Analysis of Respiratory Sounds in Asthmatic Infants

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Abstract. *The aim of this study was to validate an asthma monitoring system based on wheezing detection in phonopneumograms. Electronic auscultation and recording of breathing was performed in a group of 26 asthmatic infants (1-7 years) in order to detect the presence of wheezing and determine appropriate respiratory spectra parameters for early detection of possible asthmatic seizures. For recording two types of transducers were used: electret microphones and accelerometers, positioned over the trachea or the chest. The power spectra were calculated and analysed for indicators of wheezing off line. Wheezing was detected in 70% of patients during asthmatic seizures and no wheezing could be detected when no pulmonary obstruction was present.*

Keywords: Electronic Auscultation, Lung sound, Respiration Spectra, Asthma Monitoring, Wheezing

1. Introduction

The normal lung sound is defined as the sound associated with breathing, heard on the chest of a healthy person. This sound is noise-like, and the maximum of the power spectrum lies in the frequency range below 100 Hz. The energy of the spectrum decreases sharply between 100 Hz and 200 Hz, but it can be detected up to 1,2 kHz. The amplitude of the respiratory sounds varies with the square of the air flow, but is also individually dependent and dependent on the recording position on the chest [1].

Sounds associated with lung pathology are wheeze, rhonchus and crackle. Wheezing is considered to be a result of airway obstruction and flow limitation and it appears as a continuous sound – tone, in the frequency range between 100 Hz to above 1 kHz. In asthmatic patients wheezing is present dominantly during expiration and it lasts from 80 – 250 ms [2].

Wheezing is not associated with asthma only, but to other pulmonary pathology also. Wheezing in infants is considered to be related to predisposition to asthma [3], [4]. Though, due to increased incidence of asthma in children in the past few decades, research of respiratory sounds is of special interest for better diagnostics and monitoring of pulmonary diseases. In previous studies in children, the percentage of wheezing in inspiration and expiration signals was used as an indicator of the severity of obstruction [5]. Recordings were performed by microphones and accelerometers, the first being more sensitive, and the others more immune to background noise [2]. Different measurement set-ups and algorithms were developed for pulmonary disease diagnostics in specialist clinical departments [6], but it seems that possibilities of lung sound analysis as a non-invasive preventive and monitoring method have not been extensively researched. Monitoring of co-operative (adult) asthmatic patients is usually performed by self–testing spirometry [7]. Early detection of asthmatic seizures, especially in infants where self-diagnostics or parents observations usually are (from the clinical point of view) late and lead to extensive and prolonged use of medications, should be more investigated.

2. Materials and Methods

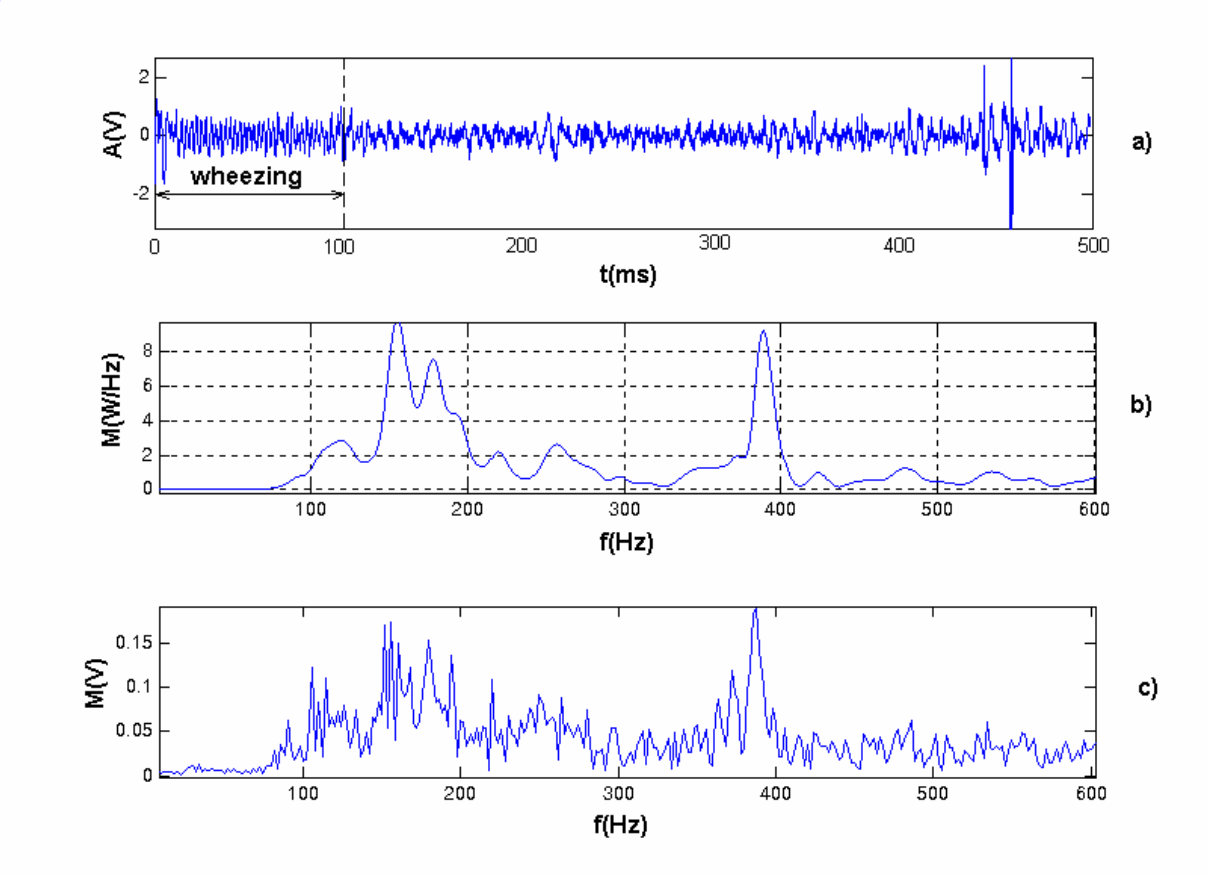

Fig. 1. Respiratory sound of an infant asthmatic patient presented in a) time domain, b) PSD estimation by Welch method and c) spectrum calculated by FFT using a rectangular window. Wheezing (abnormal sound) can be recognised in both, time representation at the beginning of the record and in frequency domain, just below 400 Hz. "Normal" breathing sounds were filtered by a digital high pass YuleWalker filter with cut off frequency 200 Hz.

In a period of 6 months, the measurements and recordings of respiratory sounds were performed on 28 infants (1-7 years) identified as pulmonary patients. All patients are treated by the General Hospital "St. Vlaho", Dubrovnik. Some of the patients came to the hospital for regular examination, and some because of they were not feeling well. The recordings were made during the auscultatory examination by a physician who determined the state of the patients' pulmonary obstruction on a scale from 0-9. The recordings were made in a quiet room (though some background noise is present in some recordings) with the patients in supine position. The patients were instructed to either breathe normally or to forced breathing. We used two types of transducers: electret microphone (EK-3024, Knowles Electronics) and accelerometers (BU-3173, Knowles Electronics) (in order to simplify the text, we use the wording from acoustics when we mention vibrations measurement due to respiration). The transducers were attached to the patient with a double-sided adhesive tape on *trachea* or posteriorly, on the right lung base. The transducers were connected to a custom made preamplifier and the 16 bit sound blaster PC card PCI64. The linearity of the amplitude-frequency characteristic was within ±5dB in the frequency range from 100 Hz to 2 kHz. The respiratory signals were sampled with a rate f_s = 8 kHz and stored for later data analysis. The analysis was performed in *MATLAB* V6. The program enables visual and auditory inspection of the recorded signals, calculation of spectra and parametric spectral analysis. The sound segments were analysed for presence or absence of wheezes.

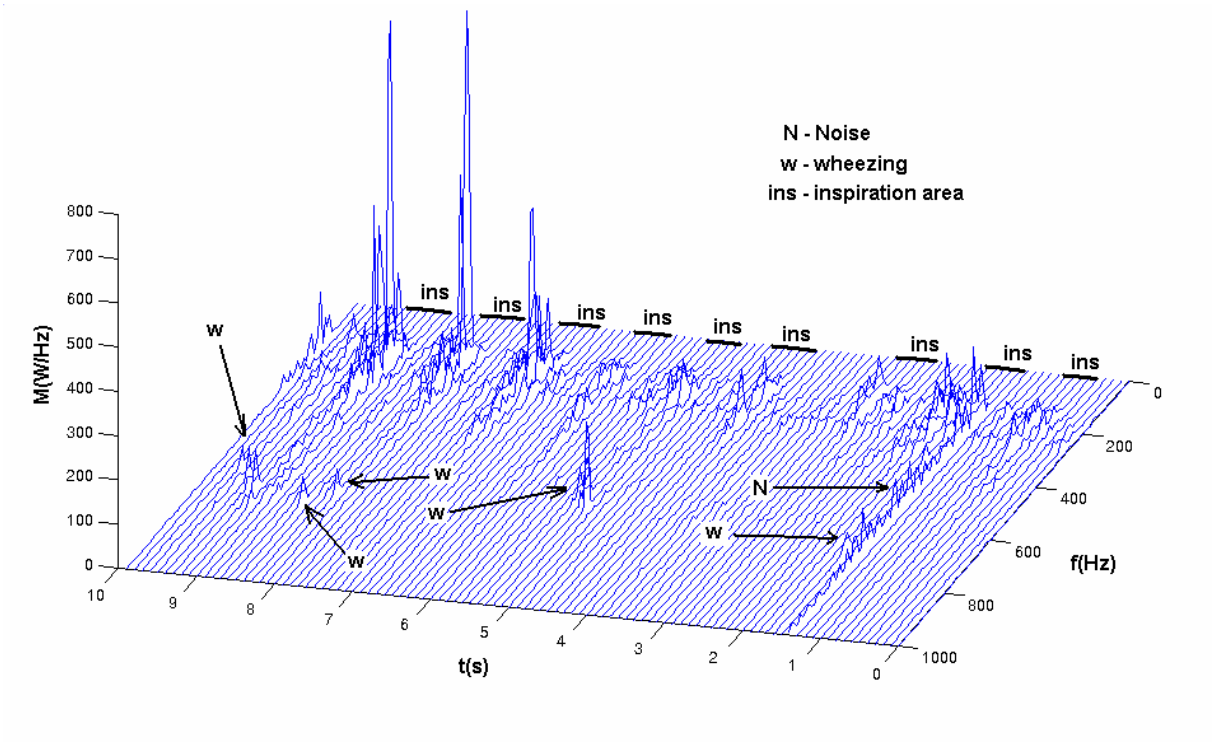

Fig. 2. Successive power spectra presentation of a 10 s segment of forced breathing of a wheezy patient. Periodogram with 100 ms Hanning window. Wheezing (w) is present during inspiration. When covered by noise (N), wheezing is not detectable.

3. Results

In this study, we have detected wheezing in seven patients who were brought to the hospital during an asthmatic seizure. All these children were between 3 and 7 years old. Table 1. shows the pitch frequency and average duration of wheezing, as measured from successive power spectra with time resolution 50 ms and frequency resolution 20 Hz. In patients with more severe attack, wheezing was detected during normal breathing as well. The grade of pulmonary obstruction was declared by the physician, with 0 in the scale indicating no obstruction and 9 the most severe degree of obstruction.

Table 1. Detection of wheezing in patients that showed pulmonary obstruction. f_p – wheezing pitch frequency, T_w – duration of wheezing, BT – breathing type (FB – forced breathing, NB – normal breathing), POB – pulmonary obstruction grade, N_D/N_E – number of detected wheezing episodes / total number of wheezing episodes in 10 s records

Patient	f_p [Hz]	T_w [ms]	BT	POB	N_D/N_E
1	300	200	FB	2	1/4
2	380	250	FB/NB	6	3/4
3	250	350	FB	5	1/4
4	460	150	FB	6	2/4
5	380	250	FB/NB	7	2/2
6	400	100	NB	4	2/2
7	400	100	FB	6	1/1

In three patients who were brought during a seizure, no wheezing was detected. One of those was medicated before the measurement of the respiratory sounds which may be the reason for missing of wheezing. The second patient was asleep and the air flow was low. These two children were under three years of age. The third patient had the obstruction grade 2 but wheezing could not be detected even with forced breathing. In three additional patients, who were suspected for possible asthmatic seizure, but had the lowes level of respiratory obstruction (1), no wheezing was detected. In three patients who came for regular control examination, wheezing was detected though no obstruction was diagnosed by the physician. 16 patients who came for a regular examination and had no obstruction diagnosis had also no wheezing.

4. Discussion and Conclusions

This study showed that in seven out of 10 patients (70%) who had an asthmatic seizure, wheezing was detected. In 16 patients with no obstruction, wheezing could not be detected. In three patients no wheezing was detected in spite of presence of respiratory obstruction, but two of them could not be brought to forced breathing and therefore it is questionable whether the air flow was sufficient for wheezing induction. In three patients wheezing was detected when no obstruction was diagnosed. Though this study was performed on a limited number of infants (which is often a case in literature), in our opinion, respiratory sound analysis of forced breathing for presence of wheezing in asthmatic infants could be used in patients home for early detection of asthmatic seizures. In such a way self-diagnostics with hand-held spirometers that is common for adult patients and considered by clinicians for not useful with infants, would be replaced by a more objective method based on automatic detection of wheezing during forced breathing. However, it seems that this method could be used for children older than three years only.

References

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