Proceedings of the International Conference of
Bioelectromagnetism, Electrical Bioimpedance, and Electrical Impedance Tomography
June 28 – July 1, 2022 / Kyung Hee University, Seoul, Korea

Using temporal electrical impedance spectroscopy measures to differentiate lung pathologies with the 3-electrode method

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Abstract– Minimally invasive lung bioimpedance measurements could serve in the future diagnosis of lung pathologies complementing biopsies and imaging techniques. Through the electrical impedance spectroscopy (EIS) technique using the 3-electrode method, distinction of lung pathologies could be possible depending on the state of the tissue. Since now, only averaged information has been used for the analysis of bioimpedance data in lungs. The aim of this study is to use temporal information to evaluate changes in the impedance signal due to the mechanism of ventilation and perfusion produced by the lungs. Preliminary results show: 1) correlation between ventilation and perfusion with the bioimpedance signal and 2) changes in the amplitude of the bioimpedance time signal depending on the pathology. As conclusion, together with cycled averaged data, temporal data could be useful for lung pathologies distinction.

Keywords: lung; electrical impedance spectroscopy (EIS); modulation; bronchoscopy.

1. Introduction

Lung pathologies present different histological results. Some pathologies lead to an increase of cell concentration and extracellular matrix in lung tissue while others lead to the destruction of the lung parenchyma. Moreover, other lung pathologies lead to the increase of mucous that hinders the passage of air in the respiratory tract. Electrical impedance spectroscopy (EIS) offers an opportunity to differentiate lung disorders based on the different patterns associated with each of them. Moreover, changes in the blood perfusion and changes in the ventilatory movement of the tissue (two phenomena present during the acquisition of lung bioimpedance measures) may help to differentiate these lung pathologies.

In previous studies, Sanchez *et al.* observed the effect of the ventilation and the perfusion of the blood present in the alveoli in the EIS measurements taken using the 4-electrode method [2]. However, the 4-electrode method, as discussed in Company-Se *et al.* [1] when measuring lung tissue is more difficult for the clinicians than the measurement of bioimpedance data with the 3-electrode method due to the difficulty of ensuring the contact of the 4 electrodes with the tissue target. Also, the capacity of tissue differentiation is the same on both methods. For this reason, EIS lung measurements using the 3-electrode method are being taken in the current project during a bronchoscopy process.

The aim of this study is to demonstrate the effect of the ventilation and the perfusion mechanisms in the bioimpedance signal in preliminary measurements.

2. Materials and methods

Participants

Minimally invasive EIS lung measurements are being taken in patients for whom a bronchoscopy is indicated at the "Hospital de la Santa Creu i Sant Pau" using the 3-electode method in bronchi, healthy lung tissue and in pathological tissue if applied (neoplasm, emphysema, pneumonia and fibrosis). Ethics approval has been obtained from the Ethics

Committee of Hospital de la Santa Creu i Sant Pau (CEIC-73/2010) according to principles of the declaration of Helsinki. All patients participating in the study have provided signed informed consent.

Measurement system

To acquire the bioimpedance measures, a tetrapolar catheter, 115 cm long with a diameter of 1.65 mm (5 F) is being used (Medtronic 5F RF Marinr steerable catheter with electrode separation 2/5/2 mm). Also, two skin electrodes (Ambu BlueSensor VLC ref: VLC-00-s/10 and 3M Company ref: 9160F) placed on the right side of the patients at the level of the ribs are being used.

The measurement system consists of an optically insulated battery powered patient interface (including the impedance front end), a rugged PC platform based on a National Instruments PXI system and an analog-optical interface to connect the PXI with the insulated front end. An arbitrary waveform generator generates a multisine excitation signal which is a broadband signal composed of 26 frequencies between 1 kHz and 1 MHz.

To acquire the bioimpedance measurements, only the electrode located at the tip of the catheter is used to inject the current and to detect the potential while the low current and the low potential electrodes correspond to the two skin electrodes. A more detailed explanation of the measurement system is included in Company-Se *et al.* [1].

To acquire the ventilation and the ECG signals the polygraphy monitoring device Embletta MPR from Natus, with a thoracic inductive band, is used.

Measurement protocol

Records of 12 seconds of bioimpedance measurements (60 spectra/s) are obtained by inserting the catheter through the bronchoscope working channel. Patients are placed in a supine position during the process. Topical 2% lidocaine is used to anaesthetise the upper airway as well as intravenous sedation is provided through the procedure. Prior to bronchoscopy, computed tomography (CT) of the thorax was performed as part of the diagnostic process of respiratory diseases and to guide the bronchoscopy procedures.

Data extraction

To compare the effect of the ventilation and the perfusion on the bioimpedance signal a 30-points double-pass moving-average filter is applied to the signal to extract the ventilatory modulation. The difference between the original signal and the signal filtered is supposed to be the modulation corresponding to the perfusion.

3. Results

Efect of the ventilatory and perfusion modulations in the bioimpedance signal

Figure 1 shows the 12 seconds acquisition of the bioimpedance magnitude signal at 33 kHz, in blue, as well as the breathing, in black, and electrocardiographic (ECG), in red, signals.

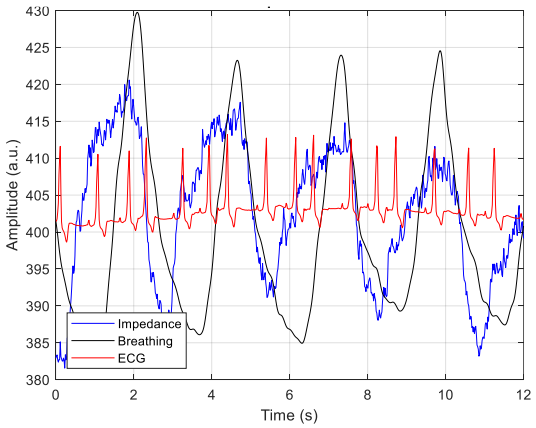

Figure 1. Superposition of the 12 seconds impedance signal at 33 kHz with the ventilation and ECG signals in a healthy lung tissue location

Figure 2 shows the power spectral density of the impedance signal (blue) after applying the 30-points double-pass moving-average filter and the ventilation signal (orange).

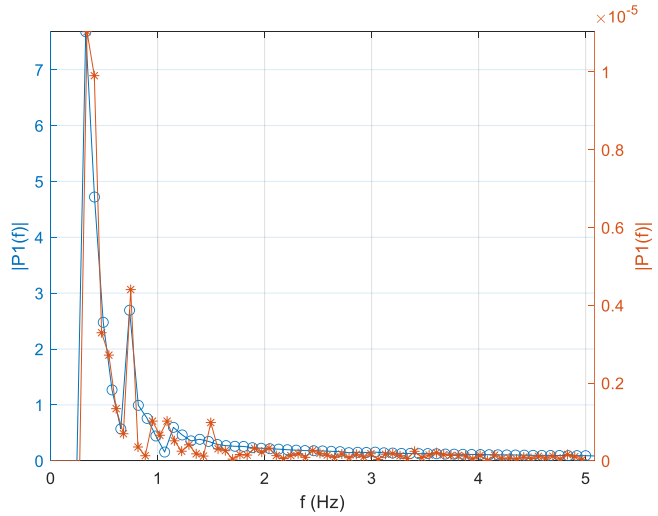

Figure 2. Power spectral density of the bioimpedance signal after applying a 30-points double-pass moving-average filter (blue, peak at 0.33 Hz) and power spectral density of the ventilation signal (orange, peak at 0.33 Hz).

Figure 3 shows the power spectral density of the signal after making the difference between the original signal and the signal resulting of the application of the 30-points double-pass moving-average filter (blue), considered to be the perfusion signal, and the power spectral density of the ECG signal (orange).

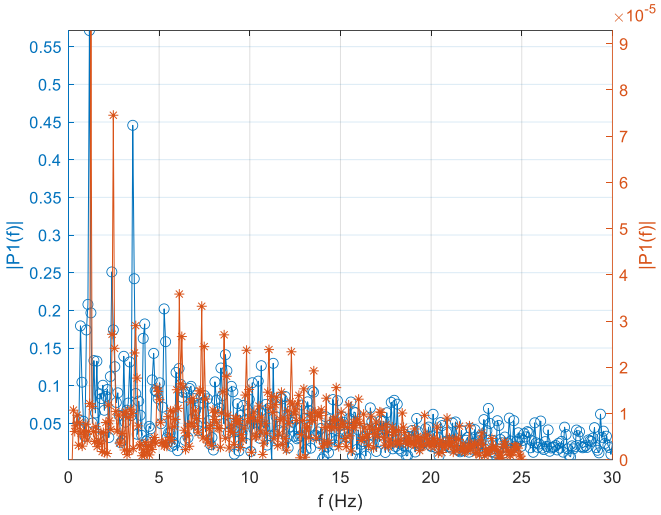

Figure 3. Power spectral density of the perfusion signal (blue, peak at 1.2 Hz) and ECG signal (orange, peak at 1.2 Hz).

Changes in amplitude of the bioimpedance signal based on different states of the tissue

Figure 4 shows amplitude changes due to ventilation depending on the state of the tissue measured at 33 kHz from 3 different cases (healthy tissue, pneumonia and neoplasic tissue). Healthy tissue shows a higher breathing modulation than neoplasic lung tissue which, in turn, shows higher breathing modulation than the area of lung with pneumonia. Also, different ventilatory frequencies and shapes are visible.

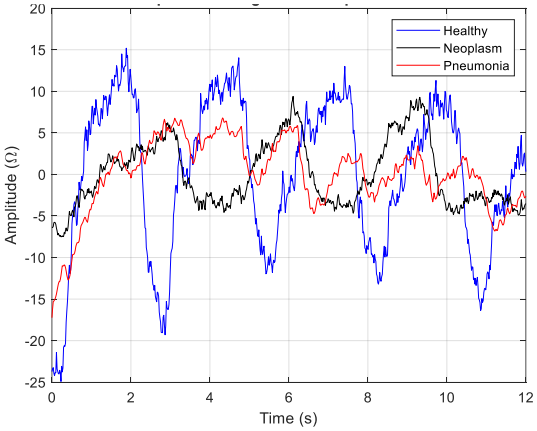

Figure 4. Amplitude changes in bioimpedance signals at 33 kHz from different patients and different tissue states.

4. Discussion

Electrical impedance spectroscopy can represent an opportunity to differentiate lung pathologies in order to complement the actual diagnostic processes. Together with averaged impedance results, temporal information could be useful to improve the tissue differentiation through changes in amplitude and shape of the signals acquired due to the effect of the ventilation and the perfusion.

The effect of the modulation is easily observable while the effect of the perfusion is not (Figure 1). The comparison between the spectrum of the signal considered to be the breathing modulation and the spectrum of the breathing signal (Figure 2) show a high frequency component at the same frequency (between 0.3 and 0.4 Hz) validating the existing modulation due to the inhalation and exhalation of the patients during the acquisition of the measure.

The effect of the perfusion is not so easily observable. This effect is demonstrated in the power spectrum of the two signals, the one representing the perfusion extracted from the bioimpedance signal and the ECG. In both cases there is a high frequency component in the 1.2 Hz corresponding to the cardiac rhythm.

The presence or absence of these two modulations could be used in the future to distinguish between different tissue states. An absence of breathing modulation could represent that the tissue measured is rigid while a high modulation of perfusion could represent the presence of neoplasic tissue, due to the nature of this pathology. These changes have also been demonstrated on Figure 4 in which the amplitude of the neoplasic tissue due to breathing is lower than the amplitude for healthy tissue. This phenomenon is due to the higher concentration of cells in the neoplasic tissue and, in consequence, the lower concentration of air. We have also seen that the amplitude of the signal related to breathing in lung with pneumonia is lower than the amplitude of the neoplasic tissue signal. This phenomenon could be due to the excessive concentration of mucous, which hinders the air flowing through the ventilatory ways.

5. Conclusions

Ventilatory and perfusion modulations are present in the bioimpedance signal and could be a tool to distinguish between different lung pathologies.

Acknowledgments

The authors would like to specially thank the patients without whom this study would not have been possible. In addition, the authors would like to thank Marta Navarro Colom, Laura Romero Roca and Margarita Castro Jiménez from the Interventional Pulmonology Unit, Respiratory Medicine Department, Hospital de la Santa Creu i Sant Pau for the invaluable support.

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