Localizador web
Artículo 136.557

Electrical Impedance Tomography. Standardizing the Procedure in Pneumology

Bruno de Lema,[a] Pere Casan,[a] and Pere Riu[b]

[a]Unitat de Funció Pulmonar, Departament de Pneumologia, Hospital de la Santa Creu i de Sant Pau, Facultat de Medicina, Universitat Autònoma de Barcelona, Barcelona, Spain.
[b]Centre de Recerca i Enginyeria Biomèdica (CREB), Universitat Politècnica de Catalunya, Barcelona, Spain.

The following conditions are optimal for obtaining an adequate number of informative images by electric impedance tomography: *a)* patient seated with hands at the nape of the neck; *b)* breathing at rest; *c)* recording of at least 300 images (at a frequency of 10 Hz), and *d)* readings taken at the sixth intercostal space.

Key words: *Electrical impedance tomography. Pneumology.*

Tomografía por impedancia eléctrica. Estandarización del procedimiento para su aplicación en neumología

Las condiciones para la obtención de información en imágenes y en números más adecuadas con la tomografía por impedancia eléctrica serían las siguientes: *a)* paciente en sedestación con las manos en la nuca; *b)* respiración en reposo; *c)* adquisición de al menos 300 imágenes (frecuencia de adquisición de 10 Hz), y *d)* medidas en el sexto espacio intercostal.

Palabras claves: *Tomografía por impedancia eléctrica. Neumología.*

Introduction

New imaging techniques such as high resolution computed tomography (CT) or ultrasound have enhanced the ability of pneumologists to diagnose and study many diseases. Furthermore, tools for quantifying observations continue to be important for respiratory medicine physicians, who measure parameters such as forced expiratory volume in 1 second, PaO_2, or $PaCO_2$. The combination of images and numerical data in a single procedure is often a goal that is difficult to achieve.

Electrical impedance tomography (EIT) is a noninvasive technique for obtaining thoracic images at the same time that various aspects of respiratory physiology are quantified. It is based on measuring electrical bioimpedance between electrodes placed around the thorax. A high frequency, low intensity alternating current is injected and adjacent electrodes pick up the potential differences. That data is used to generate quantifiable dynamic images for studying pulmonary ventilation or perfusion.

Although EIT is well known in the industrial world, where it is used to study materials or flow dynamics for example, its application in medicine is relatively recent and its use in pneumology began in the 1980s.[1,2] The recent use of EIT in Spain has focused on the study of myocardial cell viability and respiratory physiology.[3-5]

Respiratory medicine studies to date suggest that this technique is able to generate quantified images on variables related to pulmonary physiology, the heart, and circulation in general. Information about the shape of the thorax is of lower resolution than images obtained from other available techniques. However, the physiological information EIT provides can be useful in several ways: *a)* to assess unilateral lung function, *b)* to monitor respiratory pattern, *c)* to study ventilation and perfusion in the region of interest in the thorax, *d)* to analyze changes in upper airway shape, *e)* to estimate thoracic fluid volumes (an experimental procedure in patients with heart failure or acute pulmonary edema), and *f)* to measure pulmonary artery pressure. All these applications can occur at the patient's bedside in a manner that is economical, noninvasive and radiation-free—this last being a feature of particular interest for neonates and premature infants or during pregnancy.

Our aim was to describe the use of EIT and analyze its behavior in a small series of individuals in order to

This study was partly funded by Red Respira, Instituto de Salud Carlos III-SEPAR of the Spanish Society of Pulmonology and Thoracic Surgery (Grant PI 20387), and the TV3 Marathon Foundation (Project 041530/31).

Correspondencia: Dr. P. Casan.
Unitat de Funció Pulmonar. Departament de Pneumologia.
Hospital de la Santa Creu i de Sant Pau.
Antoni M. Claret, 167. 08025 Barcelona. España.
E-mail: pcasan@santpau.es

Manuscript received September 6, 2005. Accepted for publication November 5, 2005.

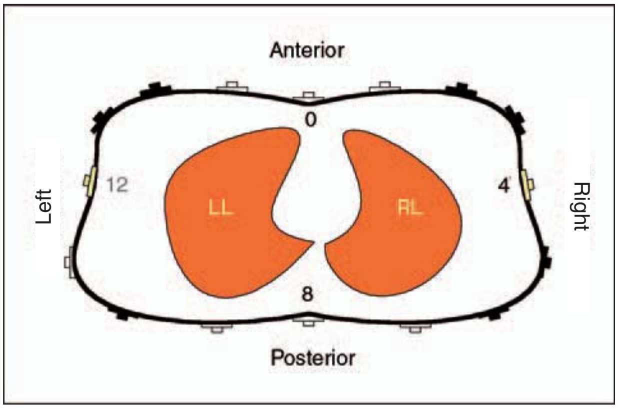

Figure 1. Positioning of electrodes around a cross-section of the thorax. LL indicates left lung; RL, right lung.

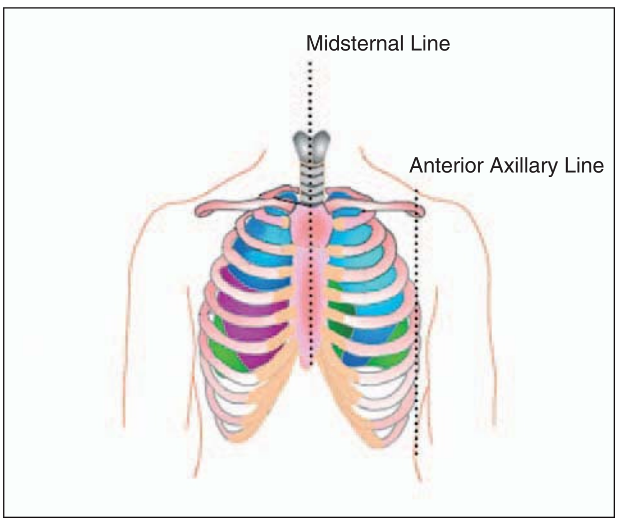

Figure 2. Lines of anatomical reference for the rib cage.

become familiar with its real application in respiratory medicine.

Methods

Measurements in Healthy Volunteers

We applied EIT in a group of 10 healthy volunteers (5 women, 5 men) with a mean (SD) age of 32 (5) years (range, 26-48 years). The inclusion criteria were absence of a history of chest or breast surgery, lack of chest wall abnormalities or thoracic skin diseases, and informed consent to the study. The aim of this part of the study was to determine the contribution of each lung to ventilation.

Procedure

We used an EIT device that is not commercially available: the prototype $TIE_{sys\text{-}4}$ designed and built at the polytechnic university in Barcelona (Universitat Politècnica de Catalunya). Sixteen conventional electrocardiographic electrodes (Red Dot 3M, St Paul, Minnesota, USA) for stress tests could be connected. The electrodes were positioned at points in the way described by Holder and Temple.[6] In our protocol we identified 4 basic anatomical points for positioning the electrodes in the simplest and most practical way. The remaining electrodes were positioned around the reference electrodes (Figure 1). The reference points for the scheme were the electrodes on imaginary straight lines parallel to the sagittal plane. The anterior line followed the sternum and the posterior one, the spinal column. The side points were on the right and left midaxillary lines. We then drew a line around the perimeter of the thorax (corresponding to the CT slice at the fourth or the sixth intercostal spaces). Three intermediate electrodes were positioned in the spaces between reference electrodes. Thus 16 electrodes were placed on a plane corresponding to a CT slice (Figures 1 and 2).

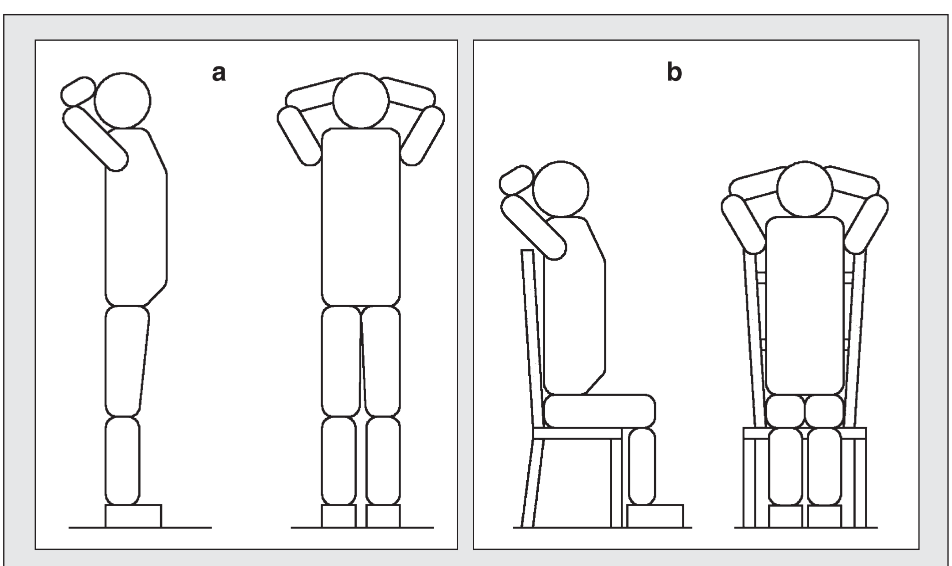

Figure 3. Body postures assessed: *a)* standing and *b)* seated. In both cases, the hands are joined behind the head.

The selection of the thoracic plane was based on reports in the literature of other groups' experiences.[7] Subjects were positioned as shown in Figure 3: comfortably seated or standing with hands on the nape of the neck. The subject was breathing spontaneously, at rest. A Student *t* test at a level of significance of $P<.05$ was used to compare the results obtained with the reference values published in 1957 by Svanberg,[8] given that it would now be considered unethical to subject healthy volunteers to gamma rays. Svanberg established that the right and left lungs supplied 53% and 47% of total ventilation, respectively, when a subject is breathing spontaneously.

Results

Results of Student *t* test comparisons were as follows:

– No significant differences were found between measurements taken in standing or sitting position: the mean values for the left lung were 46.7% (3.9%) with the subject standing and 46% (4.8%) with the subject sitting; those results were similar to those reported by Svanberg[8] for subjects breathing spontaneously.

– Maximal ventilatory maneuvers changed the results significantly to 49.9% (2.8%) and 50.4% (2.6%) for standing and sitting measures, respectively.

Simplification of the Procedure

Placing 16 electrodes around the thorax can be time consuming. One of our objectives was to establish the minimum number of electrodes needed to obtain an image that would allow us to estimate single lung function. Another was to determine whether the fourth or the sixth intercostal space would be the best place for positioning the leads. For the first objective, starting with the data gathered with 16 electrodes, we removed information until images from 8 electrodes were reached. The 8-electrode image was of poor quality with regard to thoracic morphology (Figure 4), but there were no statistically significant differences between single lung function information between results calculated with 16 or 8 leads (Figure 4).[9]

Regarding determination of the optimal intercostal space, we saw that images created for the fourth intercostal space had significantly more artifacts than those of the sixth intercostal space, and that this difference meant that calculating single lung function at the fourth would be difficult or impossible. Images could be assembled for all 10 patients at the sixth intercostal space, whereas it was possible to estimate single lung function for only 3 from data obtained at the fourth space.[9] Finally, a seated position was evidently easier to tolerate by subjects and would surely be better for patients.

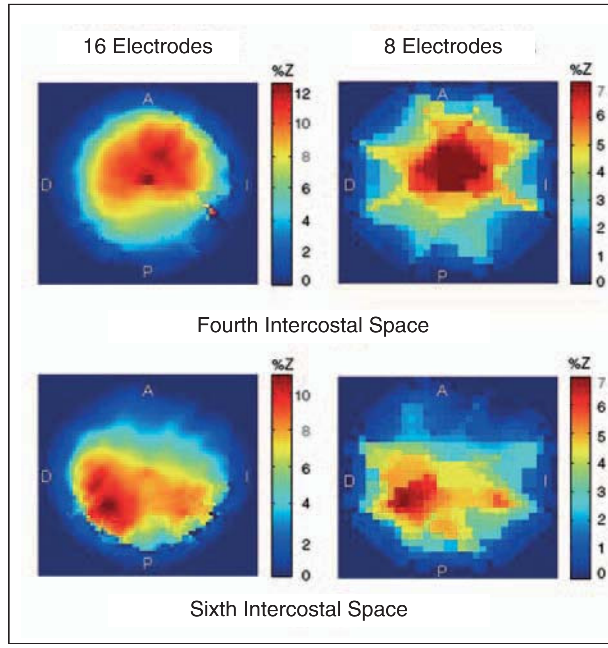

Figure 4. Comparison of images taken with 16 and 8 electrodes placed at the fourth and sixth intercostal spaces.

REFERENCES

1. Barber DC, Brown BH. Applied potential tomography. J Br Interplanet Soc. 1989;42:391-3.
2. Harris ND, Suggett AJ, Barber DC, et al. Applications of applied potential tomography (APT) in respiratory medicine. Clin Phys Physiol Meas. 1987;8:155-65.
3. de Lema B, Serrano E, Feixas T, et al. Tomografía por impedancia eléctrica. Estandarización del procedimiento para su uso en neumología. Arch Bronconeumol. 2001;37:131.
4. Serrano E, de Lema B, Casas O, et al. Use of electrical impedance tomography (EIT) for the assessment of unilateral pulmonary function. Physiol Meas. 2002;23:211-20.
5. Riu P, Rosell J, Lozano A, et al. Multifrequency static imaging in electrical impedance tomography. Part 1: instrumentation requirements. Med Biol Eng Comput. 1995;33:784-92.
6. Holder D, Temple A. Effectiveness of the Sheffield EIT system in distinguishing patients with pulmonary pathology from a series of normal subjets. In: Holder DS, editor. Clinical and physiological applications of electrical impedance tomography. London: UCL Press; 1993. p. 277-98.
7. Frerichs I. Electrical impedance tomography (EIT) in applications related to lung and ventilation: a review of experimental and clinical activities. Physiol Meas. 2000;21:1-21.
8. Svanberg L. Influence of posture on lung volumes, ventilation and circulation in normals; a spirometric-bronchospirometric investigation. Scand J Clin Lab Invest. 1957;9 Suppl 25:1-95.
9. Serrano E, Riu P, de Lema B, et al. Assessment of the unilateral pulmonary function by means of electrical impedance tomography using a reduced electrode set. Physiol Meas. 2004;25:803-13.