Bioacoustic techniques is applicable to primary health care

Per Ask, Peter Hult, Tore Fjällbrant and Bengt Wranne
Departments of Biomedical Engineering and Clinical Physiology and
Competence Center for Non-invasive Medical Measurements
Linköping University, Sweden

Abstract - **The stethoscope has been used diagnostically for nearly two hundred years to assess the heart function. We can envision the *intelligent stethoscope* which combines the advantages of the traditional instrument with advanced functionality for analysis of the signal and other information support. The bioacoustic technique is basically simple and robust and fits therefore into a scenario where investigations are performed in a distributed health care system as in primary health care or even home health care. We have focused on detection of respiratory sounds and third heart sounds. The later is performed with a new wavelet technique which makes it possible to automatically detect and identify the sounds and possibly relate them to myocardial insufficiency**.

I. INTRODUCTION

Sound can be defined as a physical phenomena which has a close relation to a body in a state of vibration. These vibrations can propagate from the source and can be picked up by a microphone.

Bioacoustics can be defined as the use of acoustic methods to monitor or diagnose human functions - for example the circulation [1].

The main criteria for our research can be derived from the above definitions:
The body sound should be considered as a reflection of the mechanical process which produces the sound. It conveys a message in the form of a mechanical fingerprint indicating the state of the process, which in turn gives a clinical indication of the health status of the patient.

Bioacoustic technique has a long period of clinical use. The bioacoustic breakthrough was 1816 with the invention of the stethoscope by Renné Laennéc. This instrument has become one of the most commonly used instrument in medical care. By including a microphone we obtain a sensor instrument that is basically simple and robust and fits very well into a scenario where investigations are performed in primary health care or even home health care.

The advantage of modern signal processing tools and modern computer technology, together with the old knowledge of auscultation, acquired over many years, makes it possible to develop a new bioacoustic instrument for auscultation, *the intelligent stethoscope*, which also can be used in a networked telemedicine environment.

The aim of our research on bioacoustics is:

1. To obtain knowledge about sound originated in the human body, e.g. the special features of the sounds and the pathological connections of the sounds.

2. To develop tailored signal analysis procedures from which the bioacoustic signal can be used for monitoring purpose or for diagnosing a pathological condition.

3. To take advantage of powerful computers, on which the bioacoustic signal can be analyzed, at a low cost. This makes it possible to suggest that the technique could also be applied in the broader field of primary health care.

In this we see the vision of the Intelligent stethoscope.

II METHODS AND RESULTS

Most of our bioacoustic research has been concentrated in two fields: respiratory sounds and heart sounds. In particular, we have studied the characteristics of the respiration sound in order to develop a method for timing the start and stop of inspiration and expiration. Another area of special interest has been the study of the third heart sound, in order to describe its characteristics, and to find methods for automatic detection of this sound.

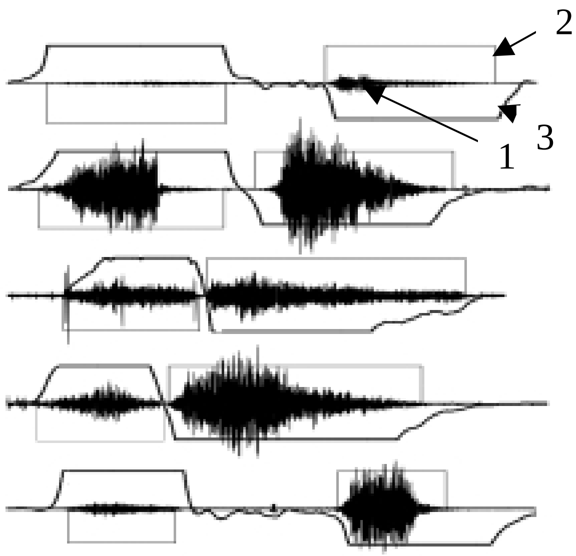
Automatic timing of respiration phases
The aim of this work was to describe a method for respiration monitoring, and where the start and stop of the respiration phases can be timed accurately [2,3]. A microphone applied over the trachea measures respiratory airflow. The airflow is turbulent and give rise to vibrations. This method is therefore a direct method to detect flow. The features of the frequency content of the respiration sounds were utilized.

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle Bioacoustic Techniques is Applicable to Primary Health Care	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Departments of Biomedical Engineering and Clinical Physiology and Competence Center for Non-Invasive Medical Measurements Linkoping University, Sweden	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)
Distribution/Availability Statement Approved for public release, distribution unlimited	
Supplementary Notes Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom.	
Abstract	
Subject Terms	
Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU
Number of Pages 4	

The time position of the different respiration phases can be determined by a time resolution of 50 ms, Fig. 1. The developed algorithm could accurately



detect and separate inspiration and expiration.

Fig. 1. Timing and monitoring of the respiration signal. The microphone signal (1), the timing/monitoring signal (2) and the reference Fleish signal (3).

Automatic detection of the third heart sound
The third sound of the heart occurs at the time of rapid diastolic filling of the left ventricle. The rapid filling-phase begins when the AV-valves open and blood can pass the valve and enter the ventricle. After a short time the inflow decreases and at this point in time the third heart sound can be heard. The most accepted theory suggests that the third heart sound emanates from vibrations in the left ventricle wall. The sudden resistance causes the mass of the ventricular walls to vibrate which seems sensible from a physics perspective. The 3rd sound is clinically important because of its established connection with heart failure/myocardial insufficiency.

A tool for the automatic detection of the third heart sound would therefore appear to be valuable as a help for analysis of the phonocardiogram. Examples of phonocardiograms with first, second and third heart sounds are shown in Fig. 2.

Analysis of the phonocardiogram shows that the features of the third heart sound are low amplitude, short duration and low frequency content. This means that it is very difficult to auscultate the sound with an ordinary stethoscope, even for trained physicians.

The automatic method for the detection of the third heart sound [4] was based on the knowledge of the features of this sound. Our choice of method was the wavelet transform. The main advantage of the wavelet technique is the possibility for obtaining both time and frequency information from the signal at the same time, which is suitable for analysis of transient components in signals. This would appear particularly suitable for the analysis of the third heart sound.

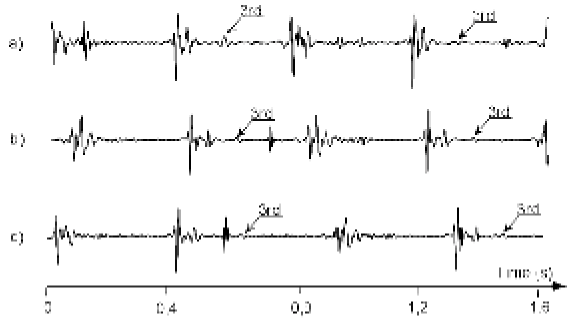


Fig. 2. Three examples of phonocardiograms with 1st, 2nd and 3rd heart sounds included.

To solve the problem with detection of the third heart sound, a tailored wavelet-based method was developed [5]. This method uses a specially developed tailored mother wavelet, Fig. 3.

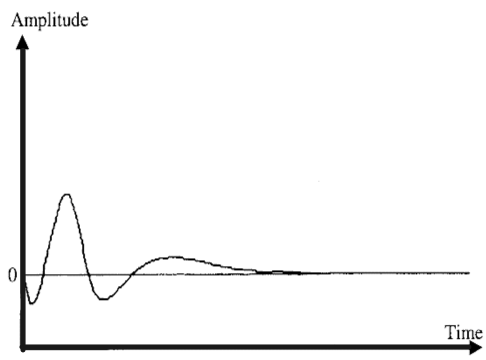


Fig. 3. Mother wavelet för the analysis of the 3rd heart sound.

This mother wavelet is the impulse response from a Bessel filter with properties which give an impulse response with similar features to those of the third heart sound. The wavelet analysis of the phonocardiogram shows that the third heart sound has a lower frequency content as compared with those of the first and second sounds, Fig. 4.

The method is based on the separation of the phonocardiogram into four frequency bands, 17, 35, 60 and 160 Hz, in which the components from the first, second and third heart sounds reflect in different ways. The algorithm checks for peaks in those frequency bands that correspond to the sounds and can, by means of a set of conditions, decide whether a peak corresponds to the third heart sound or to either the first or second sounds. A schematical description of the method is given in Fig. 5.

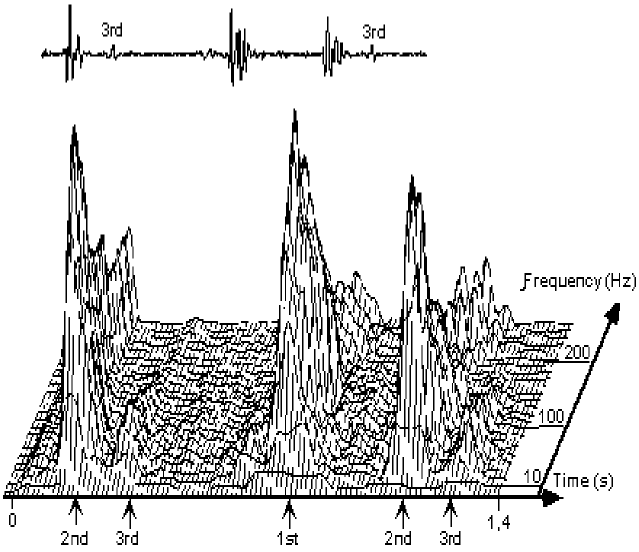


Fig. 4. Wavelet analysis of the phonocardiogram

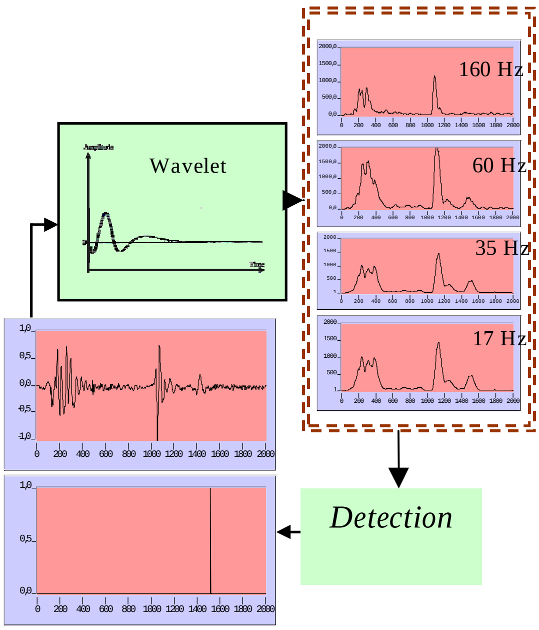


Fig. 5. Illustration of system for detection of the 3rd heart sound in phonocardiograms.

This method has been developed from a study of children and verified at a patient study with patients with severe myocardial insufficiency. The method has been shown to be capable of detecting the majority of the third heart sounds.

III. DISCUSSION

The stethoscope has for a long time been one of the most important clinical instruments, and auscultation is probably the most common method for diagnosis in primary health care. The development of the stethoscope, and related bioacoustic techniques, has not made any considerable progress when seen in relation to the broad use of this method. Bioacoustic methods have now reached a stage where it is possible to develop what is in reality a new and modern instrument, which incorporates the auscultation experience from long clinical practice in an “intelligent stethoscope”. This new instrument has the potential to include booth advanced signal analysis of the bioacoustic sounds and decision support.

We have so far focused on bioacoustic techniques for detection of respiration and for identification of the third heart sound. We can therefore monitor respiration but there is also a potential to use respiratory sound diagnostically in a similar way as the physician does when he identify e.g. pneumonia or obstructive disease. The idea with detection the third heart sound is to relate it to myocardial insufficiency. However, an intelligent stethoscope approach can be used as a generalized workbench for phonocardiography.

The intelligent stethoscope is suitable for telemedicine applications when connected to a network. The bioacoustic signal can be recorded locally. The advanced signal processing that detects and classifies the heart sounds is offered centrally and can be available as a service obtainable over the internet. The signals from the patient and the electronic stethoscope are transferred using a webb protocol to the analysis center, from which processed information is returned. The central facility will be able to offer a sophisticated processing and interpretation system that is continuously updated. The central location can also include consultation of a medical specialist.

REFERENCES

[1] Ask P, B Hök, D Loyd, H Teriö: Bioacoustic signals from stenotic tube flow. Med & Biol Eng & Comp 33: 669-675, 1995.

[2] Hult P., Ask P., Wranne B. A bioacoustic method for timing of the different phases of the breathing cycle and monitoring of breathing frequency. Medical Engineering & Physics. 2000a. 22:425-433.

[3] Hult P., Fjällbrant T., Dahle S., Danielsson P., Ask P. A method for respiration monitoring by the use of a bioacoustic signal. International conference

on advances in medical signal and information processing (MEDSIP). Bristol UK. 4-6 september. 2000b. 22-25.
[4] Hult P., Fjällbrant T., Wranne B., Ask P. Detection of the third heart sound using a tailored wavelet approach. Submitted 2001

[5] Hult P., Fjällbrant T., Wranne B., Ask P. Method and system for detecting abnormal components of a body sound signal. Patent application Nr. 9904381-2. ,1999