

ABSTRACT

Background: Computer-aided lung sound analysis (LSA) has been reported to be useful for evaluating airway inflammation and obstruction in asthma patients. We investigated the relation between LSA and impulse oscillometry with the evaluation of peripheral airway obstruction.
Methods: A total of 49 inhaled corticosteroid-naive bronchial asthma patients underwent LSA, spirometry, impulse oscillometry, and airway hyperresponsiveness testing. The data were analyzed to assess correlations between the expiration: inspiration lung sound power ratio (dB) at low frequencies between 100 and 195 Hz (E/I LF) and various parameters.
Results: E/I LF and X5 were identified as independent factors that affect $\dot{V}_{50,\%predicted}$. E/I LF showed a positive correlation with R5 (r = 0.34, p = 0.017), R20 (r = 0.34, p = 0.018), reactance area (AX, r = 0.40, p = 0.005), and resonant frequency of reactance (Fres, r = 0.32, p = 0.024). A negative correlation was found between E/I LF and X5 (r = −0.47, p = 0.0006). E/I LF showed a negative correlation with FEV_1/FVC(%), $FEV_{1,\%predicted}$, $\dot{V}_{50,\%predicted}$, and $\dot{V}_{25,\%predicted}$ (r = −0.41, p = 0.003; r = −0.44, p = 0.002; r = −0.49, p = 0.0004; and r = −0.30, p = 0.024, respectively). E/I LF was negatively correlated with log PC_{20} (r = −0.30, p = 0.024). Log PC_{20}, X5, and past smoking were identified as independent factors that affected E/I LF level.
Conclusions: E/I LF as with X5 can be an indicator of central and peripheral airway obstruction in bronchial asthma patients.

Introduction

In asthma patients, lung sounds have typically been used to assess the degree of airway narrowing, where rhonchi and wheezes are important adventitious sounds.[1–3] However, it is often difficult to distinguish slight abnormalities in lung sounds in asthmatic patients when they are not having exacerbations and when no rhonchi or wheezes are audible. Several studies have attempted to overcome such difficulties by utilizing computer-aided lung sound analysis (LSA).[4,5] In auscultation, vesicular breath sounds generally originate from areas far from the large airways, such as the base of the lungs. Vesicular breath sounds are primarily inspiratory sounds that have a soft quality. In contrast, bronchial breath sounds have a harsher quality in areas closer to the large airways. When we listen to bronchial breath sounds in the peripheral lung area, they are abnormal and suggest stiff lungs or narrowing airways.[6] We previously reported that the expiration-to-inspiration sound power ratio in a low-frequency range, between 100 and 195 Hz (E/I LF), increased in bronchial asthma patients with airway inflammation and obstruction.[7]

Recently, impulse oscillometry (IOS) has been increasingly used as a noninvasive method to assess airway resistance and reactance.[8,9] IOS is effort independent and quantifies the obstruction degrees in the central and peripheral airways.[10] Though the evaluation of IOS is still controversial, the reactance at 5 Hz (X5) is suggested as an index of the peripheral airway obstruction.[9]

We performed analyses to assess correlations between E/I LF or flow-volume curves, especially with $\dot{V}_{50}$ as peripheral airway

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Peer review under responsibility of Japanese Society of Allergology.

http://dx.doi.org/10.1016/j.alit.2016.06.008
1323-8930/

obstruction index, and assessed whether E/I LF can be used to evaluate airway obstruction. We also investigated potential factors affecting E/I LF levels.

Methods

Subjects

The analysis set consisted of 49 mild and moderate persistent bronchial asthma patients who visited our department since January 1st, 2012 to December 31st, 2014. Bronchial asthma was diagnosed according to the Global Initiative for Asthma Guidelines.[11] All subjects had positive airway hyperresponsiveness to inhaled acetylcholine and needed to have a history of wheezing and/or dyspnea. At the initial visit, 80% of the subjects showed positive reversibility (reversible with at least 12% and 200 ml improvements in FEV_1 after bronchodilator therapy), whereas the remaining 20% exhibited negative reversibility with normal respiratory function at the visit and were diagnosed with bronchial asthma based on airway hyperresponsiveness and medical history.

At the time of enrollment, the study patients were not receiving treatment with inhaled or systemic corticosteroids. The use of anti-asthma drugs, including bronchodilators, was discontinued for at least 24 h prior to the examination. Subjects with a history of chronic obstructive pulmonary disease (COPD) or any cardiovascular diseases, as well as those with a current viral or bacterial infection, were excluded from the study. The healthy volunteer subjects ($n = 32$) had no respiratory symptoms, had no overt illnesses, and exhibited no abnormalities in their lung function tests and chest radiographies. The ethics committee of Fukuoka National Hospital approved the study protocol (protocol No. 20-12), and all participants received verbal and written information about the study before providing their informed consent.

Measurement of LSA

Lung sounds were recorded for ≥30 s over the base of the left lung using a hand-held microphone according to the procedure described in a previous study.[7] The sound recording was performed in a quiet room, but not in a soundproof booth, in the outpatient

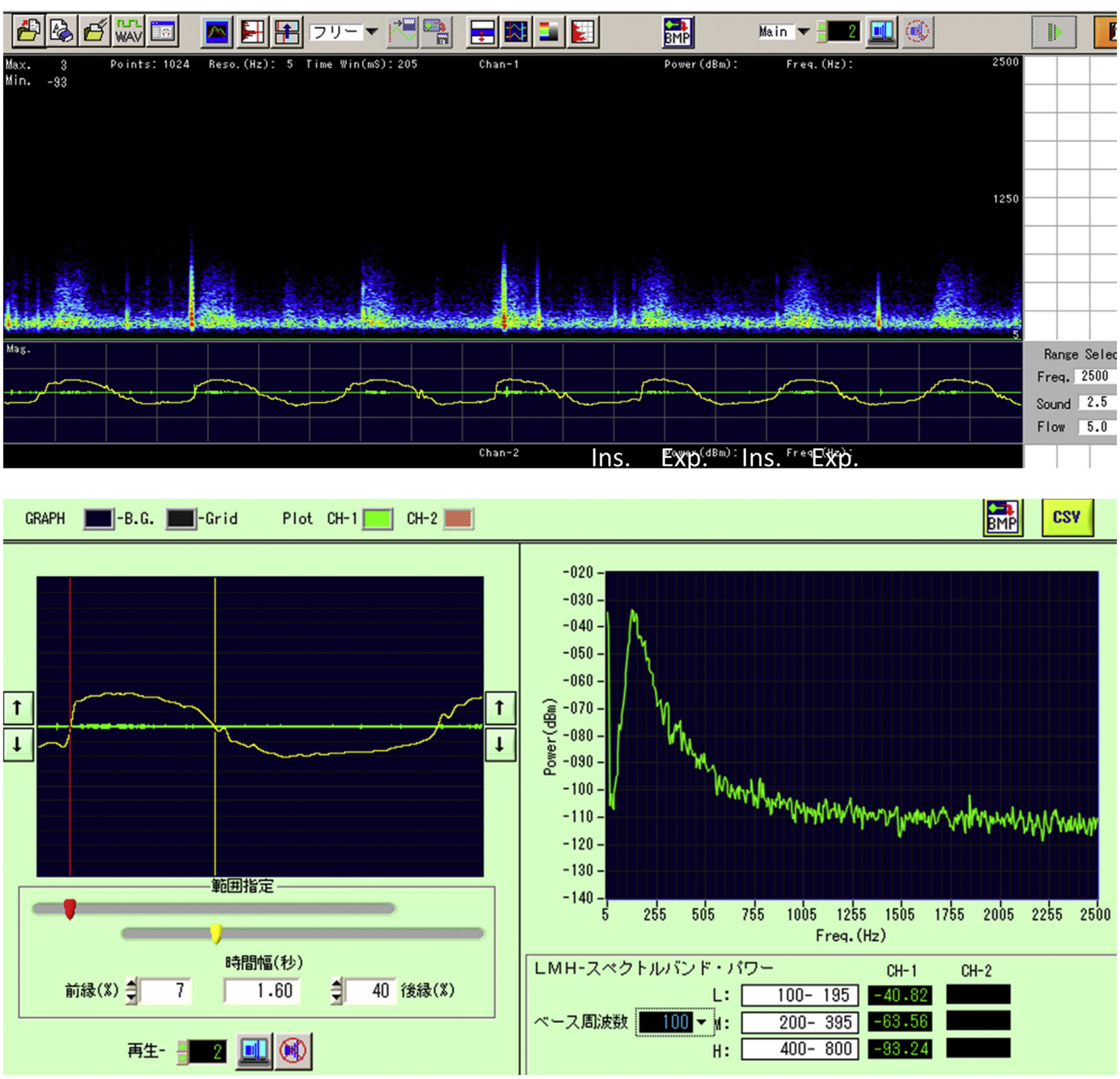

Fig. 1. Sound spectrogram display of lung sounds in a patient. **Upper figure**. The recorded sounds were analyzed using fast Fourier analysis, and the results are displayed as a spectrograph with the frequencies in Hz on the vertical axis and time on the horizontal axis. The sound intensity (dBm) is illustrated with color and brightness. **Lower figure**. A selected portion of the range of an inspiratory or expiratory position. We calculated the average power (dB) of low frequencies from 100 to 195 Hz.