A COMPARATIVE STUDY OF NONCONTACT SENSOR FOR
BREATHING MONITORING AND SLEEP APNEA DETECTION

O. Baltag, A. Banarescu, M. Rau

University of Medicine and Pharmacy "Gr. T. Popa", Iasi, Romania
Faculty of Medical Bioengineering
anca_2907@yahoo.com, obaltag@umfiasi.ro

This work presents the results of a comparative study concerning the use of microwave and ultrasounds for the non contact detection of the respiratory activity. One of the main element of the installation is a microwave Doppler transducer working on 8 GHz. The Doppler signal resulting from the movement of the anatomical structures – thorax (lung and heart) has a complex structure due to the cumulative effects of all the moving organs. The other transducer uses the ultrasounds interference in the space between the thorax and the ultrasounds receiver. The optimum position of the two transducers (microwave Doppler and ultrasounds sensors) has been established to detect a maximum signal of the respiratory activity. At the same time, two types of breathing were identified: the thoracic and the abdominal one. As a reference transducer we used an electromechanical sensor for the detection of the thorax and the abdominal movement. A good correlation was established between the two transducers and electromechanical sensor. The method used can detect without any contact with the patient of the sleep apnea and the breathing rate.

1. Introduction

The cardio-respiratory activity is an important parameter for the observation of the human body activity. A normal adult have a respiratory rate of 12 – 15 breaths/minute in normal conditions, inspiring and expiring 6 – 8 liters of air/minute.

The absence of breathing, apnea, represent the stoppage of the air flow which passes throw the nose or throw the oral cavity to pass to the lung, for an interval longer than 10 seconds. It is difficult to forecast the absence of the breathing which can be deathly in a few minutes. The mortality caused by the acute cardio respiratory diseases or the absence of breathing is significant, counting that the absence of the normal cardiac activity during the sleep phase can be also preceded or combined with the absence of breathing.

The monitoring and detection of some cardio -respiratory abnormality presents interest in some situation, the most important is the one for the patients from intensive therapy, of new born babies, and premature born babies of patients from pharmacotherapy with sedatives who can decrease the reflexes, of the performance sportive, for the sleep study, etc.

Few clinical aspects are relevant for cardio-respiratory monitoring.
- after anesthesia, both the respiratory centre and the respiratory muscles can be affected, leading to a rise in the CO$_2$ concentration and a drop in the O$_2$ concentration;
- another clinical situation that affect respiratory activity is the sedation of the patients during the examinations such us magnetic resonance imaging;
- also, certain psychiatric or psychological conditions, such us claustrophobia, anxiety, pain, can affect respiratory rate and the SaO$_2$ value during medical examination;
- patients with trauma or severe infections who seem to have normal blood pressure and even heart rate can suddenly presents a rise of respiratory rate;
- another aspect, preterm infants needs continuously respiration monitoring to decide when they need the mechanical ventilation.

In some ways, the qualified personal can be a good human observer, intelligent, adaptive, and even "ideal monitor" of cardio respiratory activity, technology independent and immune to certain disturbances. But, the human observer is subjective and practically impossible to audit; the result is not always accurate. Observing the movement of the abdomen and thorax, the clinical estimation is subjective. Also, the estimation methods for respiratory gas exchange by observing skin color variations are even more imprecise and subjective. Hence, the necessity of monitoring equipment is obviously in order to supply precise information and to minimize the rate of the false alarms or false non-alarms.
2. Clinical monitoring methods

Actually, the monitoring of cardio respiratory activity is made by the direct contact with the patient by placing the respiratory abdominal and thoracic sensors (strain gauge, capacitive sensors for movement), pulse (photo-plethysmograph or pulse oxymeter) and for the detection of the heart bioelectric activity are used skin electrodes connected to an ECG monitor.

Concerning the methods and respiratory monitoring activities devices for different physiological parameters, reported in the literature, three categories of sensing principles are further presented and described.

There can be detected the following parameters:
- the movement and the thorax and abdomen volume, with sensors placed on the human thorax or abdomen;
- airflow detection, with sensors placed in front of the nose and the oral cavity;
- the detection of the composition of the gases from the blood, using sensors for detecting the concentration of gases from the blood.

For applying these methods are used the following techniques:

1. Movement, volume and tissue composition detection, the used methods in this category are: the trans-thoracic impedance monitoring with skin electrodes on chest, inductance plethysmography using embedded coils around abdomen and chest, the strain gauge transducers by using resistive strain gauge around abdomen and chest, the mutual inductance method by using magnets on chest, the microwave method by using a microwave sensor, the by electromyography by using skin electrodes, the photopletysmography by using fiber optic sensors,

2. Airflow sensing can be detected because the expiratory air is warmer, has higher humidity and contains more CO\textsubscript{2} than inspiratory air. The methods used in the airflow sensing are: the temperature sensing by using temperature sensors, the humidity sensing by using hygrometer or fiber optic sensor in or in front of nose/oral cavity.

3. Blood gas measurement can be made by pulseoximetry, transcutaneous CO\textsubscript{2} measurement by using chemical sensors.

3. Experimental setup

The installation for the comparative study of three types of transducers for detecting the respiratory activity is presented in figure 1. We used two news types of movement transducers – with microwaves and ultrasounds:
- Doppler movement transducer with microwaves;
- Movement transducer with ultrasounds;
- Transducer type resistive belt as a reference element.

Figure 1. Experimental installation for the study of the cardio respiratory activity with non contact transducers.

The proposed method is the use of ultrasounds and microwaves.

The use of ultrasounds in non-contact monitoring equipments of the respiratory activity is adequate because the ultrasounds are easy to generate and detect, their wavelength is relatively small compared to the thorax movement during a respiratory rate, their low energy and without negative consequences on the monitored subject.

Based on the ultrasound interference has been developed a device that could be used for the non-contact respiratory rate monitoring especially in the most difficult situation such as the prediction of apnea episodes. The method is noninvasive, without contact, without dangerous radiations, and the device is easy to manipulate.

The Doppler movement transducer with microwaves can detect record and interpret the signals produced by the cardio respiratory activity. The method is noninvasive, without contact, without any risks, allowing also the separation between the signals from the cardiac activity and the signals caused by the respiratory activity. The transducer with microwaves uses the Doppler effect for detecting the complex movements made by the anatomical structures of the thorax and abdomen, caused by the cardio respiratory activity.

As a reference, the respiratory activity is recorded using a transducer type resistive belt fixed on the circumference of the thorax. This is the fourth channel for measuring and allows the achievement of some information regarding the amplitude and frequency, and also the records of the apnea after expire or inspire.

4. Experimental results

We made simultaneous records for both transducers using the resistive belt as reference.
In Figure 3 we represent the signals collected by three transducers. The signals have been acquired by Data Acquisition card DAS 1601 type connected by PC. After that, the signals are processed.

![Figure 3](image)

**Figure 3.** B – Doppler microwaves, C – ultrasonic interferometer D – resistive belt.

In Figure 4 are presented, separately, the signal generated by interferometer by using the reference signal generated by ultrasound interferometer and reference signal (D-resistive belt) for 7 respiratory cycles. We remark the signal generated by the ultrasound interferometer that have two components: an oscillatory one and a slow variable one. This fact can be explained by slow movement of the subject’s thorax during the experiment and the coming back of that on initial position after that. We can remark that the resistive belt reference transducer doesn’t detect this movement.

![Figure 4](image)

**Figure 4.** C – ultrasonic interferometer, D – resistive belt

In Figure 5 we showed the correlation function between the two signals: the reference and the ultrasound.

![Figure 5](image)

**Figure 5.** The function of correlation between ultrasound signal and reference signal.

The apparition of a signal due to forced apnea made by a subject is detected by the ultrasound sensor immediately after apnea installing.

Partially, some record is affected by external noise and by this reason they are difficult to predict and to eliminate. We propose to use wavelet transform domain filtering technique as an adaptive design tool for de-noising.

5. Conclusion

The two non-contact and noninvasive methods allow the respiratory activity detection cheaper than ordinary monitor.

The sound and microwaves methods permit the detection of the apnea stage.

The signal generated by Doppler transducer is a signal that has a frequency that depends on the speed movement made by thorax and abdomen.

The signal generated by ultrasound interferometer is dependent on moving of the anatomic structures during a respiratory cycle.

The signal filtering is easy to made using analogical and digital methods. The apnea stage can be detected by detection of absence of the signal due to thorax and abdomen move.

In order to eliminate the noise and to create an easier way to interpret the signals, an autoregressive model will be used by synthetic reconstructed signal based on wavelet coefficients. Using this method, the artifacts and external noise will be removed.

References

1. M. Folke et all, Critical review of non-invasive respiratory monitoring in medical care, Medical &

3. *** Class II Special Controls Guidance Document: Apnea Monitors; Guidance for Industry and FDA U.S. Department Of Health and Human Services Food and Drug Administration Center for Devices and Radiological Health, 2002

4. *** Cardiorespiratory Events Recorded on Home Monitors Comparison of Healthy Infants With Those at Increased Risk for SIDS, JAMA, May 2, 2001—Vol 285, No. 17 2199-2208


