Title: DEVICES CONSTRUCTIVE ARRANGEMENT AND METHODS APPLIED TO THORAXIC CIROMETRY

Abstract: The present invention relates to an apparatus and method for the measurement of expansion and contraction in general and particularly for monitoring the respiration of patients by measuring the torso perimeter (thoracic cirometry) in real time, particularly to measure thoracic expansibility in patients under physiotherapy or clinical treatment or in any case that requires the evaluation of the mobility of the thorax. The measurement is made through a resistive sensor that produces a voltage signal proportional to the position of a sliding cursor. Other embodiments can use a capacitive sensor and a linear encoder as well.
DEVICES CONSTRUCTIVE ARRANGEMENT AND METHODS
APPLIED TO THORAXIC CIRTOMETRY

Field of the invention

The present invention relates to an apparatus and method for the measurement of expansion and contraction in general and particularly for monitoring the breathing of patients by measuring the torso perimeter (thoracic cirtometry) in real time, particularly to measure rib box expansibility in patients under physiotherapy or clinical treatment.

Background of the invention

Thoracic cirtometry is the measurement of the perimeter of the thorax to detect its expansion and contraction during breathing; in other words, it is the measurement of the expansibility of the thorax. Thoracic expansibility is used as one of the parameters used in the analysis of the elasticity of the anatomical elements of the thorax and lungs, that can be affected in some chronic and degenerative diseases, such as the chronic obstructive pulmonary disease (COPD), the amyotrophic lateral sclerosis, the ankylosing spondylitis, among others.

Thoracic cirtometry is usually carried out in the axillary, mammilary and xyphoid lines, before and after a therapeutic intervention. These measurements are usually done with a conventional measuring tape, at different times, reason why they can be affected by unacceptable errors if the measuring tape is not positioned in the same line before and after the intervention. Therefore, the measurement reproducibility is limited, also because of the limited precision of the tape, resulting in a non-accurate monitoring of the patient's respiration.

This method of measurement is also limited for not allowing the evaluation of the dynamic behavior of the thorax during the therapeutic intervention; in other words, it doesn't permit to monitor the movement of the thorax in function of time, this dynamic behavior being important to
evaluate the respiratory activity and its evolution.

**Objects of the invention**

In view of the above, it is first object of this invention is to provide an apparatus for evaluating the thoracic movement in real time.

Another object of this invention is to provide an equipment that can be used during the therapeutic procedures without disturbing them.

Another object of this invention consists of providing an apparatus that does not oriduce any limitation to the patient during the therapeutic procedures.

Yet another object of this invention consists of insuring that the collected data are precise and reliable.

Another object of this invention is to provide a versatile, portable and autonomous equipment, to process the measurement data and to present them in a clear and versatile form in a display integrated to it.

An additional object of this invention is to allow the data to be transferred to a remote system, preferably a microcomputer for additional processing and recording.

**Summary of the invention**

The invention hereby described overcomes the limitations of that conventional tape measuring method, by using a sensor of position to collect and register the data of the expansion and contraction of the patient's chest in real time, during the therapeutic intervention, but not restricting the movement of the thorax. The invention can also be associated with other equipment used to evaluate the mechanics and the respiratory function, making possible other simultaneous analyses.

These objects, as well as others, can be obtained with this invention that comprises a sensor to detect the thorax displacement in function of time, said sensor having a first and a second section respectively connected to first and second extremities of the inelastic belt that is fasten
to the chest of the patient. This belt is kept moderately tightened through the action of a spring, in order that, during the expansion and contraction of the thorax for breathing, the cited extremities can freely move in opposite directions, back and forth. This movement causes the sliding of the second section along said first section of the sensor, which is converted in an electric signal proportional to the expansion and contraction lengths of the thorax and, indirectly, to the pulmonary capacity of the patient.

In accordance with another feature of this invention, the inelastic belt is provided with a graduated scale in centimeters to permit also the conventional measurement of the perimeter of the thorax of the patient, having for that a cursor that indicates the forth and back displacements.

In accordance with another feature of the invention, and as a preferred embodiment, said electric signals are sent to a processing unit that comprises an analog to digital converter (A/D) to convert the analog information to digital information.

In accordance with another feature of this invention, said processing unit comprises a microcontroller.

In accordance with another feature of this invention, said processing unit processes, stores and exhibits the digital information, comprising for that a display of easy visualization.

In accordance with another feature of this invention said processing unit comprises an interface to transfer the digital data to any external system for post-processing, preferably to a microcomputer, by wireless or cable communication.

In accordance with another feature of this invention, in the non-autonomous mode, the connection between the processing unit and the microcomputer may be carried out either through a UART or USB serial port.

In accordance with another feature of this invention, the sensor is a
resistive device.

In accordance with another feature of this invention, the sensor consists of a capacitive device.

In accordance with another feature of this invention, the sensor consists of a linear encoder with optical reading of the position.

In accordance with another feature of this invention, said linear encoder supplies the information in digital form, avoiding the use of the A/D converter used with the resistive or capacitive sensors.

In accordance with plus another feature of this invention the power for the apparatus is supplied by a battery or by an electronic power supply.

In accordance with yet another feature of this invention, in a second embodiment, the power for the apparatus is directly provided by the microcomputer, either through the USB port or through the joystick port.

Still in accordance with another feature of this invention and aiming to provide precise and reliable information on the respiratory capacity of the patient, said apparatus can have two or more chest belts with respective sensors.

In accordance with another feature of this invention said two or more chest belts can be mounted in an arrangement like a vest to be worn by the patient, placed around the rib box.

In accordance with another feature of the invention, said apparatus comprises three chest belts in said vest to supply simultaneous information on the expansion and contraction of the thorax in the axillary, mammilary and xiphoid lines of the patient's chest.

In accordance with another feature of this invention, said processing unit has two or more inputs to connect many distinct sensors, each one installed in a different line of the patient's chest.

In accordance with another feature of this invention, said processing unit receives the analog signals from said distinct sensors, converts said
signals to digital signals, processes, stores the processed signals in a memory for later use, and exhibits them in a display.

In accordance with another feature of this invention, the resistive sensor consists of a linear track of resistive material (first fixed section) and a sliding contact (second mobile section), that picks up the voltages along the resistive layer, said voltages being proportional to the displacements of the sliding contact.

According to another embodiment of this invention, the resistive material comprises a resistive film deposited on an insulating base.

According to another embodiment of this invention, the resistive material consists of a film of tin dioxide deposited on an insulating base.

According to another feature of this invention, the capacitive sensor consists of a first metallic blade (first fixed section) and a second metallic blade (second mobile section), separated by a dielectric material, for instance air, which capacitance varies when the second blade slides over the first blade.

According to another feature of this invention, said capacitive sensor comprises a circuit to detect the capacitance variation providing a voltage signal proportional to this capacitance.

According to another feature of the invention, the sensor of position is a linear encoder consisting of two tracks patterned with parallel lines (or bars) uniformly spaced and with different periodicity in both tracks, said tracks sliding parallel to each other when the extremities of the belt move according to the displacement of the patient's chest.

According to still another feature of this invention, the mentioned linear encoder comprises a light source, for instance light emitting diodes (LED), and an optical reading device that detects the variation of intensity of the light reflected or transmitted by the spacings or lines, generating trains of pulses whose temporal pattern depends on the speed and
direction of the movement of the tracks associated with the movement of the patient's chest.

According to still another feature of this invention, the mentioned linear encoder sensor supplies pulsed information, which excludes the A/D converter needed by the resistive and capacitive sensors.

**Brief description of the drawings**

Other objects, advantages and novel features of the present invention can be better evaluated by means of the description of a preferred embodiment of the invention, given as an example and not in a limitation sense, and of the figures related to it, in which:

Figure 1 illustrates the apparatus comprising a resistive sensor according to the principles of the invention.

Figure 2 illustrates the apparatus comprising a capacitive sensor according to the principles of the invention as well.

Figure 3 illustrates the apparatus comprising a linear encoder sensor according to the principles of the invention as well.

Figure 4 illustrates an embodiment in which three thoracic belts and respective sensors are mounted in a vest, according to the principles of the invention.

**Detailed description of the invention**

The present invention refers to an apparatus and method for measuring thoracic cirtometry comprising at least one inelastic belt (1) that is attached to the patient's chest, which extremities are connected each one to each side of a sensor of position that monitors the expansion and contraction of the thorax during breathing by measuring the removal and approximation distances between said belt extremities as a function of time. This sensor converts this back and forth movement of the extremities of the belt (1) into electric signals that are proportional to the thorax displacement during respiration. The output of said sensor is connected to
the input of a processing unit, based on a microcontroller, that converts said electric signals into digital signals and processes these signals to be shown in a display in real time and to be stored for later use, in such way being the apparatus autonomous. This processing unit can also treat the data to be transferred to any external system, preferably a microcomputer, through an interface that can do the communication wireless or through cables.

According to the figure 1a, which shows a frontal view, and to the figure 1b, which presents a profile view, the apparatus comprises an inelastic belt (1) with a scale graduated in centimeters and inches (not shown in the figure), connected to a resistive sensor (2) with a first fixed section (4) that supports a linear resistive track (7) and a second mobile section (3) equipped with a sliding contact (6) in permanent contact with said track. One of the extremities of said inelastic belt (1) is attached to the first fixed section (4) and the opposite extremity is attached to the second mobile section (3), which are continuously drawn togethere by the spring (5), whose extremities are fixed to both sections of the sensor device (2). Both the sliding contact (6) and the extremities of said linear resistive track (7) are connected by electrical cables to the processing unit (8), the sliding contact being connected to the input of the analog to digital converter A/D (12) and the extremities of the resistive track (7) connected, respectively, to the positive terminal (11) and the ground (13) of the said processing unit (8). This processing unit (8) processes the information collected by the sensor, stores it in a memory (not shown in the figure), shows this processed information in the display (21) and sends it under the form of digitally coded data to a remote microcomputer (10) for further processing of the information. The connection (9) between the processing unit (8) and the microcomputer (10) is carried out by an interface through a UART or USB serial port. The apparatus comprises a power supply. In a second
embodiment of the invention, the power for the processing unit (8) and for the sensor (2) is supplied by the microcomputer (10), through the USB port or through the joystick port.

Figure 2 is a frontal view (Fig. 2a) and lateral view (Fig. 2b) of the capacitive sensor (2). As illustrated by this figure, the capacitive sensor (2) consists of a first blade (15) of electrically conductive material, such as a metal, overlapping a second similar blade (16) and separated from the first one by a dielectric material, which can be air. Said first metallic blade (15) is fixed to the mobile blade (3) and the second metallic blade (16) is fixed to the holder (4). When the mobile blade (3) is drawn by the inelastic belt (1), by one side and by the spring (5), by the other side, following the inspiration and expiration movement of the thorax, the two metallic blades (15) and (16) slide one over the other, varying the overlapped area and, in consequence, varying the capacitance of the device. The sensor comprises a circuit to detect the capacitance variation and provides a voltage signal proportional to this variation, which is sent to the processing unit (8). The connection between the capacitive sensor (2) and the said process unit (8) is carried out through two wires (one for each metallic blade) connected, respectively, to the positive (11) and negative (13) terminals of the process unit (8). The processing unit performs identical functions as described in the previous case with a resistive sensor: display (21), of the memory and of the connections between the encoder device and the microcomputer (10) is identical to the previous case of the resistive sensor and has the same functions.

Figure 3 depicts a frontal view (Fig. 3a) and a lateral view (Fig. 3b) of the sensor (2), that is a linear encoder composed by two tracks (17) and (18), one of them (17) being patterned with parallel lines (or bars) uniformly spaced. One track is attached to the mobile section (3) of the device and the other is attached to the fixed section (4) of the said device.
In one of the tracks (17) and (18) is fixed an optical sensor capable to read the intensity of the light reflected by the lines (or bars) and spacing between them. When one track slides in relation to the other, information about the movement is supplied as a train of pulses generated when the optical sensor (19) detects the intensity variation of the light reflected by the spaces and lines (or bars). The temporal pattern of this train of pulses is defined by the movement of one track relative to the other, this movement being the same of the patient's chest (20). As this information is generated in a digital format, the A/D converter, used with the resistive and capacitive sensors, is not needed to convert the data to be sent to the process unit (8).

The display (21), the memory and the connection (9) between the process unit (8) and the microcomputer (10) are the same previously described to be used with the resistive and the capacitive sensors and they have the same functions.

Fig. 4 shows a set up of three identical sensors (2) fixed in three identical inelastic belts (1), mounted in a vest (14) around the patient's chest.

The sensors (2) simultaneously collect information on the expansion and contraction of the thorax in the axillary, mammilary and xiphoid lines and send it to the process unit (8) that converts and send it to the microcomputer (10).

The display (21), the memory and the connection (9) between the process unit (8) and the microcomputer (10) are the same as previously described to be used with the resistive and the capacitive sensors and they have the same functions.

While the invention has been described as an example based in a preferred embodiment, those skilled in the art will be able to introduce modifications according to the basic inventive concept.
Thus, for example, a strain gage can be coupled to the spring (5) in order to supply data on the compression force exerted on the patient's chest.

The use of springs with different elasticity will make possible to adjust said compression to the physiological features (age, muscular condition, etc.) of the patient.

Therefore, the invention is defined and limited only by the set of claims that follows.
CLAIMS

1. An apparatus for thoracic cirtometry for monitoring the expansion and contraction of a patient's chest during respiration, comprising at least one inelastic belt (1) submitted to a moderate tension by a spring (5) that embraces the patient's chest, the first and the second extremities of said belt (1) being respectively connected to a first fixed section (4) and to a second mobile section (3) of a sensor of position (2), being the first fixed section (4) a non-conductive blade coated on the upper surface with a resistive film (7) and means for setting up electric currents along said resistive film, and being the second mobile section (3) a non-conductive blade with one probe tip (6) fixed to it, being this tip in contact with the resistive layer of the first blade (4) and capable to slide over and along the resistive film (7) to pick up the voltages along the film, being said detected voltages proportional to the distances covered by the tip (6) when moving back and forth according to the opposite back and forth movement of said extremities of the belt (1), due to the expansion and contraction of the patient's chest.

2. An apparatus for thoracic cirtometry, as claimed in claim 1, wherein said resistive film comprises tin dioxide.

3. An apparatus for thoracic cirtometry, as claimed in claim 1, wherein the output of said position sensor (2) is connected to the input (12) of a processing unit (8).

4. An apparatus for thoracic cirtometry, as claimed in claim 3, wherein the process unit (8) comprises a microcontroller.

5. An apparatus for thoracic cirtometry, as claimed in claim 4, wherein the microcontroller comprises an analog to digital converter (ADC) in which input (12) is connected to the output of the sensor of position (2).

6. An apparatus for thoracic cirtometry, as claimed in claims 1, 3 or 4, wherein the processing unit (8) comprises means to process the
information as well as a display to show the processed information.

7. An apparatus for thoracic cirtometry, as claimed in claims 1, 3, 4, 5 or 6, wherein the sensor of position (2) is a capacitive sensor consisting of two conductive blades (15) e (16), with a gap of air between them, said blades being capable to oppositely move, in parallel to each other, without any electric contact between them, following the back and forth movement of the extremities of the belt (1) due to the expansion and the contraction of the patient's chest, said variable capacitor supplying a voltage signal that depends on the area of the blades that are superposed.

8. An apparatus for thoracic cirtometry, as claimed in claims 1, 3, 4, 5 or 6, wherein the sensor of position (2) is a linear encoder consisting of two blades (17) and (18), patterned with parallel lines (or bars) uniformly spaced and with different periodicity in both blades, having a light source and optical detectors capable of reading the intensity of the light reflected by the lines (or bars) and spacings between them, so that when one blade moves in relation to the other, information about the movement is supplied as two trains of pulses generated by the optical sensors (19), the temporal pattern of these pulse trains giving information about the blade movement (speed and direction) due to the expansion and the contraction of the patient's chest (20).

9. An apparatus for thoracic cirtometry, as claimed in any of the previous claims comprising two or more belts (1) with respective sensors (2), each belt positioned in a different line of the patient's chest.

10. An apparatus for thoracic cirtometry, as claimed in claim 9 comprising a processing unit (8) having two or more inputs to which can be connected as many distinct sensors (2), each one positioned in a different line of the patient's chest.

11. An apparatus for thoracic cirtometry, as claimed in claim 9 comprising three thoracic belts (1) with respective sensors (2) mounted as
a vest (14), to be worn by the patient on the chest to supply simultaneous information about the expansion and contraction of the thorax in the axillary, mammilary and xiphoid lines.

12. A method for thorax cirtometry using the apparatus claimed in claims 1 to 11 comprising the following steps:
   - to follow, in real time, the chest displacement due to the inspiratory and expiratory incursions during breathing;
   - to convert such displacements in electric signals that are proportional to those incursions;
   - to convert such electric signals in digitally codified data;
   - to send this digital data to digital processing systems.

13. A method as claimed in claim 12 additionally comprising the conversion of the analog electric signals to digital signals by means of an analog to digital converter (ADC).


15. A method as claimed in claim 14 comprising the digital processing of the data in the processing unit (8) and the exhibition in a display (21) connected to said processing unit (8).

16. A method as claimed in claim 12, comprising the digital codification of the data through specific software installed in said digital processing means, provided by one microcomputer (10) and presented as tables and graphs.