Openventio PUBLISHERS

PULMONARY RESEARCH AND RESPIRATORY MEDICINE

ISSN 2377-1658

Open Journal

http://dx.doi.org/10.17140/PRRMOJ-SE-1-103

Special Edition
"Revisiting Physical Diagnosis in Respiratory Medicine"

Research

**Corresponding author*
Sadatomo Tasaka, MD
Department of Respiratory Medicine
Hirosaki University Graduate
School of Medicine, 5 Zaifucho
Hirosaki 036-8562, Japan
Tel. +81-172-39-5467
Fax: +81-172-39-5469
E-mail: tasaka@hirosaki-u.ac.jp

Special Edition 1
Article Ref. #: 1000PRRMOJSE1103

Article History
Received: June 27th, 2016
Accepted: July 18th, 2016
Published: July 18th, 2016

Citation
Tasaka S, Saraya T, Kuraishi H, Simbara H, Oda K, Takizawa H. Consistency of interpretation of lung sounds between experienced physicians and automatic analysis using a newly developed algorithm based on the acoustic characteristics. *Pulm Res Respir Med Open J*. 2016; SE(1): S8-S11. doi: 10.17140/PRRMOJ-SE-1-103

Consistency of Interpretation of Lung Sounds between Experienced Physicians and Automatic Analysis Using a Newly Developed Algorithm Based on the Acoustic Characteristics

Sadatomo Tasaka, MD, PhD[1*]; Takeshi Saraya, MD, PhD[2]; Hiroshi Kuraishi, MD, PhD[3]; Hisako Simbara, BS[4]; Keisuke Oda, BS[5]; Hajime Takizawa, MD, PhD[2]

[1]*Department of Respiratory Medicine, Hirosaki University Graduate School of Medicine, Hirosaki 036-8562, Japan*

[2]*Department of Respiratory Medicine, Kyorin University School of Medicine, Tokyo 181-8611, Japan*

[3]*Department of Pulmonology, Nagano Red Cross Hospital, Nagano 380-8582, Japan*

[4]*Departments of Development, Engineering Operation, Media Business Division, JVC Kenwood Corporation, Tokyo 192-8525, Japan*

[5]*Departments of Component Technology, Engineering Operation, Automotive OEM Business Division, JVC Kenwood Corporation, Tokyo 192-8525, Japan*

ABSTRACT

Background: Listening and interpreting lung sounds by a stethoscope has been an important component of screening and diagnosing lung diseases. However, this practice is vulnerable to inter-observer variations and difficulty in comparison with previous findings. In this study, we aimed to examine the consistency of interpretation of lung sounds between experienced physicians and automatic analysis using a newly developed algorithm based on the acoustic characteristics.
Methods: In 39 patients with various respiratory diseases, lung sounds were recorded with a stethoscope microphone on the chest. We compared 1) evaluation of live lung sounds by the attending physician, 2) evaluation of recorded lung sounds by the attending physician, 3) evaluation of recorded lung sounds by other physicians who were blinded to the underlying diseases, and 4) results of automatic analysis using a newly developed algorithm based on the acoustic characteristics.
Results: Among the lung sounds recorded, fine crackles were identified in 18 patients, coarse crackles in 5, and wheezes in 4. In 36(92%) patients, the interpretation of live lung sounds by the attending physician was consistent with that of recorded lung sounds by the same physician. In 23(59%) patients, the interpretation of recorded lung sounds by the attending physician agreed with that by other physicians. In 63% of the lung sounds with any inconsistency of interpretation, the consensus interpretation was same as the original interpretation by the attending physician. Automatic analysis and physicians' diagnosis agreed in 62% of the study subjects.
Conclusions: Repeated hearing of recorded lung sounds may exceed live auscultation in a clinic. Recording and analyzing lung sounds may contribute to further improvement of auscultation.ABBREVIATIONS: COPD: Chronic Obstructive Pulmonary Disease; UIP: Usual Interstitial Pneumonia.

KEYWORDS: Lung sounds; Auscultation; Recording; iPod touch; Automatic analysis.

ABBREVIATIONS: COPD: Chronic Obstructive Pulmonary Disease; UIP: Usual Interstitial Pneumonia.

Openventio PUBLISHERS

PULMONARY RESEARCH AND RESPIRATORY MEDICINE

ISSN 2377-1658 Open Journal http://dx.doi.org/10.17140/PRRMOJ-SE-1-103

INTRODUCTION

The auscultation of the respiratory system has been an important component of screening and diagnosing various lung diseases.[1,2] Although it is inexpensive and non-invasive, the practice is vulnerable to poor quantitatively and reproducibility and inter-observer variations in interpretation. Also, it is sometimes difficult for physicians to evaluate temporal changes in lung sounds, such as before and after treatment. However, it remains unclear how consistent the interpretation is when lung sounds are repeatedly heard by a physician or when evaluated by multiple physicians. In addition, since interpretation of lung sounds can be different between observers, a tool for sharing lung sounds among healthcare workers would be helpful.

In this study, we aimed to examine the consistency of interpretation of lung sounds between live and recorded auscultation and between experienced pulmonologists. We also compared physicians' evaluation of lung sounds and automatic analysis using a newly developed algorithm based on the acoustic characteristics.

METHODS

We enrolled 39 patients with respiratory diseases who were treated at the out-patient clinic of Keio University Hospital and Kyorin University Hospital. The underlying diseases included usual interstitial pneumonia (UIP), chronic obstructive pulmonary disease (COPD), bronchiectasis, and asthma. Lung sounds were recorded during quiet breathing using a teaching stethoscope (Littmann® Classic II S.E. 2138; 3M, Maplewood, MN, USA) with a microphone placed inside one of the hollow tubes (Figure 1). The microphone was connected to an iPod touch (Apple Inc., CA, USA) that has a newly developed application for automatic detection and analysis of abnormal lung sounds. The recorded sounds were evaluated by the attending physician at a later time and also by two other physicians who were blinded to the underlying diseases. All of the three physicians (ST, TS, and HK) have more than 15 years of clinical experience. In case of any inconsistency, the three physicians re-evaluated the recorded lung sounds together and made a consensus after being aware of the underlying diseases.

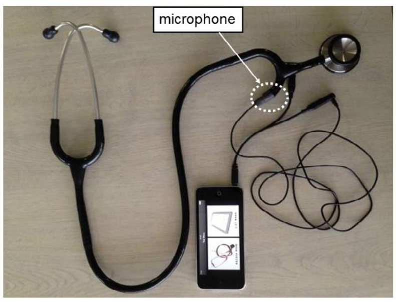

Figure 1: A device for lung sound recording and analysis.
A microphone is placed inside one of the hollow tubes of a teaching stethoscope.

To analyze the recorded lung sounds, the algorithm classified the input audio signal into 2 groups, intervals with peaks and those without peaks, calculating the signal power limited by band-pass filter (100 Hz-1 kHz). The intervals with peaks might contain continuous or discontinuous sounds. Then, feature vectors of each intervals were calculated and compared, using the width of frequency distribution range. The ratios of feature vectors and the similarity from the average of the ratios were calculated. If the similarity was below the threshold, the sound was classified as abnormal. To detect continuous sound, the frequency components of continuous sounds were filtered, and the ratio between the frequency value and the value by moving average filtering was calculated. If the duration time of the peak is short, the peak is separated from the candidates. To detect discontinuous sounds, the frequency components of discontinuous sounds were filtered with band-pass filter (500 Hz-4 kHz). Then, the envelope was calculated with Hilbert transform. The peaks of the envelope were detect as local maximums and corrected on the basis of power, duration time, distance and density. The results of the automatic analysis, such as frequency, incidence density, and amplitude of lung sounds, was graphically shown on the screen of iPod touch (Figure 2).

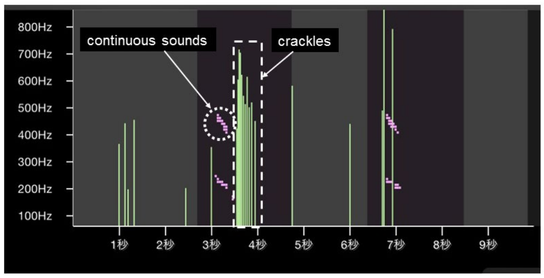

Figure 2: An example of the results of automatic analysis displayed on iPod touch screen
The result of the automatic analysis, such as frequency, incidence density, and amplitude of lung sounds, is graphically shown on the screen of iPod touch. Vertical lines and dots represent crackles and continuous sounds, respectively. Time in seconds on X-axis. Frequency (Hz) of continuous sounds on Y-axis.

We compared 1) evaluation of live lung sounds by the attending physician, 2) evaluation of recorded lung sounds by the attending physician, 3) evaluation of recorded lung sounds by other physicians who were blinded to the underlying diseases, and 4) results of automatic analysis. The evaluation items by physicians included type of abnormal sound, such as wheezes, rhonchi, coarse crackles and fine crackles and estimated diagnosis.

The study protocol was approved by the Ethical Committee of Keio University School of Medicine (approval number: 2011-327). A written informed consent was obtained before recording the lung sounds.

RESULTS

Types of Lung Sounds Identified

We evaluated the recorded lung sounds and reached a consensus after discussion. Among 39 patients evaluated, fine crackles

ISSN 2377-1658 Open Journal http://dx.doi.org/10.17140/PRRMOJ-SE-1-103

were identified in 18 patients, coarse crackles in 5, and wheezes in 4. Seven patients had normal lung sounds. Both wheezes and coarse crackles were heard in a patient. Another patient had both rhonchi and coarse crackles. In a patient, both rhonchi and fine crackles were identified. Both rhonchi and squawk were heard in a patient and coarse crackles plus squawk in another.

Consistency of Interpretation Between Live and Recorded Lung Sounds

We examined whether the evaluation of live lung sounds by the attending physician was consistent with that of recorded lung sounds by the same physician. Both evaluation agreed in 36(92%) patients but did not in 3. In a patient, the recorded lung sounds showed wheezes, which had not been realized at the examination, in addition to coarse crackles. In another patient, the physician interpreted the recorded sounds as wheezes, although he had described it as rhonchi at the examination. In a patient, the live lung sounds were described as wheezes plus coarse crackles, whereas the recorded lung sounds were interpreted as wheezes. Although interpretation of live and recorded lung sounds agreed in most cases, repeated hearing of recorded lung sounds may contribute to further improvement of auscultation.

Consistency of Interpretation of Lung Sounds Between Physicians

We examined whether the interpretation of recorded lung sounds by the attending physician is consistent with that by other physicians. In 23(59%) patients, both interpretation agreed. The most common disagreement is about classification of crackles, fine or coarse, in 5 patients. In 4 patients, classification of continuous sounds, wheezes or rhonchi, disagreed between physicians.

In 16 patients with any inconsistency of lung sound interpretation, 3 physicians re-evaluated the recorded lung sound after being aware of the underlying diseases and made a consensus. In 10(63%) of them, the consensus interpretation was same as the original interpretation by the attending physician. It was suggested that awareness of the underlying diseases might influenced the classification of crackles and continuous sounds.

After the consensus was made, the threshold of frequency between wheezes and rhonchi was estimated by automatic analysis, which showed that the border was about 200 Hz.

Consistency of Interpretation of Lung Sounds Between Physicians and Automatic Analysis

We examined whether the consensus interpretation by physicians is consistent with the results of the automatic analysis. In 24(62%) patients, both evaluation agreed. The most common disagreement is about background noises that were judged as crackles by automatic analysis in 6(40%) of 16 patients with any inconsistency. In 5 patients, normal respiratory sounds were interpreted as crackles or continuous sounds by automatic analysis. On the contrary, automatic analysis did not indicate rhonchi in 2 patients and squawk in 1 patient, which were recognized by physicians.

DISCUSSION

In the present study, we revealed that repeated hearing of recorded lung sounds might exceed live auscultation in a clinic and contribute to further improvement of auscultation. In 59% of the study subjects, the interpretation of recorded lung sounds was consistent between physicians. In 63% of the lung sounds with any inconsistency of interpretation, the consensus interpretation was same as the original interpretation by the attending physician, suggesting that awareness of the underlying diseases might have influences interpretation of lung sounds.

Automatic analysis and physicians' diagnosis agreed in 62% of the study subjects. In the most cases of inconsistent interpretation between automatic analysis and physicians, background noises and normal respiratory sounds were judged as crackles or continuous sounds by automatic analysis (i.e., overdiagnosis). It was indicated that automatic analysis using newly developed algorithm based on the acoustic characteristics may possess satisfactory sensitivity for screening of respiratory diseases although its specificity remains to be improved.

In this study, the threshold of frequency between wheezes and rhonchi was about 200 Hz. On a literature, wheezes are defined as high-pitched continuous sounds with dominant frequency of 400 Hz or more.[3] On the other hand, rhonchi are defined as low-pitched continuous sounds with dominant frequency about 200 Hz or less, which is consistent with our interpretation. We recognized that interpretation of crackles (i.e., coarse or fine) was sometimes inconsistent between the physicians. As automatic analysis graphically shows frequency, incidence density, and amplitude of lung sounds, it may contribute to uniform interpretation of continuous sounds and crackles by physicians and accurate diagnosis and evaluation of respiratory diseases.

The development of computer technology has made it possible to acquire, process, and store lung sounds from patients and visualize sound signals.[4,5] However, it usually requires larger equipment, which excludes its application to clinical practice. As our system for recording and analyzing lung sounds is compact, we could easily acquire sound data and immediately get the result of analysis in an examination room. The results of our study indicate that the algorithm of automatic analysis is promising for quantitative analysis and visualization of discontinuous and continuous sounds.

For patients with respiratory diseases or swallowing disturbance who have difficulties in accessing hospitals, it is critical to assess changes in lung sounds at home. It will be beneficial if a tool for sharing and analyzing lung sounds recorded by families or home care workers is developed. For lung sound

ISSN 2377-1658 Open Journal http://dx.doi.org/10.17140/PRRMOJ-SE-1-103

analysis, we used iPod touch that is widely available and easy to operate. In addition, lung sound data can be shared online as audio files. Further investigation is necessary to examine whether our device and analyzing system are applicable to home care or remote medicine.

CONCLUSION

In conclusion, repeated hearing of recorded lung sounds may exceed live auscultation in a clinic. In many cases, interpretation of lung sounds was consistent between physicians although awareness of the underlying disease may influence interpretation. Recording and analyzing lung sounds may contribute to further improvement of auscultation.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

1. Bohadana A, Izbicki G, Kraman SS. Fundamentals of lung auscultation. *N Engl J Med.* 2014; 370: 744-751. doi: 10.1056/NEJMra1302901

2. Loudon R, Murphy RL Jr. Lung sounds. *Am Rev Respir Dis.* 1984; 130: 663-673. Web site. http://www.atsjournals.org/doi/abs/10.1164/arrd.1984.130.4.663#.V4ng8fl97cs. Accessed June 25, 2016

3. Mikami R, Murao M, Cugell DW, et al. International symposium on lung sounds. Synopsis of proceedings. *Chest.* 1987; 92: 342-345. doi: 10.1378/chest.92.2.342

4. Pasterkamp H, Kraman SS, Wodicka GR. Respiratory sounds. Advances beyond the stethoscope. *Am J Respir Crit Care Med.* 1997; 156: 974-987. doi: 10.1164/ajrccm.156.3.9701115

5. Kiyokawa H, Pasterkamp H. Volume-dependent variations of regional lung sound, amplitude, and phase. *J Appl Physiol.* 2002; 93: 1030-1038. doi: 10.1152/japplphysiol.00110.2002