Tracheal and lung sounds repeatability in normal adults

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Summary Tracheal and lung sounds measurements for clinical applications depend on their intrasubject repeatability. Our objectives were to characterize tracheal and lung sounds and to investigate the temporal variability in normal adults. Tracheal sounds were studied in 7 subjects and lung sounds in 10 adults. Acoustic measurements were done in five occasions over a month for tracheal sounds and on seven occasions over a year for lung sounds. Sounds were recorded using contact sensors on the suprasternal notch and on the posterior right lower lobe. Subjects breathed through a pneumotachograph at flows of 0.9–1.1 l/s. Signals were low-pass filtered, amplified and Fourier analysis was applied to sounds within a target flow range. We measured the frequencies below which 25% (F25), 50% (F median), 75% (F75) and 99% (SEF99) of the spectral power between 100 and 2000 Hz. There were no differences between the measurements obtained at different days comparing each subject (P = ns, ANOVA). Our results show that the spectral pattern of tracheal and lung sounds are stable with low intrasubject variability.

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KEYWORDS
Respiratory sounds; Spectral analysis; Non-invasive techniques

Introduction

Acoustical signals from the respiratory system traditionally are assessed only by clinical auscultation. The stethoscope has been always the most widely used instrument in clinical medicine. However, the diagnostic value of the physical exam depends on the ability of the examiner to distinguish between normal and abnormal sounds.1 This is essentially a subjective clinical assessment of unknown variability that will depend on the patient effort.2 Moreover, it gives only qualitative information on the respiratory sounds.

Lung and tracheal sounds have been subject of extensive research in the last two decades. Phonopneumography is a procedure for detection and analysis of respiratory sounds that uses a computerized spectral analysis of sounds measured by sensors located on the trachea and the chest wall. This technique provides objective information and the ability to save and compare respiratory sounds that cannot be obtained by classic auscultation.3 The normal classification of respiratory sounds in bands of frequency are: low (under 100 Hz), middle (200–600 Hz) and high (600–1200 Hz) depending on the site of generation of sound. In the lower band range (under 100 Hz), heart and thoracic muscles sounds overlap, therefore this range must be filtered out for the assessment of lung sounds.4,5 The use of tracheal and lung sounds measurements for clinical applications depends on its ability to differentiate normal and abnormal patterns, and their intrasubject reproducibility. The objectives of our study were to characterize tracheal and lung sounds in young normal adults and to study the temporal intrasubject variability in those measurements.

Patients and methods

We studied two different groups of adult subjects. In the first group of tracheal measurements we
studied 7 normal and non-smokers adults (4 male and 3 female), aged 22–25 years (mean age 23.4±0.5 years, x±S.D.), mean weight 63.5±10 kg, mean height 169±7 cm, cervical circumference 35.3±3 cm and mean thoracic circumference 87.8±7 cm. Spirometric values were normal (FVC 111±8%, FEV1 116±6%, FEF25–75 117±12% of predicted values, respectively). Acoustic measurements were done in five occasions for tracheal sounds (day 1—a and time b separated by 10 min—days 2, 7 and 30). In the second group of lung sounds measurements we studied 10 non-smoker healthy adults (6 male and 4 female), aged 24–28 years, (mean 27.3±1 years), weight 64.5±9 kg, height 170±8 cm, cervical circumference 36.4±4 cm and thoracic circumference 88.4±8 cm. Spirometric values were also normal (FVC 113±9%, FEV1 114±9% and FEF25–75 119±11% of predicted values, respectively). Acoustic measurements were done in seven occasions, for lung sounds (day 1—a and b separated by 10 min—days 2, 7, 1 month, 6 months and 1 year later). All subjects were free of respiratory tract infections for at least 1 month before the study. The study was approved by the local Ethics Committee.

Subjects breathed through a mouth piece connected to a pneumotachograph (Validyne, Northridge, USA) at flows of 1l/s±10% (0.9–1.1l/s). Respiratory sounds were recorded using contact sensors (EMT25C, Siemens, Elema) on the suprasternal notch for tracheal sounds and on the posterior right lower lobe for lung sounds. Neck position was kept upright, with the same place chosen for sensors to be attached. A nose clip was used for all recordings, therefore subjects breathed only by mouth. Also, the position at the corresponding zone of the posterior right lower lobe was measured and standardized. Sound signals were low-pass filtered, amplified and fast Fourier analysis (FFT) was applied to sounds within target flow range. Sounds were low-pass filtered (sixth order Butterworth, cutoff at 2400 Hz) to avoid aliasing during analog-to-digital conversion. The signals were digitized (DT 2831-G; Data Translation, Marlboro, MA), at a rate of 10,240 samples/s with a resolution of 12 bits. Customized software was used for data acquisition and analysis (RALE, Respiration Acoustic Laboratory Environment, Mb, Canada). The FFTs were performed at 100-ms intervals, resulting in 50% overlap into adjacent 100-ms segments. This allowed a Hanning window to be applied to the data with no loss of information. The baseline noise spectra were subtracted. Reference values for sensor calibration includes filters above 1000 Hz, to correct the known roll-off that occurs at higher frequencies. We measured during inspiration the frequencies below which 25% (F25), 50% (F50 or median), 75% (F75) and spectral edge frequency 99% (SEF99) of the spectral power between 100 and 2000 Hz was contained. From the averaged spectra, power at low (100–200=P1) and high frequencies (400–2000=P2) was calculated. Analysis of variance (ANOVA) was used for statistical analysis, a P value <0.05 being considered significant.

Results

Subjects in tracheal sounds group had each five recordings undertaken. The spectral characteristics of their sounds showed peak at about 750 Hz and another close to 1700 Hz (Fig. 1). Variability of signals between subjects was broad, showing an individual pattern that was stable in repetitive recordings. Intrasubject reproducibility calculated as the mean of all measurements overtime, showed that percent variation was low when analyzing F25, F50 (median), F75 and SEF99, with all parameters showing variations below 20% (Table 1).

In the group of subjects with lung sounds measurements, we found that the curve showed a pronounced drop between 100 and 600 Hz (Fig. 2). Acoustic information in the spectra was more useful particularly below 1000 Hz. At higher frequencies, signals were flat with no differences between recording. In this group, variation between subjects was lower than in the tracheal group, and intrasubject variability comparing the seven recordings was very small (Table 1). The results were not significantly different for men and women, probably due to sample size.

![Figure 1 Tracheal sounds repeatability in one selected normal subject breathing at 1 l/s±10% in five occasions, during a 1-month period. Note that variation is small, and that the shape of the curve is stable.](image-url)
Discussion

Our results showed that the spectral pattern for tracheal and lung sounds were stable, with low intrasubject variability. Measurements of these acoustic signals were done during a longer period of time (1 month for tracheal sounds and 1 year for lung sounds) than has been done in previous studies published in the literature. There was a significant variability between subjects that could be explained by height, gender and anatomic characteristics. The finding of low variability relates to spectral edge frequencies, we cannot conclude the same with parameters such as power in frequency bands.

Our results are quite similar to current information published in the literature; there are reports showing a relatively good reproducibility of normal breath sounds during tidal breathing ($F_{50}$ variability in day to day measurements were from 5.0% to 8.5%) and also, a similarity among normal subjects regardless of the filtering techniques. Another study showed that the spectral pattern of lung and tracheal sounds in normal subjects was stable, except at the interscapular region, where the temporal variability was high, particularly at the expiratory phase, we did not use this location for our sensors. A report measuring one recording of breath sounds of 353 normal subjects to obtain the spectral characteristics of normal chest wall breath sounds; they concluded that chest wall breath sounds may be used as reference for comparison with abnormal sounds, in several diseases entities. They also found that measurements in normal women contain higher frequency components than in normal men. The repeatability of spectral parameters in healthy men and in patients with stable fibrosing alveolitis was studied, showing that the repeatability of $F_{50}$ was good in both, healthy subjects and in patients with restrictive disease. Compared to our results, they noted more variability in tracheal sounds than in lung sounds measurements.

There are two types of common transducers for lung sound recording: the electret microphone with coupling chamber and the contact accelerometer. Contact accelerometers are widely used in lung sound research, they can be calibrated on a vibration table and they have a greater sensitivity to high frequency components that selectively assess small airways. However, they are expensive, fragile and may exhibit internal resonances near the lung sounds frequencies. We used one of the latter microphones to record both tracheal and lung sounds.

This study was carried out measuring spontaneous acoustical sounds and we performed spirometry as a functional test to our subjects, we do not have information about lung volumes or airway resistance for a complete mechanical assessment. Also, our study group was small; there have been some publications with similar results to this one; however, this study allow us to have normal spectral pattern of tracheal and lung sounds recorded in our laboratory. This should allow us in the near future to compare these measurements with those from patients with restrictive and obstructive diseases. It is one of the most prolonged studies in the literature we could find and shows that signals are particular and stable in each subject over time.

In summary, tracheal and lung sounds analysis is an easy, objective and non-invasive methodology to study acoustic signals of the respiratory airway. We suggest that this methodology may become useful in the diagnosis of anatomical and functional impairment in upper airways (e.g. obstructive sleep

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<tr>
<th>Parameter</th>
<th>Tracheal sounds group (% variation)</th>
<th>Lung sounds group (% variation)</th>
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<tbody>
<tr>
<td>$F_{25}$ (%)</td>
<td>18 ± 2</td>
<td>16 ± 1</td>
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<tr>
<td>$F_{median}$ (%)</td>
<td>15 ± 1</td>
<td>14 ± 1</td>
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<tr>
<td>$F_{75}$ (%)</td>
<td>18 ± 2</td>
<td>19 ± 2</td>
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<tr>
<td>SEF99 (%)</td>
<td>8 ± 1</td>
<td>6 ± 1</td>
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*P = ns; analysis of variables (ANOVA).
apnea, subglotic stenosis). More studies have to be done to know whether it can be of a value in the assessment of lower airway diseases and in the evaluation of regional ventilation. They also have a good repeatability which makes it a secure and useful one for the monitoring of normal and adventitious tracheal and lung sounds.

References