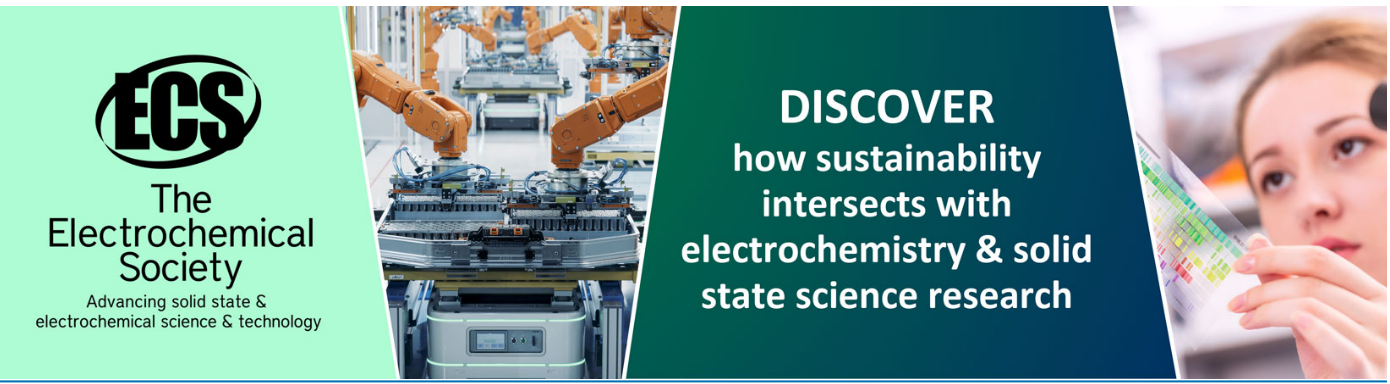
Journal of Physics: Conference Series

Tidal volume (TV) post-process obtained with electrical impedance tomography on a group of chronic obstructive pulmonary disease (COPD) patients. Use of adjust equations

To cite this article: Marco Balleza *et al* 2010 *J. Phys.: Conf. Ser.* **224** 012030



Tidal Volume (TV) post-process obtained with Electrical Impedance Tomography on a group of chronic obstructive pulmonary disease (COPD) patients. Use of adjust equations

Marco Balleza[1], Daniel Anton[1], Pere Casan[2], Pere Riu[1]

1. Universitat Politécnica de Catalunya, Centre de Recerca en Enginyeria Biomèdica, Dept. Eng. Electrònica, Barcelona, España
2. Hospital Central de Asturias, Oviedo, Asturias, España

Email. jballeza@eel.upc.edu

Abstract. Equations used to estimate ventilation out of EIT images, validated on healthy volunteers show a significant bias and a larger variance when were applied on a COPD patients group. The differences in estimation values were found to be highly correlated with anthropometric parameters. Two groups of 13 and 4 COPD male patients (FEV1/FVC<70% and FVC $\geq$ 80%) were used in this study. We have measured different anthropometric parameters like age, weight, height and skinfolds. The EIT system (TIE4sys) and a pneumotach were simultaneously connected to monitor tidal volume. The main anthropometric parameters values of 13 COPD patients were: age: 67±9 years, height: 1.65±0.05 m, weight: 72±11 kg, BMI: 26.4±3.3; and the subscapular skinfold thickness was 23±9mm. The mean tidal volume estimated with TIE4sys and the pneumotach were: 0.580±0.212 L and 0.774±0.173 L r = 0.861 (p<0.01). The mean difference was 0.196±0.096 L (p<0.01). On this group we have found out an adjust equation and we have validated it on an independent group of 4 COPD patients. The equation was Diff=-1478+15.6(weight). The mean tidal volume values obtained with pneumotach and TIE4sys on the second group of COPD patients (M:4) were: 0.798±0.395 L and 0.732±0.327 L. The mean of the differences was 0.066±0.114L. The differences of determinations estimated with pneumotach and TIE4sys can be attributed to changes of anthropometric characteristics like subscapular skinfold.

1. Introduction

The monitoring of respiratory pattern in a non-invasive way is not a completely standardized procedure in pneumology. There are different monitoring devices like inductive plethysmography bands (e.g. Respitrace™) [1] which has fallen into disuse because they presented calibration problems. On the other hand, there is another monitoring device based on the transmission of respiratory vibrations which is not yet tested enough for this application [2]. Suitability of Electrical Impedance Tomography (EIT) applied to ventilation measurement has been demonstrated for the Unilateral Pulmonary function (UPF) [3][4] and more recently for ventilatory pattern monitoring in healthy people [5]. The EIT procedure was validated for the estimation of tidal volume (TV) magnitudes in healthy people. Calibration equations depend on different anthropometric parameters like height, weight, BMI, etc. These parameters affect the impedance determinations obtaining with EIT device thus the calibration equations valid for healthy volunteers may not be adequate for COPD patients.

The aim of this work is to further obtain a new correction equation by using a new group of COPD patients with a stricter inclusion criterion.

2. Materials and methods

2.1. Pneumotachometer

The pneumotachometer used to monitor the tidal volume was a Med Graphics preVent^{TM} Pneumotach from Medical Graphics Corporation (St. Paul, MN, USA). This monitoring device records signals (volume – time) in real time,

2.2. TIE4sys device

The TIE4sys device is a prototype designed in the Department of Electronics Engineering in the Universitat Politècnica de Catalunya, Barcelona, Spian. It uses 16 electrodes and can obtain up to 17 frames/second. The electrodes (Red Dot 2560 – 3M, London; Ontario, Canada) were placed around the thoracic box on the sixth intercostals space following the protocol described in [3]. This device was programmed to apply an electrical current of 1 mA_{RMS} at 48 kHz. This electrical current was applied through all pairs of adjacent electrodes. The differential voltage at all pairs of adjacent electrodes was recorded for each injection pair, so redundant measurements were obtained allowing us calculate the reciprocity error, which is an estimation of the systematic errors and malfunctions (such as electrodes with a poor contact) present. Images are obtained by using a weighted back-projection algorithm and a median filter.

2.3. Volunteers

Three groups were used in this experiment. The first group consisted on 11 healthy volunteers males. This group of volunteers was used to establish the main relevant anthropometrical parameters and obtain a calibration equation relating ventilation in order to adjust the volume signal obtained out with EIT system. All volunteers were selected to be non smokers and they had spirometry values within the normal range. The second and third group consisted on 13 males and 4 males diagnosed with COPD and (FEV1/FVC<70% and FVC≥80%). The second group (M_{COPD}:13) was used to validate the calibration equation and obtain an adjust equation in order to adjust the determinations of volume obtained with TIE4sys. And the third one (M_{COPD}:4) was used to validate the adjust equation.

2.4. Procedures

The two monitoring devices (TIE4sys and pneumotach) were connected to take simultaneous measurements. The performance of each device is independent and there is no interference between them. The calibration procedures for each one was: 1) Pneumotach: a 3 litre needle, according to the protocol of the laboratory and manufacturer instructions. 2) TIE4sys: Acquisition speed and reciprocity error are checked before starting to record measurements. Several respiratory cycles (5 to 10) are then acquired at tidal volume to be averaged and constitute the reference for the backprojection. The tidal volume was recorded for several 30 s slots (between 5 and 8 respiratory cycles), with 3 min of resting between slots, until 25 and 30 cycles were obtained for each patient. Prior to start the measurements protocol, anthropometric data for each volunteer was collected, including sex, age, height, weight, BMI, skinfold thickness, thoracic parameters and diameters. In the case of COPD patients, the pulmonary function test data was collected.

2.5. Statistical Comparison

All data are expressed as average and standard deviation values. The comparison between the determinations obtained by pneumotach and TIE4sys device were done using a non-parametric t-test, the Spearman rank correlation coefficient and a Bland & Altman plot. Values of $p<0.05$ were considered to be significant.

 doi:10.1088/1742-6596/224/1/012030

3. Results

The anthropometric main values of the 11 healthy volunteer males were: age: 27±9 years, height: 1.80±0.1 m, weight: 78±13 kg, BMI: 24.2±3.1 kg/m^2; and subscapular skinfold thickness 23±9mm. The most relevant parameters for males were found to be the subscapular skinfold (SS_Sk) and the weight (W). The resulting equation is then:

$$\Delta V_{MALE} = \frac{\Delta IC}{2889 - 25.7(SS\_Sk) - 16(W)} \tag{1}$$

The determination coefficient of this equation was R^2 = 959 ($p<0.01$)

The anthropometric main values of the 13 COPD patients were: age: 67±9 years, height: 1.65±0.05 m, weight: 72±11 kg, BMI: 26.4±3.3 kg/m^2; and the subscapular skinfold thickness was 23±9mm. The spirometry main values of 13 COPD patients were: FVC: 83±13%; FEV1: 47±15%; FEV1/FVC: 40±9% of reference value.

The mean value for the tidal volume obtained by pneumotach and TIE4sys were: 0.774±0.173 L and 0.580±0.212 L, respectively. The mean of the differences between the determinations obtained with TIE4sys and pneumotach was 0.194±0.096 l ($p<0.01$). The acceptability of the differences between determinations was 0.003 L and 0.418L, as shown in figure 1a.

In order to reduce the error between TV estimations obtained with the pneumotach and TIE4sys (EIT device) we have obtained a linear equation which involve an anthropometric parameter: the weigth:

$$\Delta V_{ADJUST} = \frac{IC}{-1478 + 15.6(W)} \tag{2}$$

The coefficiente of determination R^2 = 0.548.

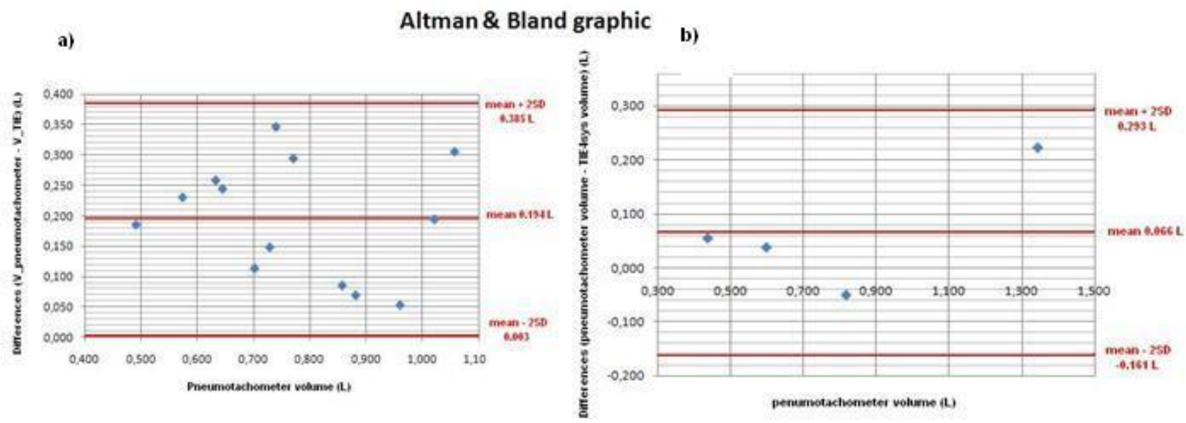


Figure 1. a) Bland & Altman plot for the differences between pnaumotachometer and EIT estimations for TV on 13 COPD patients; b) Bland & Altman for the differences between pneumotachometer and EIT estimations for TV on 4 COPD patients

In this way, the TV estimation for COPD patients is corrected as:

$$\Delta V_{TOTAL} = \frac{\Delta IC}{\big(2889 - 25.7(SS\_Sk) - 16(W)\big) + \big(-1478 + 15.6(W)\big)} \tag{3}$$

The anthropometric main values of the 4 COPD patients were: 66±14 years, height: 1.66±0.05 m, weight: 72±11 kg, BMI: 26.0±2.9 kg/m^2; and the subscapular skinfold thickness was 19±7mm. The spirometry main values of 4 COPD patients were: FVC: 74±5%; FEV1: 33±12%; FEV1/FVC: 31±9%.

On this group we have applied the calibration equation adding the adjust equation. The mean value for tidal volume obtained by pneumotach and TIE4sys were: 0.798±0.395 L and 0.732±0.327 L, respectively. The mean of the differences between the determinations obtained with TIE4sys and pneumotach was 0.066±0.114 L ($p<0.01$). The acceptability of the differences between determinations was 0.293 L and -0.161L, as shown in figure 1b.

4. Discussion

The data obtained in this paper suggest that TV estimation out of EIT in-vivo is affected by body shape and composition. This affirmation is based on the fact that differences between healthy volunteers and COPD patients show a strong relationship with composition related parameters (e.g. skinfold measurements). The visual reduction in deviation is noticeable as depicted on the figure 1b. All the patients are in the acceptability range. One of them presented a difference over 200 ml due to patient's respiratory difficulties and presented an estimation of volume with the pneumotachomer of 1.325 L. If this patient were removed from the sample, then the root mean standard error (RMSE) would be about 5%. In order to continue validating our adjust equation we need to increase our sample of COPD patients. This will be the next step in our research.

5. Conclusions

The impedance changes recorded with EIT during ventilation depend on both the external changes in thorax shape and size. It was expectable that the calibration equation derived for healthy volunteers could not be applied to COPD patients without further changes. This was already shown in a previous research with a group of less controlled COPD patients, including both obstructive and restrictive patterns [6]. Hopefully it seems feasible to correct the equations based on some anthropometrical parameters and reduce the estimation error down to a level acceptable for a monitoring device.

References

[1] Stick SM, Ellis E, LeSouëf PN and Sly PD. (1992) Validation of respiratory inductance plethysmography ("Respitrace") for the measurement of tidal volume breathing parameters in newborn. Pediatr Pulmonol 13;187-91

[2] Phillip Dellinger R, Smith J, Cinel I, Tay C, Rajanala S,, Glickman YA and Parrillo JE (2007) Regional distribution of acoustic-based lung vibration as a function of mechanical ventilation mode. Critical Care 11:R26

[3] Serrano RE, de Lema B, Casas O, Feixas T, Calaf N, Camacho V, Carrión I, Casan P, Sanchis J and Riu PJ (2002). Use of electrical impedance tomography (EIT) for the assessment of unilateral pulmonary function. Physiol Meas 23:211-220.

[4] Serrano RE, Riu PJ and Casan P (2004). Assessment of the unilateral pulmonary function by means of electrical impedance tomogephy using a reduce electrode set. Physiol Meas 25:803-813.

[5] Balleza M, Fornos J, Calaf N, Feixas T, González M, Antón D, Riu PJ, Casan P. (2007) Monitoring of Breathing Pattern at Rest by Electrical Impedance Tomography. Arch Bronconeumol 43:300-303.

[6] Balleza M, Fornos J, Calaf N, Feixas T, Gonzalez M, Anton D, Riu PJ, Casan P. (2007) Ventilatory Pattern monitoring with Electrical Impedance Tomography (EIT). Validation for Healthy Subjects. IFMBE Proceedings 17: 572-575.