THE 21st
INTERNATIONAL CONFERENCE
ON LUNG SOUNDS

第 21 回国際肺音学会

Presented by

The International Lung Sounds Association

September 4-6, 1996

Chester, England

S. Kudoh.
Japan.

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FINAL PROGRAM AND ABSTRACTS

21st INTERNATIONAL CONFERENCE ON LUNG SOUNDS

Chester, England September 4 - 6, 1996

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PREFACE

1976 Boston, MA

1977 Cincinnati, OH

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1989 Winnipeg, Canada

1990 New Orleans, LA

1991 Verona, Italy

1992 Helsinki, Finland

1993 Calgary, Canada

1994 Haifa, Israel

1995 Long Beach, CA

1996 Chester, England

Welcome to the 21st Annual International Lung Sounds Conference. We are looking forward to having you here. At the first meeting, the objectives of the conference were stated as follows:

''Studies of lung sounds have been reported with increasing frequency in recent years. This conference is convened to provide an opportunity for exchange of ideas and experience among those who have an active interest in the subject. Clinicians, physiologists, engineers and perceptual psychologists can each contribute towards a better understanding of what lung sounds mean. They will have a better chance of doing so after talking together.

We hope that comparisons of methods of recording, analyzing and describing lung sounds will reduce ambiguity. We hope that discussions about work in progress may prevent unnecessary duplication of effort. We hope that investigators will save time and and avoid some mistakes by learning what others have done.''

While considerable progress has been made in these areas, much remains to be done to achieve our overall goal of improving noninvasive diagnosis via the improved understanding of respiratory acoustics. We hope you enjoy the meeting.

John Earis
Robert Loudon
Ray Murphy

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Makoto Yonemaru	Tokyo, Japan

21ST INTERNATIONAL LUNG SOUNDS CONFERENCE

Chester, England   September 4-6, 1996

Wednesday, September 4

1:00 - 2:00	Lunch Available	
2:00 - 3:00	Registration	
3:00 - 5:00	Workshop -- The International Lung Sounds Association: Coming of Age Past History, Future Direction	
6:30	Reception and Welcoming Address	

Thursday, September 5

8:15	Coach from Moat House, Chester to Liverpool Medical Institute	
8:55	Welcome	

Session A

Dr. Steven Kraman & Dr. Noam Gavriely, Chairmen

9:00 - 9:20	Measurements and Theory of Normal Tracheal Breath Sounds	Gavriely
9:20 - 9:40	Origin and Significance of Tracheal Sound Spectral Features	Kraman
9:40 - 10:00	The Measurement of Acoustic Impedance of Lung Parenchyma at Low Frequencies	Leung
10:00 - 10:20	Respiratory Sound Generation and Transmission During Induced Airway Narrowing	Pasterkamp
10:20 - 10:40	*Coffee Break*	
10:40 - 11:00	A Study On The Placing of the Inspiratory Crackles in the Flow-Volume Plane	Vannuccini
11:00 - 11:20	"Pendelwheeze" Case Observations on	Pasterkamp

	Wheezing During Breath Hold	
11:20 - 12:00	Talk - The Sound of Sleep	Calverley
12:00 - 12:20	Photo	
12:20 - 1:30	*Lunch*	

Session B

(Instrumentation)

Dr. Filiberto Dalmasso & Dr. Hans Pasterkamp, Chairmen

1:30 - 1:50	A New Versatile PC-Based Lung Sound Analyzer With Automatic Crackle Analysis (HeLSA)	Sovijarvi
1:50 - 2:10	SIDS Wireless Acoustic Monitor	Rusin
2:10 - 2:30	Effects of Finger-Stiffness on the Frequency Characteristics of a Hand-Held Stethoscope	Sakao
2:30 - 2:50	*Break*	
2:50 - 3:20	TALK - Comparison of Air Coupled and Contact Sensors for Lung Sound Measurement	Wodicka
3:20 - 3:40	A Prototype System for Studying Lung Sound Microphones	Lipponen
3:40 - 4:00	Characterisation of Pre-Filter Response for Lung Sounds Measurements	Sun
4:00 - 4:20	Computerized Respiratory Sound Analysis (CORSA); Techniques, Standardization and Clinical Evaluation - An European Community Concerted Action Project	Sovijarvi
4:20	Discussion of CORSA Project - Workshop	
6:15	Visit to Liverpool Cathedral	
7:30	Drinks, Reception followed by Dinner Liverpool Maritime Museum, Albert Docks	
11:00	Coach to Chester	

Friday, September 6

Session C

(Monitoring) Disease Detection

Dr. Shoji Kudoh & Dr. Sadamu Ishikawa, Chairmen

9:00 - 9:20	Detection of Mild Airway Narrowing in Children Based on Spectral Characteristics of Normal Lung Sounds	Takase
9:20 - 9:40	Sonagram-Based Automatic Wheeze Detection Method	Waris
9:40 - 10:00	Computerized Lung Sound Analysis As An Indicator of the Need for Endotracheal Suctioning in Mechanically Ventilated Patients	Schmelz
10:00 - 10:20	*Coffee Break*	
10:20 - 10:40	Non-Invasive Diagnosis of Chronic Obstructive Pulmonary Disease Utilizing Multi Channel Lung Sound Analysis	Murphy, M.
10:40 - 11:00	Characteristics of Lung Sounds in Patients with Pneumonia and Congestive Heart Failure	Murphy, R.
11:00 - 11:20	The Analysis of Upper Airway Sounds By Inverse Filtering	Plante
11:20 - 11:40	Discrimination of Productive Cough and Non-Productive Cough By Sound Analysis	Murata
11:40 - 12:00	Oral Flow Transducers Can Modify Breath Sounds Spectrum	Dalmasso
12:00 - 1:30	*Lunch*	
1:30 - 2:00	Business Meeting	

Session D

Dr. Masashi Mori & Dr. John Earis, Chairpersons

2:00 - 3:00 Poster Discussion

Digital Recording and Computer-Based Analysis of Lung Sounds	Schuettler

Classification of Fine and Coarse Crackles		Brown
Nocturnal Asthma Assessed By Intermittent Sleep Trachael Sounds Recording		Kiyokawa
Observer Variability in Chest Auscultation		Parziale
3:00 - 3:20	Lung Sounds Visualized by Symmetrized Dot Patterns (SDP)	Davidson
3:20 - 3:40	Cough Sounds Spectra in Asthmatics: Steroid Effects	Ishikawa
3:40 - 4:00	Measurement and Analysis of Spectral Respiratory Sound in Healthy Chinese Part One in Youths - 122 Students	Tan BIN-Yong
4:00 - 4:20	Respiratory Auscultatory Skills Among Internal Medicine and Family Practice Trainees: A Comparison of Diagnostic Proficiency	Mangione
4:20 - 4:30	Closing Remarks	
4:30 - 5:00	Conference Summary - Robert Loudon, M.D.	

5:00 Steering Committee Meeting

Wilmot Ball, M.D.
David Cugell, M.D.
Filiberto Dalmasso, M.D.
Noam Gavrielly, M.D.
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21ST INTERNATIONAL LUNG SOUNDS CONFERENCE

SESSION A

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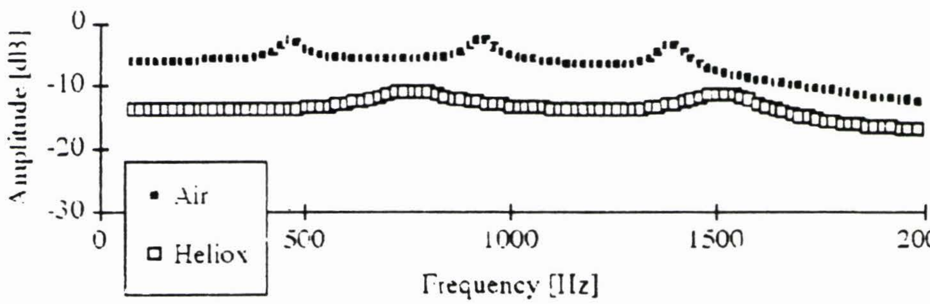
12:00 - 12:20	Photo	
12:20 - 1:30	*Lunch*	

MEASUREMENTS AND THEORY OF NORMAL TRACHEAL BREATH SOUNDS

Noam Gavriely, Raymond Chow, Muhammad Mahagnah, and David. W. Cugell

Department of Physiology and Biophysics, Bruce Rappaport Faculty of Medicine and Institute, Technion, Haifa, Israel 31096; and the Anesthesia Department, and the Pulmonary Division, Department of Medicine, Northwestern University Medical School, Chicago Illinois, 60611

We studied the mechanisms by which turbulent flow induce tracheal wall vibration, perceived and detected as tracheal breath sounds (TRBS). The effects of flow rate and gas density on TRBS were measured in 10 normal subjects, and the transfer function (TF) of supraglottic (SG) and tracheal (TR) sounds during breathing and during oral noise application were measured in 6 additional subjects. We found that normalized TRBS were proportional to flow to the 1.75±0.17 power irrespective of gas density, were lower in amplitude during 80-20% He-O_2 breathing than during air breathing by a factor of 0.39±0.13, equivalent to the He-O_2/air density ratio, and had resonances at frequencies that were higher during He-O_2 than during air breathing by a factor of 1.6 - the square root of the reciprocal density ratio. Expiratory TF had significantly higher coherence (0.67±0.17) than inspiratory coherence (0.43±0.09), and was similar in shape to the transmitted sound TF. Both inspiratory and expiratory TR spectra had lower amplitudes than SG spectra, (0.37±0.19 and 0.44±0.25, respectively), but expiratory spectra had significantly more prominent resonance peaks. We conclude that TRBS are generated by intratracheal pressure fluctuations with two components - a local turbulent eddy component proportional to flow to the 7/4 th power and to gas density, and a transmitted acoustic component with resonance frequencies determined by the upper airway length and by the speed of sound. The likely location of TRBS generation is in the upper airway, mouthward to the supraglottic area from where sound waves propagate retrogradely to the trachea during expiration and turbulent eddies get carried with the in-flowing gas during inspiration.



Predicted spectra of normal tracheal breath sounds during air and Heliox breathing.

ORIGIN AND SIGNIFICANCE OF TRACHEAL SOUND SPECTRAL FEATURES

Steve S. Kraman, M.D.[1], Hans Pasterkamp, M.D.[2], Martin Kompis, M.D., Ph.D.[3], Masato Takase, M.D., Ph.D.[2] and George R. Wodicka, Ph.D[3]

VA Medical Center and Univ. of Kentucky, Lexington, KY, USA[1], University of Manitoba, Winnipeg, Canada[2] and Purdue University, W. Lafayette, IN, USA[3]

Spectral analyses of breathing sounds recorded over the trachea typically reveal two or three peaks in the vicinity of 700 Hz and 1500 Hz. In this study, we investigated the source of these peaks and the conditions that contribute to their presence. Materials and Methods: We studied five adult subjects (4 male, 1 female) with normal lung function. Sounds were measured at the suprasternal notch and on the right cheek (2 cm from the lips) using contact sensors (Siemens EMT25C). While sitting in a sound-proof chamber, the subjects breathed at target airflows of 15 ml/s/kg and at 30 ml/s/kg as measured with a pneumotachograph, first through the mouth with nose clips attached and then via the nose using a cushioned face mask. The mouth breathing maneuvers were performed sequentially with three different lengths (3.6, 21.1, 38.6 cm) of 2.6 cm diameter tubing between the mouth and the pneumotachograph. The nose breathing maneuver was also performed with the longest tube (between the mask and pneumotachograph). The acoustic signals were digitized at 10,240 samples/second after amplification and low pass filtering (8th order Butterworth, 2.5 kHz cutoff frequency) and data at target flows ±20% tolerance were used in the spectral estimations via 2048 point FFTs with 50% overlap of adjacent 200 ms segments. Results: All subjects had two predominant spectral peaks; a ~700 Hz peak loudest over the trachea and a ~1500 Hz peak loudest over the cheek. The frequency of both peaks negatively correlated with body height (and presumably, airway length). There was no systematic effect of breathing phase (inspiration v. expiration) or of the length of the tube connecting the mouth to the pneumotachograph on the two predominant spectral peaks. However, the power of tracheal sounds at frequencies above roughly 1000 Hz increased significantly when the subjects breathed through the mask and nose compared with breathing through the mouth without the mask. Conclusion: The lower tracheal sound spectral peak appears to reflect resonance within the major airways and is relatively independent of extrathoracic influences. This indicates that the acoustic behavior of tracheal sounds is not explained by a simple tube model. The effect of the breathing route illustrates a significant influence of the vocal tract configuration on tracheal sounds.

The authors acknowledge the generous support of the Department of Veterans Affairs, the Children's Hospital of Winnipeg Research Foundation, the National Science Foundation, and RESONEX INTERNATIONAL.

THE MEASUREMENT OF ACOUSTIC IMPEDANCE OF LUNG PARENCHYMA AT LOW FREQUENCIES

A.H. Leung and S. Sehati
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Headington, Oxford OX3 0BP, UK

Previous workers have demonstrated that sound propagation characteristic of the human lung is frequency dependent [1,2]. A frequency dependent model could help elucidate this behaviour. This however requires a thorough knowledge of the characteristics of the elements within the model.

The proportion of sound energy transmitted across a boundary between two acoustic media is a function of the ratio of the acoustic impedance of the media. The acoustic impedance of lung parenchyma is therefore an important parameter to investigate.

This paper investigates the feasibility of using a two-microphone transfer function method for the acoustic impedance measurement of lung parenchyma at low frequencies (100-500 Hz). A loudspeaker was used to issue sound at one end of a 1.6 meter long tube at the other end of which the specimen under test was placed. Two microphones were placed apart inside the tube and flush with the inner surface of the tube. The impedance of the specimen was then calculated by measuring the transfer function of the sound pressure between the two microphones with the aid of a FFT analyser.

Our findings suggest that both the microphone spacing (T) and the distance between the nearest microphone and the specimen under test (h_b) are crucial to the accuracy of the results. For accurate measurement h_b and T should be equal to a quarter of the wavelength of the generated sound.

[1] Leung A and Sehati S, *Sound transmission through normal and diseased lungs*, IEE Journal of Engineering Science and Education, Volume 5 Number 1, 1996
[2] Jackson A.C., et al.. *Density dependence of respiratory system impedances between 5 and 320 Hz in humans*, J. Appl. Physiol. 67(6): 2323-2330, 1989

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Oral presentation is preferred and an overhead projector will be required

RESPIRATORY SOUND GENERATION AND TRANSMISSION DURING INDUCED AIRWAY NARROWING

H. Pasterkamp,[1] M. Takase,[1] M. Kompis[2] and G. R. Wodicka,[2] University of Manitoba,[1] Winnipeg, Canada, and Purdue University,[2] West Lafayette, USA

Characteristic changes in lung sounds occur during airway obstruction induced by bronchial provocation. Attention has therefore been drawn to the potential diagnostic use of respiratory sound measurements. However, little is known about the mechanisms of sound generation and transmission during airway narrowing. We studied normal respiratory sounds and acoustic transmission during a standardized methacholine challenge (MCh) in five male volunteers with asthma, ages 10 to 19 y. Fourteen microphones (Sony ECM155, conical coupler with diameter 10 mm, depth 2 mm) were attached over homologous sites of the chest in the front and back and one tracheal microphone was placed at the suprasternal notch. Subjects breathed at target flows of 15 ml/s/kg. Recordings of respiratory sounds and of transmitted broad band noise, introduced at the mouth, were made in a sound proof chamber at each step of the MCh and after subsequent bronchodilation. Fourier analysis of sounds at target flow ± 20% tolerance provided average spectra for inspiration and expiration. Spectra of background noise were obtained during breath holding. Preliminary analysis of sounds at the trachea, the anterior and posterior right upper lobe, and the posterior basal right lower lobe showed the following results: A) power of inspiratory tracheal sounds at medium (P_{med}: 300 to 600 Hz) and high frequencies (P_{high}: 600 to 1200 Hz) increased by 7 ± 4 dB and 8 ± 4 dB (mean ± SD), respectively, during maximal airway narrowing ($\Delta maxFEV_{1.0}$ = -27 ± 15%); B) P_{med} and P_{high} of expiratory lung sounds increased at most chest wall sites and measured +7 ± 4 dB and +5 ± 4 dB, respectively, at the most consistent (right posterior lateral base) site; C) all subjects showed these changes even if $FEV_{1.0}$ decreased less than 20% (n = 2); D) improvement of lung function after bronchodilator was not necessarily accompanied by a return of lung sound spectra to baseline; E) sound transmission to the chest wall sites relative to the trachea at $\Delta maxFEV_{1.0}$ did not change significantly: -3 ± 4 dB at P_{med} and 0 ± 2 dB at P_{high} over the posterior lateral base; F) comparison of sound transmitted during breath hold and during breathing showed that the magnitude of sound transmission at medium and high frequencies could be estimated during expiration. This may facilitate clinical studies in untrained subjects who often find it difficult to keep the glottis open during breath hold. In summary, altered regional flow patterns and sound generation rather than alterations in acoustic transmission appear to be responsible for the changes in lung sounds during induced airway narrowing.

Support by the following institutions is gratefully acknowledged: the Children's Hospital of Winnipeg Research Foundation (H.P., M.T.), the Nippon Medical School, Tokyo, Japan (M.T.), the Swiss National Research and Roche Research Foundations (M.K.) and the National Science Foundation (G.R.W.)

A STUDY ON THE PLACING OF THE INSPIRATORY CRACKLES IN THE FLOW-VOLUME PLANE

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In this study we present some observations coming from the analysis of inspiratory crackles in patients with Pulmonary Fibrosis (4), Bronchiectasis (3) and COPD (1). The relationships among their position in breath cycle and the corresponding flow (at the mouth) and volume were studied. In particular, the possibility to place crackles in the flow-volume plane without loss of information was investigated. In fact, in this plane the temporal parameters are not represented.

The linear correlation among flow, volume and time have been investigated by Pearson's R. Principal Component Analysis (PCA) was also performed to verify the effective dimensionality of these data.

The results show a strong correlation among time of occurrence (T) and volume (V) in all cases we examined. In some cases there is also a good correlation between T and flow (F) and between F and V. It is not possible to give some interpretations of these last results since the samples are few and not homogeneous. From these results we can only say that T and V are highly correlated. This means that they give the same information. Therefore, crackles can be observed on the flow-volume plane. PCA shows that the multidimensional datum (T,F,V) is really a bidimensional one.

"PENDELWHEEZE"
CASE OBSERVATIONS ON WHEEZING DURING BREATH HOLD

Hans Pasterkamp and Masato Takase
Dept. of Pediatrics, University of Manitoba, Winnipeg, Canada

Wheezing is a clinical sign of airway flow obstruction and is typically found during both respiratory phases. Critical air flows and transpulmonary pressures are required to generate wheezing during forced expiration. We present observations on wheeze recorded at the chest wall during zero air flow at the mouth. **Case 1** is a 19 year old male subject with asthma who developed wheeze during a standard methacholine challenge (11% decrease in $FEV_{1.0}$). Respiratory sounds were recorded at 14 sites over both lungs and showed wheeze of 0.9 sec duration during breath hold only at the left upper lobe posteriorly (Fig.1, arrow). **Case 2** is a 12 year old boy with asthma, studied with the same protocol during methacholine challenge. At maximum bronchoconstriction (26% decrease in $FEV_{1.0}$) there was wheeze during the diastolic filling of the heart, detected only at the left anterior upper chest (Fig.2, arrow). **Case 3** is a 14 year old boy, presenting with acute asthma to the emergency room. Lung sounds were recorded over the right posterior lower lung and showed wheezing during inspiration, continuing into expiration (Fig.3a). Wave-form analysis (Fig.3b) shows the wheeze without interruption but with an increase in frequency during expiration. We suggest that pendelluft, or the flow of air between adjacent lung units with greatly different time constants, could explain our observations. In the second case, the effect of cardiac volume change on the adjacent lung is a likely mechanism of regional flow generation, known to also affect normal lung sounds in this region. To our knowledge, case 3 is the first objective documentation of wheeze that spans continuously across both respiratory phases. It can be assumed that small airways and low airflows are involved in the cases of wheeze presented herein. Detailed observations on wheeze characteristics may therefore help to define the predominant sites of airway obstruction in asthma.

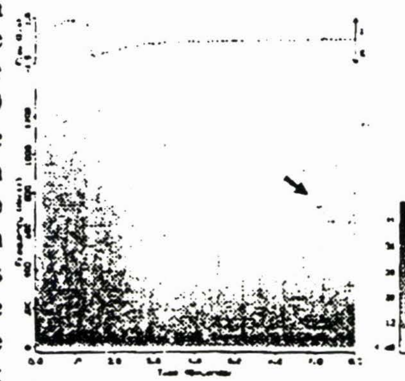

Figure 1

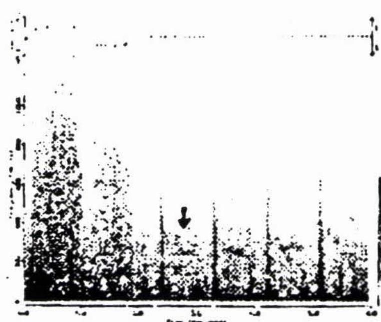

Figure 2

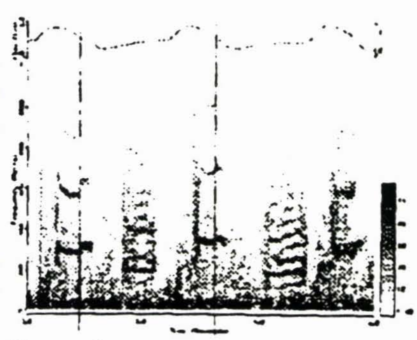

Figure 3a

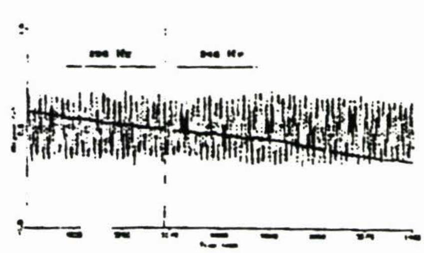

Figure 3b

Supported by the Children's Hospital of Winnipeg Research Foundation (M.T., H.P.) and the Nippon Medical School, Tokyo, Japan (M.T.)

21ST INTERNATIONAL LUNG SOUNDS CONFERENCE

SESSION B

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Session B

(Instrumentation)

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2:10 - 2:30	Effects of Finger-Stiffness on the Frequency Characteristics of a Hand-Held Stethoscope	Sakao
2:30 - 2:50	*Break*	
2:50 - 3:20	TALK - Comparison of Air Coupled and Contact Sensors for Lung Sound Measurement	Wodicka
3:20 - 3:40	A Prototype System for Studying Lung Sound Microphones	Lipponen
3:40 - 4:00	Characterisation of Pre-Filter Response for Lung Sounds Measurements	Sun
4:00 - 4:20	Computerized Respiratory Sound Analysis (CORSA); Techniques, Standardization and Clinical Evaluation - An European Community Concerted Action Project	Sovijarvi
4:20	Discussion of CORSA Project - Workshop	
	Dinner	

A NEW VERSATILE PC-BASED LUNG SOUND ANALYZER WITH AUTOMATIC CRACKLE ANALYSIS (HeLSA)

Sovijärvi A, Kallio K, Paajanen E, Malmberg P, Helistö P, Lipponen P, Piirilä P, Lukkarinen S, Pesu L, Haltsonen S, Saarinen A, Karp P, and Katila T.
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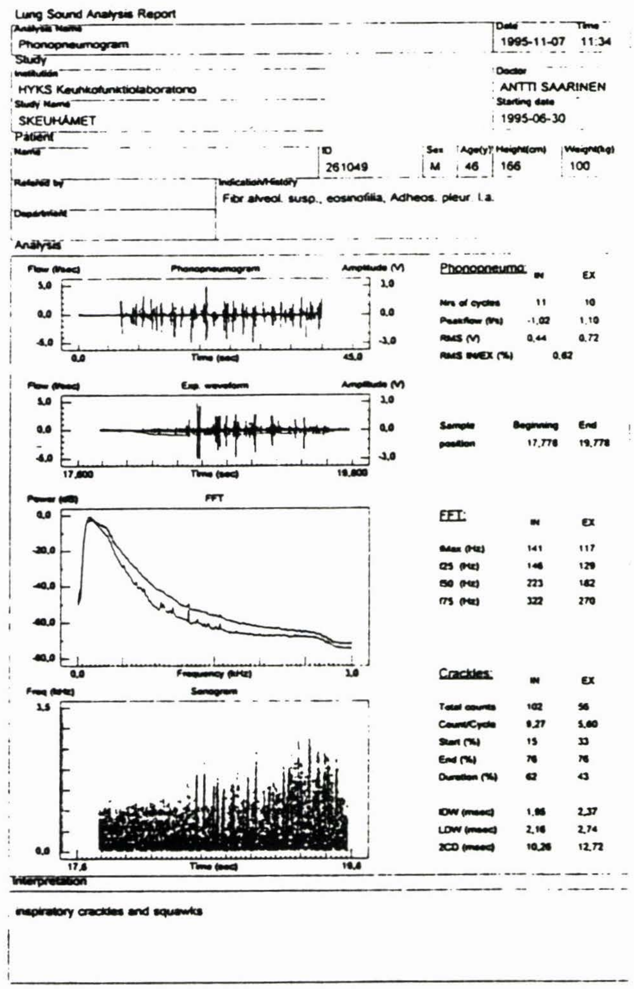
A versatile PC-based lung sound analyzer (HeLSA) has been developed for short-term recording and off-line analysis of breath sounds for research and clinical purposes. For the capturing of breath sounds two types of microphones have been developed and their frequency response characteristics have been tested. The tracheal microphone is an air-coupled electret microphone with an inner diameter/depth of 25/3 mm, sensitivity of 10 mV/Pa, and frequency range of 20 Hz-20 kHz (2 dB). The lung microphone is a larger, air-coupled condenser microphone with an inner diameter/depth of 30/2 mm, sensitivity of 50mV/Pa, and frequency range of 2.6 Hz-20 kHz (2 dB). The airflow at the mouth is measured with a pneumotachograph (Jaeger GmbH, Germany). After adjustable amplification (gain 0-90 dB) and analog high-pass prefiltration at 50 Hz, the signals in both channels are sampled at the rate of 6 kHz (16 bits). The system includes a signal processor with an antialiasing filter with a cut-off frequency at 2700 Hz. High-pass filtering at 80 Hz (24 dB/oct) is accomplished by the software.

The computer is an IBM compatible PC, Pentium 90 MHz/32 MB RAM. Data storing can be accomplished to an optical disk. For monitoring an 16 inch SVGA screen is used and a bubble jet printer or a laser printer for printing the documents. The software of HeLSA has been programmed by using Visual Basic and Labview and includes programs for graphical user interface, recording, analysis, data base and reporting. Monitoring of air flow and volume, phonopneumogram and audio control of the sound signals are accomplished on-line. The following analyses can be performed immediately after recording: phonopneumogram, expanded waveform analysis, FFT-analysis with averaging possibilities, sonagraphic analysis, automatic detection and analysis of crackles and flow volume spirometry. The following parameters can be measured, calculated and reported: peak tidal flow, sound amplitude, frequency of maximum intensity and quartile frequencies. The software includes automatic detection of crackles (Kaisla et al. Med Biol Eng Comput 1991;29:517) and a program for interactive verification of the crackles by using expanded waveform display. The following crackle characteristics can be measured and reported: number of crackles/cycle, starting point of crackles, end point of crackles, duration of crackling in a respiratory cycle, initial deflection width, largest deflection width, and two cycle duration. An example of the automatic report printout is presented in the figure.

With the analyzer several hundred patients and subjects have been studied. The sensitivity of the microphones meet well the needs for good signal capturing and the program is easy to use by doctors and technicians.



SIDS Wireless Acoustic Monitor (SWAM)

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Abstract

Sudden Infant Death Syndrome (SIDS) is the leading cause of death for infants. Current methods of monitoring respiration and pulse of sleeping infants use traditional transthoracic impedance monitors placed on the patient with adhesive. Using Acoustic Pad technology, rapid Computer Aided Prototyping, and Digital Signal Processing, this research demonstrates the use of Acoustic Pads to monitor patient vital signs in a wireless fashion.

The main problem addressed by this research is the development of a software interface and prototype for the Acoustic Monitoring Pad hardware developed by the U.S. Army Research Laboratory using the Computer Aided Prototyping System (CAPS), of the U.S. Naval Postgraduate School to create the SWAM (SIDS Wireless Acoustic Monitor) that eliminates the use of the adhesive electrodes, and monitors patients via the cardiac and respiratory sounds of the patient, in a "wireless" method.

The approach taken was to use an iterative requirements development process involving users and implementing changes to the requirements as development progressed.

The results demonstrate that by using the iterative design approach and by using CAPS, in less than eight months a prototype can be created that validates the acoustic pad concept.

EFFECTS OF FINGER-STIFFNESS ON THE FREQUENCY CHARACTERISTICS OF A HAND-HELD STETHOSCOPE

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Abstract

A simple model for a stethoscope (or sensor) of air-coupled-microphone type held by human fingers onto skin is devised.

Results of analysis show that elastic supporting may seriously alter the frequency characteristics of the stethoscope. In the absence of such support, the response is that of a conventional second order system, with a resonance peak. With the elastic support by fingers added, the following two alterations take place.

First, the response level at sufficiently low frequencies is higher than the response at medium range frequencies up to the resonance peak. The difference depends on the ratio of masses of the sensor-container and the skin covered by it, and can amount to as much as 10 dB's.

Second, there is a couple of resonance peak and anti-resonance valley at the transitional zone between the "low-end" and "medium" frequencies. The exact locations of the peak and valley depend on the exact value of the stiffness of the finger support, and their amplitudes depend on damping property of the support. Although those values are not definitely known at present, requiring further investigation, it is quite possible that the above mentioned effects may have serious influences on the signal obtained with a sensor of such a type.

Key Words: Hand-held stethoscope, Frequency characteristics, Stiffness of finger

A PROTOTYPE SYSTEM FOR STUDYING LUNG SOUND MICROPHONES

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A prototype system is developed for measuring the frequency response of lung sound microphones under realistic conditions [1]. The equipment consists of a PC, DSP card, the measuring bench, and microphone and audio amplifiers.

The bench is composed of two boxes on top of each other with a middle range loudspeaker in between. Sound is transmitted from the loudspeaker to the upper cavity and an artificial tissue. The microphone to be measured was attached against the artificial tissue.

Frequency responses were measured by feeding a white noise signal to the bench and by calculating the FFT power spectrum of the registered microphone signal. Because the frequency response of the bench is not flat, it's only possible to compare microphones to some reference (or to each others). Six lung sound microphones and a laser vibrometer, which detected the surface motion of the tissue, were used to study the bench, and the results for two of them are shown in Figs. 1-2.

It was observed that there are large differences between the lung sound microphones and that the biggest differences were between air coupled and contact sensors. The results obtained here have already been useful in microphone development. As lung sound analysis becomes a more and more standardized technique, the need for objective microphone test equipment increases.

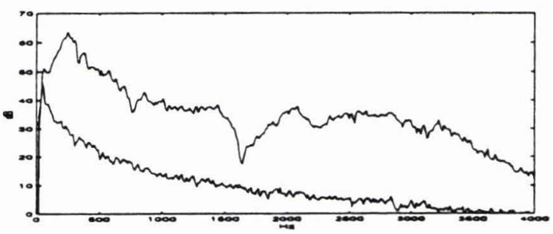

Figure 1: Frequency response of the Pulmer lung microphone [2]. The lower curve is the background spectrum.

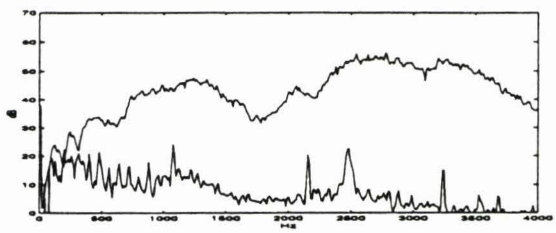

Figure 2: Frequency response of the 1" Haifa contact sensor [3].

[1] P. Lipponen, V. Halla, P. Helistö, "A Prototype System for Calibration of Lung Sound Microphones: Analysis of 6 Microphones", 2nd CORSA WPIII Symposium on Signal Prosessing in Lung Sounds, June 1996, Helsinki.

[2] A. Sovijärvi, K. Kallio, E. Paajanen, P. Malmberg, P. Helistö, S. Haltsonen, T. Katila, "A new versatile PC-based lung sound analyzer (HeLSA)", 2nd CORSA WPIII Symposium on Signal Prosessing in Lung Sounds, June 1996, Helsinki.

[3] N. Gavriely, "Phonopneumography Contact Sensor", 15th International Conference of Lung Sounds, October 1990, New Orleans.

CHARACTERISATION OF PRE-FILTER RESPONSE FOR LUNG SOUNDS MEASUREMENTS

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Abstract

Much of the knowledge of lung sounds has been gained by using wide variety of data acquisition, filtering , amplification and digitisation techniques. It has not always been the practice to fully document the techniques and the precise characteristics of the equipment being used. Indeed, in some cases, some of these characteristics may have been difficult to ascertain, and some of these difficulties may continue to exist with current equipment.

A problem arises with the characterisation of the frequency responses of the analogue pre-filters which precede the digitisation process. This filtering may be realised partly by components on a commercial acquisition card and partly by custom designed external analogue equipment. For various reasons, the precise details of the pre-filters may not be known, and may even be variable due to, for example, temperature variations, impedance matching and programmability.

The low-pass anti-aliasing filter characteristics are not likely to be critical, especially when a sampling rate is used which is high enough to allow a relaxed specification. However, it is the practice, particularly when analysing adventitious lung sounds, to include a high-pass analogue filter, with cut-off frequency typically between 50 and 100 Hz, to remove heart sounds and extraneous microphone pick-up which could otherwise cause non-linearities due to overload and amplifier clipping. The effect of the high-pass filter may be considerable. The gain response will strongly affect spectrographs, for example. Also, non-linearities in the phase response will effect the time domain waveshapes and this may affect measurements made, for example, of crackles .

The lung sound researcher therefore needs a means of measuring and documenting the frequency response particularly of the high pass filter. A calibration procedure is required which is easily carried out using laboratory equipment readily available to all researchers. The frequency response must be determined solely from the response of the pre-filters to some agreed analogue test signal. This pre-filter response will be in digitised form stored in a computer file. The test signal itself will be assumed not to be available because digitising it would require a second channel with its own filtering effects. The test signal can therefore be specified only in general terms and its exact nature must be deduced from the stored digitised response of the pre-filter.

Four possible solutions to this problem have been investigated: the swept sine-wave method, the step response method, the square-wave response method and the swept square-wave response method. These methods are evaluated and compared, and their relative advantages and disadvantages are outlined. It is concluded that the prefilter characteristics can be successfully ascertained without the need for sophisticated laboratory equipment.

Computerized Respiratory Sound Analysis (CORSA); Techniques, Standardization and Clinical Evaluation - an European Community Concerted Action Project

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*) Project Leader, Lab. of Clinical Physiology, Dept. of Medicine, Helsinki University Central Hospital, Helsinki, Finland
**) Work Package Leaders

CORSA is a concerted action of project of EC (BIOMED 1). It has been started on the first October 1994 to be continued for 28 months. The total economic contribution from EC is 260.000 ECU. Thirteen research centers from seven European countries: Belgium, Great Britain, Finland, France, Germany, Italy and the Netherlands, are participating the project which contains four major objectives and work packages (WP).
The purpose of the project is to produce guidelines for standardization and to enhance the development of computerized respiratory sound recording and analysis methods. The work packages of CORSA are:

WP1) Standardization of lung sound recording and analysis. (WP leader Ass. Prof. Jan Vanderschoot, Leiden). The objective is to produce and publish guidelines or recommendations for standards of respiratory sounds recording and analysis. This is the main objective of CORSA. The strategic purpose of WP1 is to obtain the necessary means for comparison of conclusions and outcomes of respiratory sound analysis techniques and research projects. The activities in WP1 have been divided into 8 subprojects, each one dedicated to a coherent set of topics. 1. Definition of Terms (subgroup Leader F. Dalmasso), 2. Respiratory Sounds Capturing and Analogue Preprocessing (L. Vannucini, Siena), 3. Minimal Data Sets (G. Righini, Torino), 4. Experimental Conditions (M. Rossi, Arona), 5. Digitization of Data (B. Cheetham. Liverpool), 6. Validation Methods of Analysis Techniques (A. Giordano, Veruno), 7. Report Contents and Form (P. Piirilä, Helsinki), 8. Basic Standards of Analysis (G. Charbonneau, Paris).
WP2) Computerized stethoscope and long-term monitoring of lung sounds .(WP leader Dr. John Earis, Liverpool). The objective is to assess how a computerized stethoscope may be developed by surveying the current European activity for measurement and long-term monitoring of lung sounds.
WP3) Signal processing and diagnostic feature extraction. (WP leader Dr. Panu Helistö, Helsinki).The aim is to provide a comparison of the applicability of modern digital signal processing techniques to automatic analysis of respiratory sounds.
WP4) Reference values and clinical validation. (WP Leader Dr. Filiberto Dalmasso, Torino). The objectives are:
1. to provide a proposal of recommendations for making "reference values" of respiratory sounds and 2. to evaluate the collected respiratory sound data to characterize the patterns of abnormality of lung sounds in clinical syndromes.

The deliverables of CORSA will be published guidelines, recommendations and survey reports in European Respiratory Journal (ERJ) or European Respiratory Review (ERR). The CORSA-project has been accepted as a Task Force of the European Respiratory Society.
The project has progressed almost as proposed in the original time schedule. The second draft of the guidelines for standardization is at present under revision and will be sent to the International Lung Sound Association for evaluation.
The draft report of WP2, a survey of computerized stethoscope and long-term monitoring of lung sounds in Europe will be ready in September 1996. Within the frames of WP3, signal processing and feature extraction of respiratory sounds, two scientific symposia under the title Signal Processing in Lung Sound Analysis have been organized in Helsinki, the first in June, 1995 and the second in June, 1996. The papers of the first symposium have been published in the Report Series of Helsinki University of Technology (Report TKK-F-C170, ISSN 0358-0741). Revised papers of the symposia will be published in an issue of Technology and Health Care by the European Society of Engineering and Medicine (ESEM)

The task of WP4 of CORSA, to provide guidelines how to produce reference values of respiratory sounds is, as well as the tasks of WP1 (standards) and WP2 (devices) essential for a future task to create European reference values of respiratory sounds in healthy non-smoking and smoking populations.

21ST INTERNATIONAL LUNG SOUNDS CONFERENCE

SESSION C

21ST INTERNATIONAL LUNG SOUNDS CONFERENCE

Chester, England   September 4-6, 1996

Session C

(Monitoring) Disease Detection

Dr. Shoji Kudoh & Dr. Sadamu Ishikawa, Chairmen

9:00 - 9:20	Detection of Mild Airway Narrowing in Children Based on Spectral Characteristics of Normal Lung Sounds	Takase
9:20 - 9:40	Sonagram-Based Automatic Wheeze Detection Method	Waris
9:40 - 10:00	Computerized Lung Sound Analysis As An Indicator of the Need for Endotracheal Suctioning in Mechanically Ventilated Patients	Schmelz
10:00 - 10:20	*Coffee Break*	
10:20 - 10:40	Non-Invasive Diagnosis of Chronic Obstructive Pulmonary Disease Utilizing Multi Channel Lung Sound Analysis	Murphy, M.
10:40 - 11:00	Characteristics of Lung Sounds in Patients with Pneumonia and Congestive Heart Failure	Murphy, R.
11:00 - 11:20	The Analysis of Upper Airway Sounds By Inverse Filtering	Plante
11:20 - 11:40	Discrimination of Productive Cough and Non-Productive Cough By Sound Analysis	Murata
11:40 - 12:00	Oral Flow Transducers Can Modify Breath Sounds Spectrum	Dalmasso
12:00 - 1:30	*Lunch*	
1:30 - 2:00	Business Meeting	

DETECTION OF MILD AIRWAY NARROWING IN CHILDREN BASED ON SPECTRAL CHARACTERISTICS OF NORMAL LUNG SOUNDS

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Characteristic changes occur in the spectra of normal lung sounds during induced airway narrowing even in the absence of wheeze. These changes are reversible by bronchodilator inhalation. To investigate the diagnostic value of lung sound measurements without bronchial provocation we studied children who were referred for assessment of pulmonary function. Forty five subjects were initially enrolled but 15 were excluded because spirometry was not sufficiently reproducible. Of the remaining 19 boys and 11 girls (ages 7 to 17 years), 15 had diagnosed and 15 had suspected asthma. Lung sounds were recorded with two accelerometers (EMT-25C, Siemens) at the right upper anterior (RUA) and the right lower posterior (RLP) lobe. Subjects breathed at a target flow of 15 ml/kg/s and then held their breath for a few seconds at resting end-expiration. Recordings were made three times, before and after baseline spirometry and 15 min after salbutamol (200µg) inhalation. Flow and sound signals were digitized at 10 kHz. On subsequent computer analysis, visual and auditory verification was used to avoid inclusion of wheezes and artifacts. At least 20 spectra each of sound within 20% of target flow were averaged for inspiration, expiration and breath holding. After subtraction of background noise from lung sounds, the power in three octave bands (P_{low}: 150 to 300 Hz, P_{med}: 300 to 600 Hz, P_{high}: 600 to 1200 Hz) was determined for each respiratory phase and site of recording. The 50th and 99th percentile of power distribution within the 150 to 1200 Hz range were identified (F_{50}: median frequency and F_{99}: spectral edge frequency). Power ratios between P_{low} and P_{med} (P_{low}/P_{med}) and between inspiration and expiration (I/E-P_{low} and I/E-P_{med}) were also calculated. Lung function tests before and after salbutamol inhalation detected 18 (60%) of 30 subjects with mild to moderate abnormalities. Only 14 (78%) of these 18 children were identified on baseline spirometry without measurement of airway resistance and conductance or bronchodilator response. Abnormalities in four acoustic parameters (inspiratory F_{99} and P_{high} at RLP, inspiratory F_{50} and I/E-P_{low} at RUA), predicted abnormal lung function with 89% sensitivity and 92% specificity. Abnormality was defined as values outside the normal range (mean ± 2SD) established from 12 subjects with normal lung function. Our findings indicate that most of the lung function abnormalities in non-wheezy asthmatic children may be detectable by analysis of normal breath sounds recorded with few sensors while the child breathes at a flow rate only slightly above normal. Considering the easy application and the level of diagnostic accuracy, computerized lung sound analysis is promising as a new tool for pediatricians who often experience difficulties in obtaining reliable information from standard spirometry.

Supported by the Nippon Medical School, Tokyo, Japan (M.T.) and the Children's Hospital of Winnipeg Research Foundation (M.T., H.P.)

SONAGRAM-BASED AUTOMATIC WHEEZE DETECTION METHOD

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A new automatic wheeze detection method is presented here [1]. The method is based on image processing techniques applied to the sonagram. In the calculation of the sonagram, FFT and AR spectrum estimation methods are compared. Edges are detected in the sonagram by using two Sobel operators [2], and peaks are found between upward and downward edges. A labelling algorithm [2] is then applied to identify the connected components. Information about the strength and duration of a wheeze is used to form a criterion for true wheezes. At the end, broken wheezes are connected with the help of a connection algorithm.

The method was validated by a pulmonary physician in four wheezing asthmatic patients and four control subjects. The lung sounds were recorded from the chest with a PC-based lung sound analyzer [3]. Nine out of ten wheezes longer than 250 ms were detected in the FFT-sonagram, and all ten wheezes were found in the AR-sonagram. However, the harmonic frequencies were detected better in the FFT-sonagram. Very short wheezes (squawks) were not detected as well. The false positive amount of wheezing in control subjects was only 1%. An example of the validated results is shown in Figure 1.

The new wheeze detection method finds wheezes varying in frequency with good accuracy. The method also extracts useful information about the frequency, duration and associated flow and volume of the wheezes. It can therefore be a useful tool for pulmonary physicians.

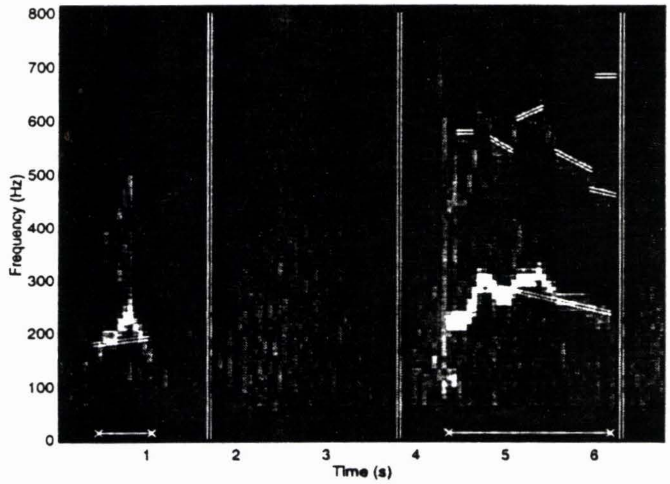

Figure 1: *Detectected wheezes in a FFT-sonagram (FFT-length = 512 points, overlap = 35 %, sampling rate = 6 kHz). The end points of the wheezes are connected with double lines. Vertical white lines show the boundaries of inspiration and expiration. The single horizontal lines at the bottom of the sonagram show the validation results of a pulmonary physician.*

[1] M.Waris, S.Haltsonen, P.Helistö, A.Saarinen, A.Sovijärvi, "A method for automatic wheeze detection", 2nd CORSA WPIII Symposium on Signal Processing in Lung Sounds, Helsinki (1996).

[2] M.Sonka, V.Hlavac, R.Boyle, *Image processing, analysis and machine vision*, Chapman & Hall Computing, London (1993).

[3] A.Sovijärvi, K.Kallio, E.Paajanen, P.Malmberg, P.Helistö, S.Haltsonen, T.Katila, "A new versatile PC-based lung sound analyzer (HeLSA)", 2nd CORSA WPIII Symposium on Signal Processing in Lung Sounds, Helsinki (1996).

COMPUTERIZED LUNG SOUND ANALYSIS AS AN INDICATOR OF THE NEED FOR ENDOTRACHEAL SUCTIONING IN MECHANICALLY VENTILATED PATIENTS

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The purpose of this study is to extend prior research on the role of adventitious lung sounds as an accurate indicator of the need for endotracheal suctioning (ETS) in adult patients requiring mechanical ventilation and endotracheal intubation. Prior research has demonstrated a link between the presence of adventitious lung sound and secretions in the tracheobronchial tree.

We used a Multi Channel Lung Sound Analyzer (MCLSA) to study the pattern of adventitious lung sounds present immediately before and following endotracheal suctioning and compared sounds to the volume of tracheobronchial secretions aspirated by ETS. Repeated measurement of 15 patients was made when the patient's primary nurse indicated the need for suctioning.

There was no consistent pattern of lung sounds prior to suctioning. Five types of adventitious lung sounds were identified; rhonchi, wheezes, crackles, type II rhonchi and coarse sounds. There was a 14% reduction in the occurrence of adventitious lung sounds after suctioning and coarse sounds decreased in duration after suctioning in most patients. There was no relationship between lung sounds and the volume of aspirate obtained or the reason the nurse gave for suctioning the patient.

This study failed to support the association between rhonchi and tracheobronchial secretions obtained by blind suctioning which may be an unreliable method of measurement. Further study utilizing specific disease categories, direct visualization and localization techniques is necessary to establish when and if ETS should be done.

NON-INVASIVE DIAGNOSIS OF CHRONIC OBSTRUCTIVE PULMONARY DISEASE UTILIZING MULTICHANNEL LUNG SOUND ANALYSIS

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To determine whether objective pattern differences exist in Chronic Obstructive Lung Disease (COPD) we studied 24 patients with this diagnosis and 23 elderly volunteers using a Multichannel Lung Sound Analyzer (MCLSA). Realistic microphones embedded in the chest pieces of 3M cardiac stethoscopes were used to collect data from over the trachea and from 24 chest sites at the posterior and lateral bases bilaterally.

Patients had a clinical diagnosis of COPD and spirometric evidence of obstruction {FEV 1% Predicted (P) = 19% to 68%}. All volunteers denied clinical history of significant lung disease and had normal spirometry (FEV 1% P = 76% to 155%).

Length of inspiration (I) and length of expiration (E) were measured and the ratio of I/E calculated (R1). The R1 was significantly different between COPD and volunteer group (t = 4.4, p = <01). Differences between mean inspiratory time in the COPD and volunteer groups were significant (t = 3.2, p = <01); expiratory time was not different.

R2, the multiple of R1 and amplitude of the sounds over the chest wall during inspiration was calculated and showed significant differences between groups (t = 4, p = <01). Regression of R2 on FEV 1% P indicates a low explained variance (R-squared =.37). Crackles, wheezes and rhonchi were not significantly different in the two groups, but this may reflect the age of the subjects and other health conditions.

Lung sound patterns that exist in COPD patients were significantly different from elderly volunteers in this study.

CHARACTERISTICS OF LUNG SOUNDS IN PATIENTS WITH PNEUMONIA AND CONGESTIVE HEART FAILURE

R. Murphy, M. Murphy, K. Bergstrom and M. Jean

Congestive Heart Failure (CHF) and Pneumonia (PN) are among the most common causes of acute illness requiring hospitalization. While the diagnosis of these conditions is often easily made, many patients present with nonspecific findings such as dyspnea, cough, chest discomfort and atypical roentgenographic shadowing, the cause of which is unclear. We studied the lung sounds of 6 patients with PN and 6 patients with CHF to determine if the patterns of their lung sounds were different. Sounds were examined at 24 chest sites and over the trachea using a multichannel lung sound analyzer, as previously described.(1) Results are presented in the following table:

	PN	CHF
Duration of Inspiration in msec	871 (217)	1124 (350)
Duration of Expiration in msec	1252 (310)	1869 (851)
Ratio (I/E)	.706 (.128)	.513 (.115)
Inspiratory Crackles:		
Fine	3	1
Medium	22	13
Coarse	31	9
TOTAL Inspiratory	56	23
Expiratory Crackles:		
Fine	0	2
Medium	4	3
Coarse	4	15
TOTAL Expiratory	8	20
TOTAL CRACKLES	64	43
Insp. Crackles, Left	44	11
Insp. Crackles, Right	11	11
Rhonchus: Inspiration	1	0
Expiration	4	1
Wheezes: Inspiration	2	1
Expiration	2	2

Numbers in parenthesis are standard deviations.

As seen in this table, this pilot study of a small number of patients, those with CHF tended to have a longer expiratory phase and relatively more crackles in expiration. Pneumonia patients had more crackles in inspiration and they were more asymmetric in their distribution. This suggests that lung sounds pattern differences exist that may be helpful in the differential diagnosis of these conditions. We believe that the additional study of lung sounds in such patients is warranted.

(1) Murphy M., Schmelz J.O., Murphy R.L.H., Characteristics of Lung Sounds in Chronic Obstructive Lung Disease, American Journal of Respiratory and Critical Care Medicine, April 1996: Vol 153:4 p.A322.

THE ANALYSIS OF UPPER AIRWAY SOUNDS BY INVERSE FILTERING.

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+ Aintree Chest Centre, Fazakerley Hospital, Liverpool, UK

Abstract

The human mechanism for producing upper airway sounds such as stridor, snoring and speech may be modelled as an excitation sound source coupled to a resonating acoustic tube. The nature of the excitation signal can tell us much about the physical mechanism responsible for its production e.g. vibration of vocal cords, soft palate or pharynx. It is known that abnormalities can be detected by analysing excitation signals extracted from speech for example. The nature of the resonances within the upper airway, being determined by its physical shape, is also likely to have diagnostic value. To extract the excitation signal from sound measured at the mouth, the resonances introduced by the upper airway and other spectral colouration due, for example, to lip radiation, must be cancelled out. This is possible using a time-varying digital filter whose parameters are periodically updated by a spectral estimation algorithm. The process of estimating the upper airway resonances and hence cancelling them out is referred to as inverse filtering. LPC analysis is a simple example of an algorithm for the required spectral estimation, and may be used as the basis of more sophisticated techniques.

With current digital signal processing technology, inverse filtering can be readily implemented in real time to produce time-domain or spectrographic displays. We report here preliminary results from two clinical investigations based on inverse filtering.

The first is concerned with a non-invasive method of clinical assessment of the snoring mechanism in patients being considered for treatment by surgery. This method involves the analysis of sustained vowels recorded from patients in sitting and lying postures and comparisons between these sounds. It is believed that abnormality in the upper airway may be detectable as greater than normal differences in the sounds.

The second investigation is concerned with the detection of vocal cord abnormalities which present as hoarse voice. Such abnormalities may be due to laryngeal disease, or the long term effect of inhaled steroids used for the treatment of asthma.

DISCRIMINATION OF PRODUCTIVE COUGH AND NON-PRODUCTIVE COUGH BY SOUND ANALYSIS

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There are two types of coughs, productive and non-productive. The former is caused by the excess of airway secretion. The analysis of cough may provide important clues, not only for the diagnosis, but also for the drug selection. In this study, we compared cough sounds recorded from patients with productive cough due to chronic airway diseases with those of voluntary cough sounds of healthy subjects.

Both cough sounds were recorded on a digital audio tape recorder (SONY TVD-D7) with an electret condenser microphone (Panasonic RP vc3) and analyzed by Sound Scope II (GW Instrument Company, U.S.A.).

Non-productive cough sounds were separable into two phases, while those of productive coughs were separable into three phases. In the second and third phases of cough sounds, overtone structures were observed in the low frequency area of the sound spectrograms. We speculate that these overtones are related to the resonance, or fluttering, of the wall of the airways. In the analysis of productive cough sounds, we noticed prolongation of the duration of the cough sounds and some pulsive components in the second phase.

ORAL FLOW TRANSDUCERS CAN MODIFY BREATH SOUNDS SPECTRUM

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*Instituto Elettrotecnico Nazionale ''Galileo Ferraris'', Torino
Divisione di Pneumologia, Osp., Civ. Arezzo, ITALY

Oral flow is usually measured when the lung sounds are recorded on the chest wall. The aim of this study is to verify if and how much the oral flow transducers modify the recorded breath sounds (tracheal and bronchial breath sounds). These were detected respectively on the sternal notch, right anterior chest, 2nd intercostal space and on the posterior right in the respiratory triangle by an air coupled microphone (ECM144 Sony) and a digital tape recorder (DAT, DA-R100, Casio) with and without oral flow transducer. Two groups (A and B) of four healthy subjects were each instructed to perform maneuvers of slow vital capacity at controlled flow rate (1L/s). Group A used the Fleisch pneumotachograph n.3 (Fenyves & Gut) and Group B used the turbo-digital transducer (Pony, Cosmed). Sounds were analyzed in the frequency domain by Fast Fourier Transform (FFT). The central frequency and the frequencies of given percentiles (25, 50 and 75%) of the spectrum energy have been used for statistical processing of the results:

FLEISH n 3

Parameter (Hz)	Without	With	p
Central Frequency	424 ± 35	325 ± 67	0.04
F 25	283 ± 92	166 ± 55	0.072
F 50	478 ± 61	292 ± 115	0.029
F 75	576 ± 23	448 ± 98	0.172

We found significant differences for inspiratory sounds in the spectral parameters between maneuvers, with and without, only in the tracheal site of recording. In the other sites, the differences are not significant. In Group B we have not found systematic differences in all of the sites, but the spectrum shape differs, particularly at the bronchial site. Even at low flow resistance and at low respiratory flow, the oral flow transducer distorts the spectrum of breath sounds in different ways.

21ST INTERNATIONAL LUNG SOUNDS CONFERENCE

SESSION D

21ST INTERNATIONAL LUNG SOUNDS CONFERENCE

Chester, England September 4-6, 1996

Session D

Dr. Masashi Mori & Dr. John Earis, Chairpersons

2:00 - 3:00	Poster Discussion	
	Digital Recording and Computer-Based Analysis of Lung Sounds	Schuettler
	Classification of Fine and Coarse Crackles	Brown
	Nocturnal Asthma Assessed By Intermittent Sleep Trachael Sounds Recording	Kiyokawa
	Observer Variability in Chest Auscultation	Parziale
3:00 - 3:20	Lung Sounds Visualized by Symmetrized Dot Patterns (SDP)	Davidson
3:20 - 3:40	Cough Sounds Spectra in Asthmatics: Steroid Effects	Ishikawa
3:40 - 4:00	Measurement and Analysis of Spectral Respiratory Sound in Healthy Chinese Part One in Youths - 122 Students	Tan BIN-Yong
4:00 - 4:20	Respiratory Auscultatory Skills Among Internal Medicine and Family Practice Trainees: A Comparison of Diagnostic Proficiency	Mangione
4:20 - 4:30	Closing Remarks	

4:30 Steering Committee Meeting

Wilmot Ball, M.D.
David Cugell, M.D.
Filiberto Dalmasso, M.D.
Noam Gavrielly, M.D.
Sadamu Ishikawa, M.D.
Steven Kraman, M.D.
Shoji Kudoh, M.D.
Robert Loudon, M.D.
Masashi Mori, M.D.
Raymond Murphy, M.D.
Hans Pasterkamp, M.D.
Anssi Sovijarvi, M.D.
S.A.T. Stoneman, M.D.

DIGITAL RECORDING AND COMPUTER-BASED ANALYSIS OF LUNGSOUNDS

F. Schuettler, T. Penzel, P. von Wichert
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Introduction: The clinical value of lung auscultation may be enhanced by digital recording and computer-based analysis. This technique may show variances in different lung diseases with specialized algorithms. Beyond that, it would be an advancement in the medical education to hear and visualize lungsounds on a usual personal computer.

Method: The recording system is based on an analog to digital converter (SORCUS M4/486 and M-AD12-16) and two air-coupled microphone cartridges (Monarch MCE-200). A flow sensor (BiScope) and a pressure transducer (SenSym SCXL004DN) was used for the measurement of ventilation. The system is able to continuously record three channels (two sounds and airflow) with sampling rates up to 11024Hz and 12 bit resolution on a computer harddisk. We used the standard European Data Format (EDF) to enable easier data exchange between working groups. The program manages the transformation of the time series into the frequency domain (FFT) and also can converts any part of the data into WAVE audio files. There are many programs available to work with the recorded data in this standardised form, for example the playing-back of the sound on any multimedia suitable personal computer.

Results: In a preliminary study, we recorded the lung sounds of patient with pneumonia and volunteers with normal lung functions. The differences between normal and pathological lungsounds that were found subjectively with classic auscultation, could also be visualised in compressed spectral arrays.

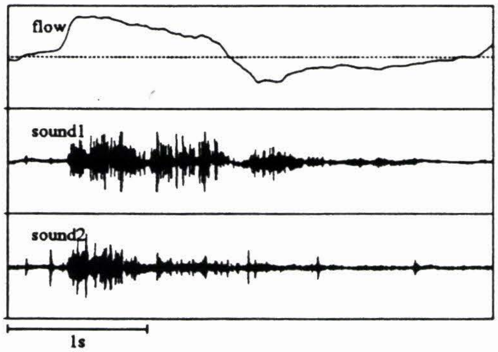

Figure 1: One breathing cycle of an 35 years old patient with pneumonia.

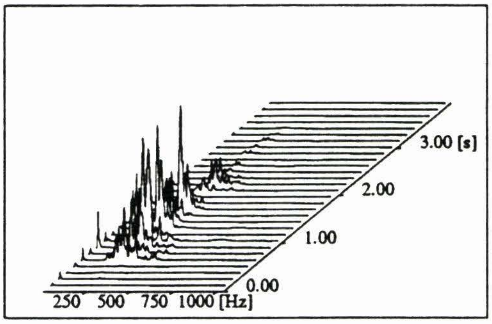

Figure 2: The recording of microphone 1 in the frequency domain (analyse window=0.185s, overlapping=30%).

THE CLASSIFICATION OF FINE AND COARSE CRACKLES USING WAVEIETS AND TIME-FREQUENCY DISTRIBUTIONS

A.S. Brown, Dr. Graham, G. Jamieson, G. Boote, J.L. Moruzzi

Whiston Hospital & Liverpool John Moore's University, UK..

The objective analysis of lung sounds has primarily revolved around spectral analysis. The fast Fourier transform (FFT) and paramethic modelling (PM) have been used successfully to analyze wheeze [1,2], which is a tonal sound with a duration of several seconds. FFT/PM are limited when applied to crackles which have considerably different characteristics to wheezes. This study presents results obtained using novel Wavelet transforms and Time-Frequency distribution techniques which have advantages over the FFT/PM that allow them to be applied to crackles to generate meaningful spectrographs. Parameters extracted from the spectrographs allow crackles to be classified as fine or coarse. Thirteen patients with bronchiectasis/bronchitis or pulmonary fibrosis exhibiting crackles have been studied. The crackles were subjectively classified *a priori* by three experienced chest physicians and then objectively analyzed using the above techniques. A summary of results is shown in the following table.

Parameter (avg breath cycle)	Coarse Crackles	Fine Crackles
Median frequency	294 Hz	386 Hz
Peak power	-21 dB	-24 dB
Bandwidth	149 Hz	246 Hz
Density (crackles breath/cycle)	<13	<24
Proximity of crackles in cycle	Throughout Inspiration	Late Inspiration
Proportion of cycle with crackles	1:36% E:14%	1:61% E:26%

These new techniques have been found to objectively classify coarse and fine crackles based on the parameters extracted above, with greater accuracy and robustness compared to previous work using the FFT/PM. For parameters such as peak power and median frequency, it is not possible to get meaningful results using FFT/PM, and hence, it is difficult to distinguish between coarse and fine crackles. Inter-observer variation and subjectivity are also removed using these techniques. It is envisaged that the methods employed will facilitate the establishment of an objective classification of crackles. The techniques will be of value in both clinical medicine and in education.

References: [1] Spence DPS; *et al.* AJCCM, 1995.
[2] Jamieson, G. Ph.D., University of Liverpool, UK, 1993.

NOCTURNAL ASTHMA ASSESSED BY INTERMITTENT SLEEP TRACHEAL SOUNDS RECORDING

Hiroshi Kiyokawa, Makoto Yonemaru, Ikuma Kasuga, Kazushige Minemura, Hiroshi Kusumoto, Shinobu Horie, Yoko Hiramine, Naoshi Yanagisawa, Yuichi Ichinose and Keisuke Toyama

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Bronchial asthma is known to cause nocturnal bronchoconstriction (nocturnal asthma) or dyspnea early in the morning. The nocturnal attack is important because it is one of the major complaints of asthmatic patients and sometimes causes sudden death. Wheezes detected by intermittent sleep tracheal sounds recording (STSR) were used to assess nocturnal asthma. Forty STSRs were obtained from 28 asthmatics. Ninety percent of these STSRs contained nocturnal wheezes. The number of nocturnal wheezes had a tendency to increase in severe attack compared to that in mild attack. The number of nocturnal wheezes correlated with the patient's perception of severity in asthmatic attack during day time. The number of nocturnal wheezes per hour significantly increased during 5 to 6 AM compared to that during midnight to 1 AM. We conclude that STSR disclosed several characteristics of nocturnal bronchoconstriction in bronchial asthma.

SIDS Wireless Acoustic Monitor (SWAM)

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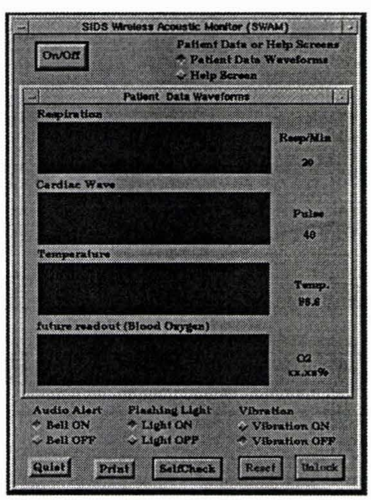
Abstract

Sudden Infant Death Syndrome (SIDS) is the leading cause of death for infants. Current methods of monitoring respiration and pulse of sleeping infants use traditional trans-thoracic impedance monitors placed on the patient with adhesive. Using Acoustic Pad technology, rapid Computer Aided Prototyping, and Digital Signal Processing, this research demonstrates the use of Acoustic Pads to monitor patient vital signs in a wireless fashion. The main problem addressed by this research is the development of a software interface and prototype for the Acoustic Monitoring Pad hardware developed by the U.S. Army Research Laboratory using the Computer Aided Prototyping System (CAPS), of the U.S. Naval Postgraduate School to create the SWAM (SIDS Wireless Acoustic Monitor) that eliminates the use of the adhesive electrodes, and monitors patients via the cardiac and respiratory sounds of the patient, in a "wireless" method.The approach taken was to use an iterative requirements development process involving users and implementing changes to the requirements as development progressed. The results demonstrate that by using the iterative design approach and by using CAPS, in less than eight months a prototype can be created that validates the acoustic pad concept.



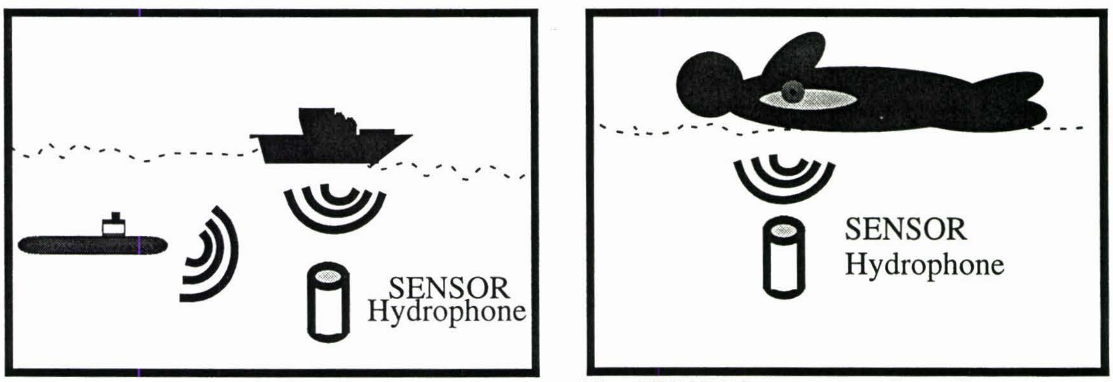
I. INTRODUCTION

A. BACKGROUND

1. General:

This research uses the Software Engineering requirements analysis process to develop the interface for an acoustic cardiac and respiratory apnea monitor called the "SIDS Wireless Acoustic Monitor (SWAM)". It takes the project from user's idea through the design and prototyping process by applying the Computer Aided Prototyping System (CAPS) of the Naval Postgraduate School in the development of the SIDS Wireless Acoustic Monitor (SWAM). This report is a summary of the work done in developing a computer interface for the Acoustic Pad hardware originally designed by Michael Scanlon of the U. S. Army Research Laboratory, Maryland.

This monitor uses a fluid filled pad to as the primary sensor to "listen to" the heart and lung sounds of an infant. Some of the fundamental principals are similar to current technology used in under sea acoustics to listen for and distinguish between different types of ships, submarines, etc. The use of the Acoustic Pad enables the patient to be monitored in a wireless fashion, without the attachment of electrodes to the torso.



Current acoustic monitoring and noise filtering can monitor and differentiate between various sound sources.

The SWAM is an extension of current technology, separating respiratory and cardiac sounds, potentially replacing the traditional impedance monitoring approach.

Figure 1. Illustration of the Overall Acoustic Pad Concept.

2. Definitions:

Sudden Infant Death Syndrome (SIDS): The sudden death of any infant or young child, which is unexplained by history and in which a thorough postmortem examination fails to demonstrate an adequate explanation of the cause of death.

Apnea; Apnea of Infancy (AOI): Cessation of respiratory air flow. An unexplained episode of cessation of breathing for 20 seconds or longer, or a shorter pause associated with pallor, and/or hypotonia. *AOI* is reserved for those infants for whom no specific cause [of respiratory cessation] can be identified [1].

3. General Discussion:

The current method of monitoring respiration and pulse of sleeping infants is to use traditional transthoracic impedance monitors (or "stick-on" electrodes) with wires placed on the torso of the infant. The Sensors Branch of the Army Research Lab is experimenting with the possibility of using a wireless approach to monitor respiration and heartbeat of infants. This approach would remove the electrode wires from the patient and would provide a more convenient method of home apnea monitoring. Currently, they do not have a computer interface or a software requirements model for their acoustic sensor approach. By applying the software engineering approach and using CAPS, we developed the first iteration of a graphical interface for the Acoustic Pad sensor. Promising directions for future research include Digital Signal Processing work to apply noise cancellation techniques to the data received through the hydrophone in the acoustic pad to separate cardiac and respiratory sounds.

E. Scope of Research:

This research uses prototyping and requirements analysis process to take the SWAM system from a user's idea through the design and prototyping process. This enables users to see and comment on a working model of the system before hardware decisions are finalized. This paper is a report of the initial requirements and is intended to stimulate dialogue between parents, technicians and medical professionals to gain feedback regarding the SIDS Wireless Acoustic Monitor. The NPS Computer Aided Prototyping Design (CAPS) is being used to develop the interface to connect the sensors. We are interacting with the potential final users; the parents and medical professionals who are involved with Sudden Infant Death Syndrome, through the SIDS Network, Inc., the California SIDS Program, and through association with the SIDS electronic mailing listserver (sids@eartha.mills.edu) to meet their needs as well. The initial product to be delivered is a model of the SIDS acoustic monitor using CAPS.

F. Approach:

The actual monitor device incorporates a pad type receiver that resembles a typical crib sized mattress pad. A hydrophone sensor placed within the pad feeds input to the monitor in real time. The monitor accepts the sensor data and activates an alarm to alert the nurse or parent in the event of respiratory or cardiac trouble. The CAPS design process allows the rapid development of a workable interface. This project demonstrates the benefit of using the Computer Aided Prototyping System in the development of a real-time, real-life system. Figure 2 shows a very abstract, top level concept of the design.

The device monitors the patient by using a fluid-filled sensor pad placed under the patient to detect pressure fluctuations caused by the acoustic signatures that accompany

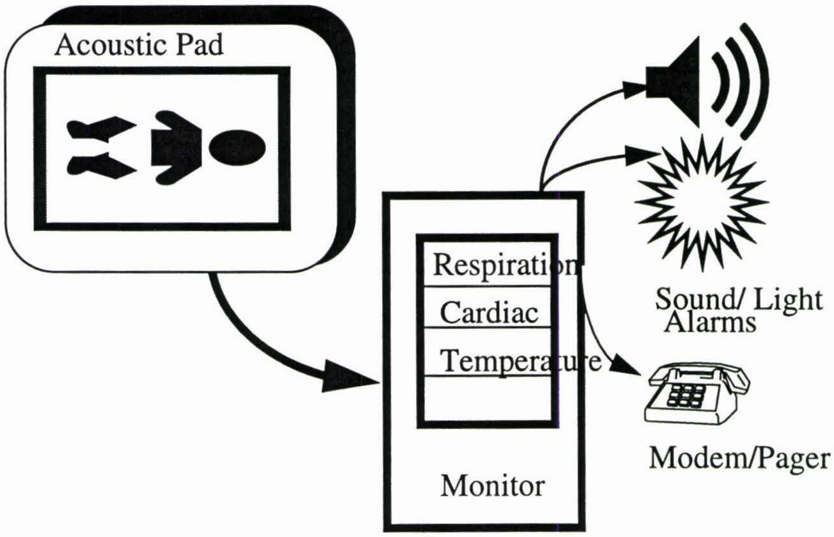


Figure 2. Sketch of Overall Acoustic Monitoring Pad System Concept

normal breathing and heart sounds. The excellent coupling between the human body and the sensor pad gives a high signal-to-noise ratio over ambient sounds. The signals allow medical personnel to detect cessation of breathing, fluid in the lungs, an obstructed airway, or an irregular heartbeat [2].

G. Relevance of Project:

"Sudden Infant Death Syndrome" is the leading cause of death for people under the age of one each year. Each year, 7000 people under the age of one die in their sleep due to unexplained causes, i.e.: autopsies have ruled out suffocation and other possible causes (one death per 500-600 live births). There is currently no "cure" for Sudden Infant Death Syndrome (SIDS).

Home monitoring is used for high risk patients: those who have demonstrated lapses in breathing, or the subsequent siblings of SIDS victims. While home monitoring is not a cure, it is able to alert the parent/caregiver to an episode of apnea or period of cessation of breathing. Medical studies of babies who have lapsed into a period of respiratory cessation show that in some cases, the immediate stimulation with light, sound, and/or vibrations is enough to cause the infant to naturally start breathing again [3]. While this device in no way will take the place of a parent or health care provider, it is meant to assist them in the care and treatment of the infant.

Through contact with physicians involved in SIDS research, we have found that research using a pad oriented approach was done almost twenty years ago, and the technology was abandoned because the devices were not sensitive enough. Advances in computer aided prototyping, acoustic monitoring, digital signal processing and sensor technology over the past twenty years will enable this to approach to become a tremendous aid to infants, parents, and the medical community.

The signal processing applications of the unit will allow physicians to isolate the cardiac and respiratory sounds and focus on either of the particular sounds. It is easy to ask a patient to stop breathing for a short period so that you can listen to only the heart, however it more difficult to stop the heart from beating so that you can listen to lung sounds only. The separation of the two signals will enable physicians to more efficaciously prepare diagnosis and treatment.

Advanced Trauma Life Support (ATLS) applications are one extension of acoustic pad monitoring with future units developed from this research. A crib sized mattress pad can be placed under an adult patient's torso on a standard ambulance stretcher to monitor vital signs. This will enable the medic on the trauma scene to concentrate on other important aspects of patient care without the task of attaching adhesive torso sensors. Any method that allows medical personnel to capitalize on care during the first "Golden Hour" at a trauma scene improve the patient's chance for survival. Noise cancellation techniques can be applied to this project to allow an acoustic monitoring pad to be used during patient transport.

This area of research holds direct relevance to the Department of Defense and the civilian medical community. Remote monitoring features a distinct advantage by alerting attendants via transmitter for remote diagnostics; and by using the acoustic pad approach, this wireless system eliminates the danger of cords entangling or strangling the patient. In medical applications off the battlefield, acoustic data from a patient can be collected and remotely analyzed for indication of cessation of breathing or heartbeat.

Military medical care in the year 2001 will involve telemedicine and telepresence surgery [4,5]. Telepresence surgery will benefit from this technology in at least two major aspects. First, by minimizing time spent on patient preparation prior to battlefield surgery, surgeons will have greater time and flexibility for surgical procedures. Secondly, by removing the adhesive sensor pads and the attached wires from the torso of a patient, the mechanical manipulator arms used in telepresence surgery will not be tangled or otherwise impeded by any wires coming from the adhesive sensors. The acoustic pad would monitor patient vital signs by being placed on the stretcher or operating table under the patient in a non-intrusive manner.

H. RESEARCH QUESTIONS:

This research raises the following questions in the areas of requirements analysis, rapid prototyping, human computer interface, and software/ systems management.

1. Exactly what are the user's requirements and how can CAPS be applied to solve the problem?

2. How do you define and incorporate requirements that arise during the modeling phase or later?

3. How does abstraction aid in the design process?

4. How do you go from an idea to a software design and an interface that accepts an analog data stream from a sensor, or series of sensors?

5. What special concerns does the software engineer of a biomedical application have and how do they affect the design process?

II. REQUIREMENTS ANALYSIS

A. STAKEHOLDERS

1. "Who is the User?":

Before any clear specifications can be outlined, the customer must be identified. To be effective, and serve the complex mix of user requirements in this SIDS Monitor project, we must balance a triad of users and act as Project Managers.

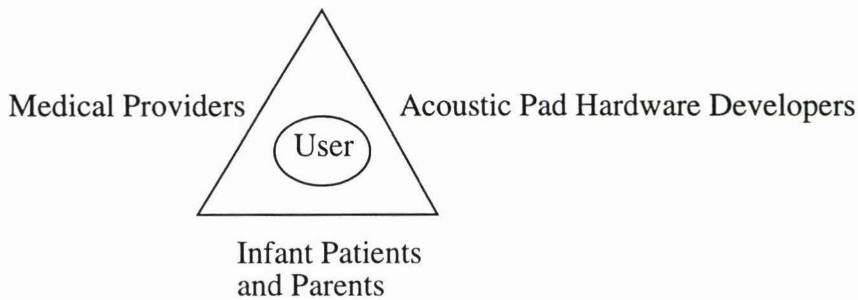


Figure 3. The User Triad

The question of "Who is the user" is difficult to define and the answer incorporates all of the above elements. Each stakeholder group has individual considerations and must be integrated in the best mix to provide optimum performance for all concerned. The design presented here is the first draft of an iterative design process. As routine in a military staff process, the prototype requirement document is being routed through the three "critical edges" of the user triad. Medical input/ comments will be obtained through discussion with members of the SIDS research community, including:

a. Acoustic Pad Hardware Developers.

b. Medical Providers.

c. Parents who are using, or formerly used SIDS monitors representing the Infant Patients.

2. Initial User Input:

We have been in contact with several of the individuals of the groups mentioned above. As this application of biotechnology is a unique area, as are most software engineering projects, we needed to learn a great deal about the current technology and gather a resolution of the user's perspective from the domain experts. Our findings are summarized below in section B.

B. REQUIREMENTS AND DESIGN CONSTRAINTS:

The requirements for a software system are expressed at different levels of abstraction and with different degrees of formality. The highest level requirements are usually informal and imprecise, but they are understood best by the customers. The lower levels are more technical, precise, and better suited for the needs of the system analysts and designers, but they are further removed from the user's experiences and less well understood by the customers. Because of the differences in the kinds of descriptions needed by the customers and developers, it is not likely that any single representation for requirements can be the "best" one for supporting the entire software development process[6]. CAPS provides the necessary means to bridge the communication gap between customers and developers.

The top level goals for the SIDS Wireless Acoustic Monitor are separated into the three corresponding areas:

1. Medical Providers/ Parents considerations:

a. Consistent appearance with current apnea monitors. Several monitors are currently in use, however they are all of the style that use impedance type sensors directly attached to the patient's torso with adhesive. Signals are transmitted via small wires to the monitor. A variety of formats are used, but several models display both cardiac and respiratory data.

b. Ease of use. Instructions should be understandable by a child in grade eight.

c. Self calibrating. The unit must be able to calibrate itself to a series of potential users, each with different cardiac and respiratory patterns. One current monitor (RespriTrace) uses the first five minutes of data collected to establish "normal" thresholds which are unique to that patient. Other self calibration techniques could be used to reduce the number of preparatory steps the provider must accomplish before monitoring.

d. Reliability/ lack of "false alarms": One of the most common complaints about current systems is that there are too many "false alarms" which ultimately reduce the urgency of the caregiver.

e. Cost: The end product should be within a reasonable market price.

f. Event History/ memory: The system should provide a printout or some other reliable history of the entire time monitored.

g. Portable: Final size should be small enough for convenient transport.

2. Infant/ Patient considerations:

a. Non-invasive, non-permanent monitoring: The term "wireless" in this case refers to the approach of collecting cardio-pulmonary data from the patient without attaching any traditional wire electrodes or leads.

b. Position Insensitive: The device must remain accurate regardless of the position of the patient. One of the advantages of the acoustic pad approach is that the device should not have to be "reset" when the patient changes position during sleep.

c. Accurate: The final manufactured product will have to pass FDA approval and as such, must be accurate and reliable.

3. Technical considerations regarding the Acoustic Pad sensor:

a. Signal Processing capabilities: At a very minimum, the monitor must be able to separate the incoming sound signals to differentiate between the cardiac sounds and the respiratory sounds. The initial sensor input is delivered via the hydrophone in the acoustic pad. To graphically display the signals for clarity and diagnosis, the signals must be separated. The separated signals are graphically displayed on the screen in stripcharts similar to a standard EKG strip. This provides consistency and familiarity with current medical devices. By separating the cardiac and respiratory sounds, both cardiac and respiratory specialists can examine the patient's history. The signal processing aspect is treated as an abstract "black box" at the onset of the project.

Data gathered by Scanlon [7,8] shown in figure 4 shows data collected by placing a small monitoring pad under the torso of an adult male lying on a mattress, similar to the method of collection that would be employed for home monitoring, medical transport or hospital monitoring. Heartbeats are clearly visible in the 0-50 Hz region, and the breaths from 0-500 Hz. The inhalation is higher in amplitude than the exhalation for the first two breaths, and the person takes a much deeper breath the third time in anticipation of holding his breath. From the high signal to noise ratio of the breath cycles, with respect to background noise, it is possible to determine of the patient has stopped breathing.

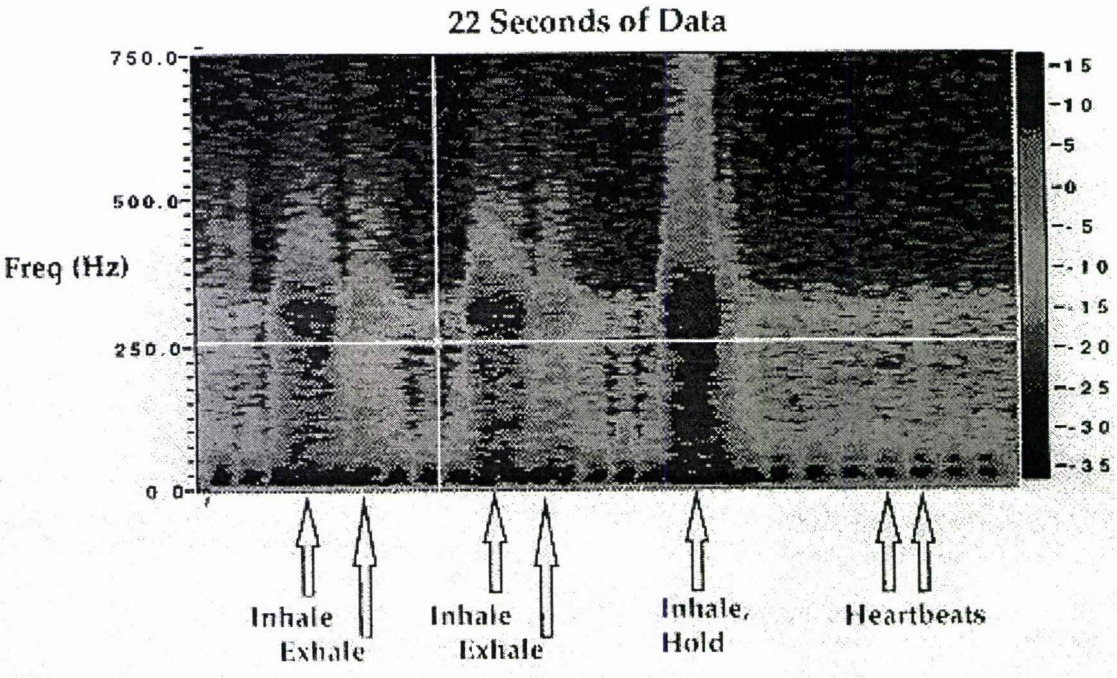


Figure 4. Time-frequency spectrogram of the acoustic sensor pad output.

b. Expandable: The system design should accommodate the addition of other monitoring sensors, i.e.: pulse oxymmetery sensors, temperature sensors, etc.

4. Additional consideration:

One non-trivial factor to be considered is the reluctance of some parents and medical professionals to try a new type of device. Initial response seems to be quite mixed. Many people are reluctant to switch from a known system to a new, experimental prototype. Once the product is developed, the initial research and testing phase would involve simultaneous monitoring with an infant monitored traditionally, while also being monitored via the SIDS Wireless Acoustic Monitor. Because of the non-invasive nature of the device, simultaneous testing should not be a problem. I have received one very encouraging e-mail from a woman who stated:

> "How are you testing the wireless monitors? Have you gotten that far? I would be interested in using one for my next child (I'm hoping to get pregnant soon). Let me know if you will need test subjects in about nine or ten months! Thanks...Sherly"

C. SYSTEM INTERFACE:

The final product that the user of the system will interact with must functionally combine the technical aspects required. The SWAM is intended to be simple enough for home use, while maintaining sufficient technical data for the physician. Figure 5 shows a sketch of the first version of prototype design. Home users will interact with the device via buttons that permit only limited selection of choices, i.e.: On/Off, Print patient data history, Toggle between the patient data waveforms, and a method to silence an audio-visual alarm while continuing to monitor. The monitor's default mode is "On" and always monitoring. The moment a patient lies down on or is placed on the acoustic pad, the monitor begins sampling respiratory and cardiac sounds. A standard disk drive is necessary to capture data for later analysis by medical personnel. A modem connection allows the device to alert parents via a standard telephone pager, and will allow the ability to include automatic data transfer of the past 24 hours data to be transmitted over standard telephone lines using standard TCP/IP techniques. An external printer will provide the option for standard paper copy EKG style strips showing heartbeat, respirations, and other data side by side over time. The variety of data collection mediums permit increased flexibility in diagnosing treatment.

D. DISCUSSION OF THE INTERFACE CONCEPTS AND GOALS:

1. Use of Metaphors: The prototype should resemble similar existing interfaces. Users have preconceived notions of what the system should look like and how they should interact with it. This initial design should not be a barrier to the user.

2. Aesthetic Integrity and Consistency: Due to the medical application, it is recommended that the final product be packaged by a company who currently manufactures medical equipment and can use a standard color, texture, size combination for the external case. Any information displayed on the screen (which could be LCD) must be identical to the paper history printout. Use of one large screen LCD screen, similar to

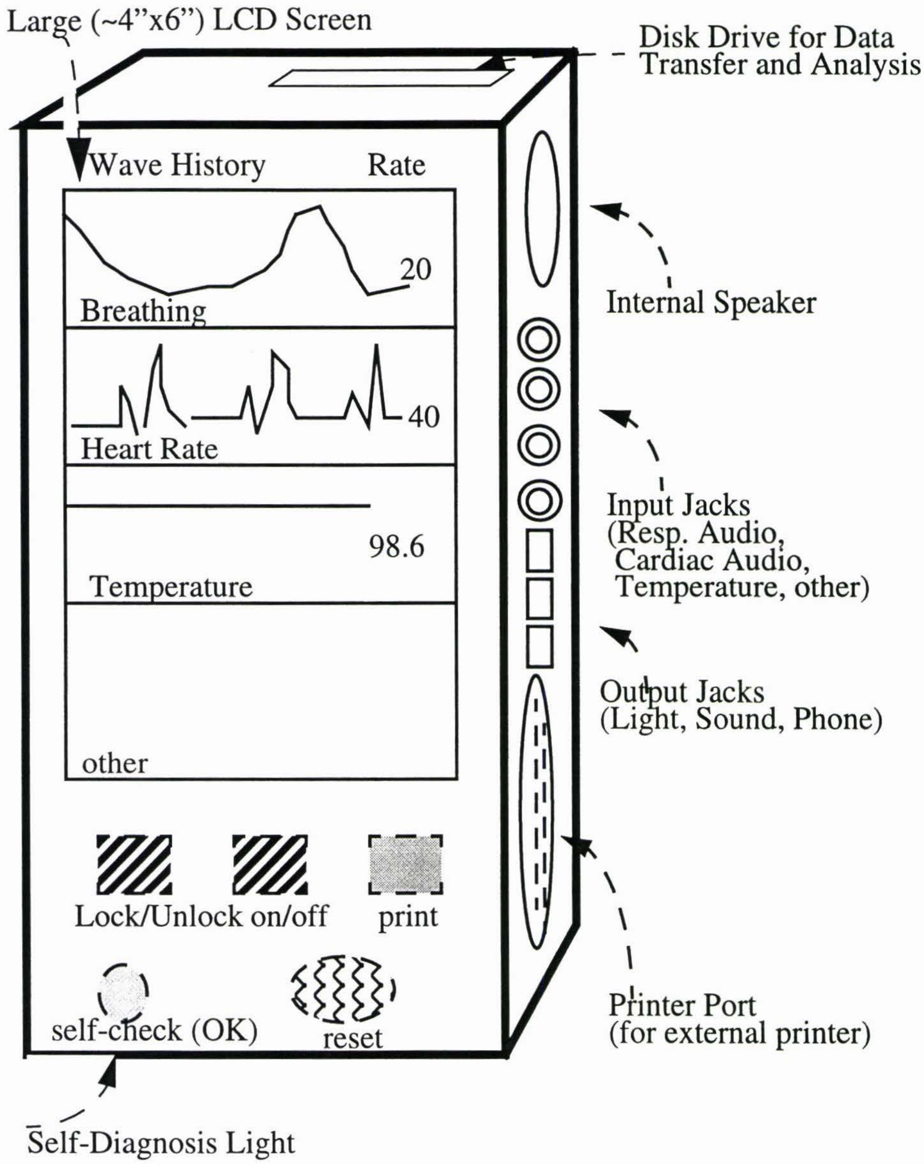


Figure. 5. Prototype of SIDS Wireless Acoustic Monitor Design

the "Apple Newton" would support flexible interface design and the addition of future data "strip" windows.

3. Direct Manipulation: The system must have a "safety" device which requires positive (two finger) control of any act of reset or switching the system off. The alarms should be able to be silenced/ paused at the touch of a button. The only other user interaction possible is printing patient history.

4. Feedback and User Control: The first method of feedback for the system is alarm sounding, which can be extended to activate a horn, light, vibration device, and dial a

telephone modem to call a pager number. The second method of feedback is the printed history of the entire sleep period.

E. GRAPHICAL USER INTERFACE PROTOTYPE:

To complete a development of the initial interface in a timely fashion, we concentrated on the look and feel of the functional interface (shown as figure 6). The primary screen displayed is the "Waveform" screen which shows EKG style stripcharts of respiratory and cardiac sounds. A help screen can be activated and the user can be prompted if assistance is desired. Audible and flashing light alarms can be adapted to alert physically challenged providers to extend the user base.

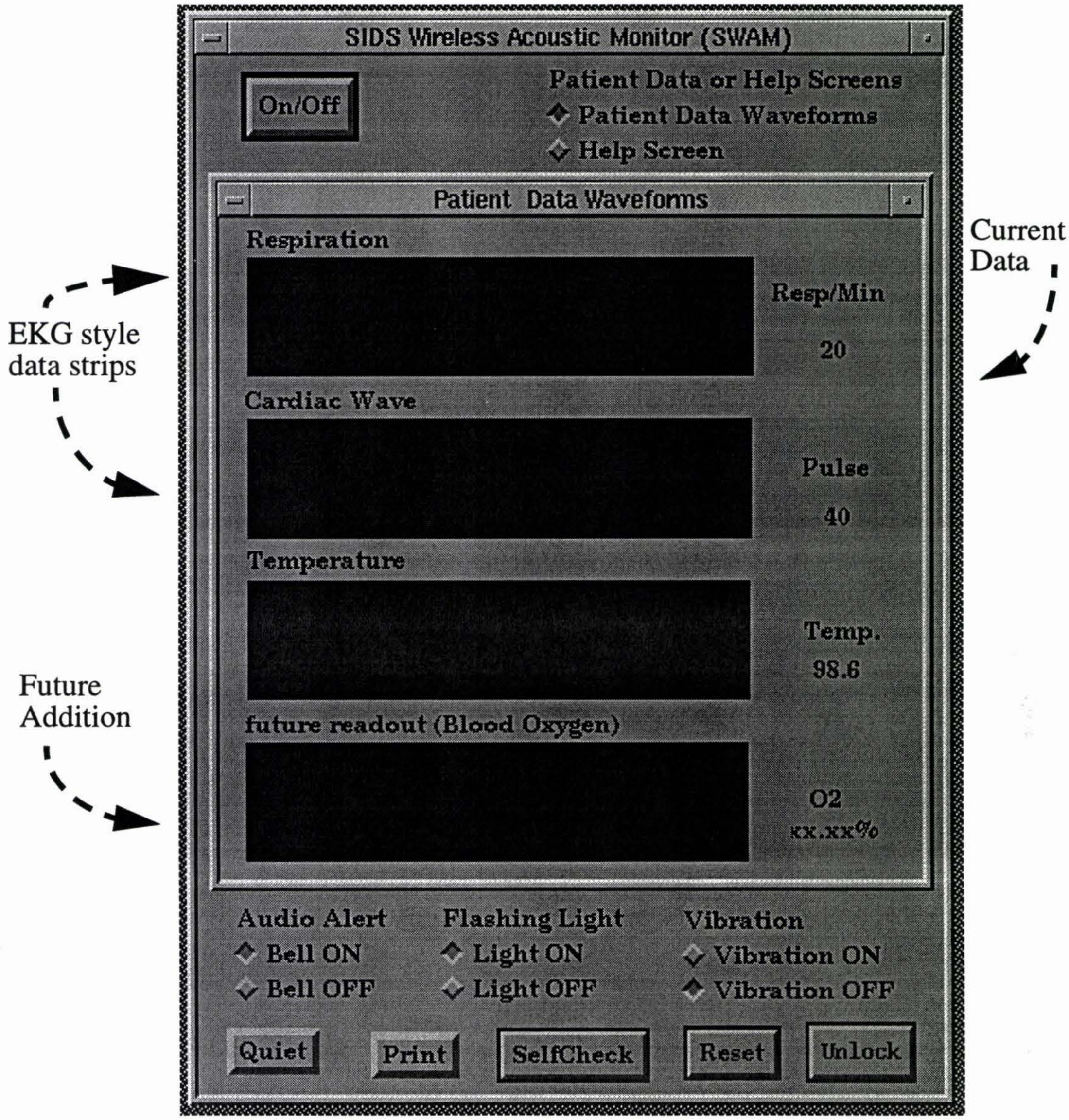


Figure. 6. SWAM Graphical User Interface Prototype

F. SOFTWARE ABSTRACTION:

The initial top level functional diagram shown in figure 7 is the CAPS Augmented Data Flow Diagram of the SIDS Wireless Acoustic Monitor. The bubbles on the left represent input to the monitor via the noninvasive Acoustic Pad and a remote temperature sensing device. Through the use data abstraction, additional sensor types or classes may be installed or modified at a later date as sensor technology improves. This type of object modeling allows the technique of code reuse to save time in future versions of the system.

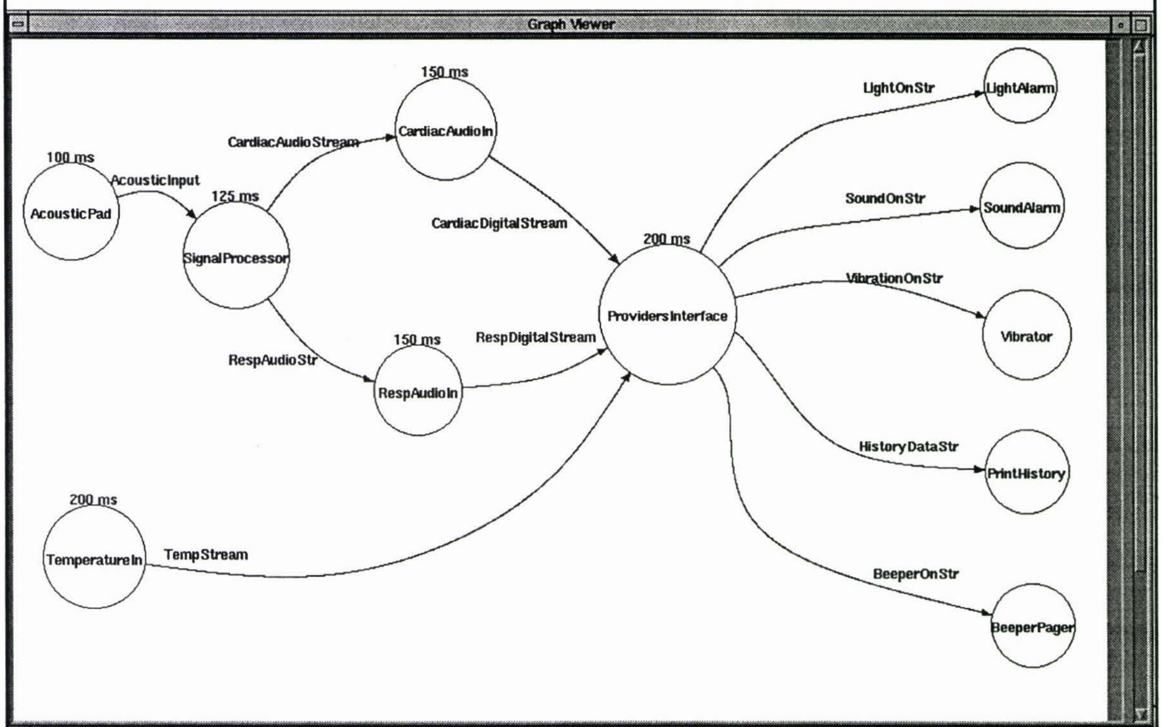


Figure 7. A CAPS Augmented Data Flow Diagram of the SWAM

One of the significant features of rapid computer aided prototyping and design is to take a preliminary design, convert it to a detailed design and quickly produce prototypes for evaluation and later for production. The design of computer prototypes of medical applications requires the designer to allow for a considerable amount of flexibility for future changes [9].

G. CONCLUSIONS:

In order to develop any system effectively, designers must include users and domain experts early on, and the review of initial prototypes and requirements are essential to an effective design process. Computer prototyping is a very effective method of defining and detailing the requirements of a potentially complex system. The material presented here is intended to illustrate the initial feasibility of the SWAM system through the use of CAPS. Additional work in the digital signal processing of the input signal is needed to reach a hardware solution.

H. ENDNOTES:

Comments relating any aspect of this system are welcome and encouraged. Correspondence regarding this paper should be sent to Captain Daniel S. Rusin, Computer Science Department, Code 32, Naval Postgraduate School, Monterey, CA 93943. E-mail: dsrusin@cs.nps.navy.mil

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official, or as reflecting the views of the Department of the Army, the Department of the Navy or the Department of Defense.

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OBSERVER VARIABILITY IN CHEST AUSCULTATION

Lynne Parziale, Kirsten Bergstrom, R. Murphy

A major motivation for developing objective methods for lung sound analysis is that observer variability is considered to be a significant problem. We reviewed reported studies that provide information on observer performance of auscultation, including those that compared observers:

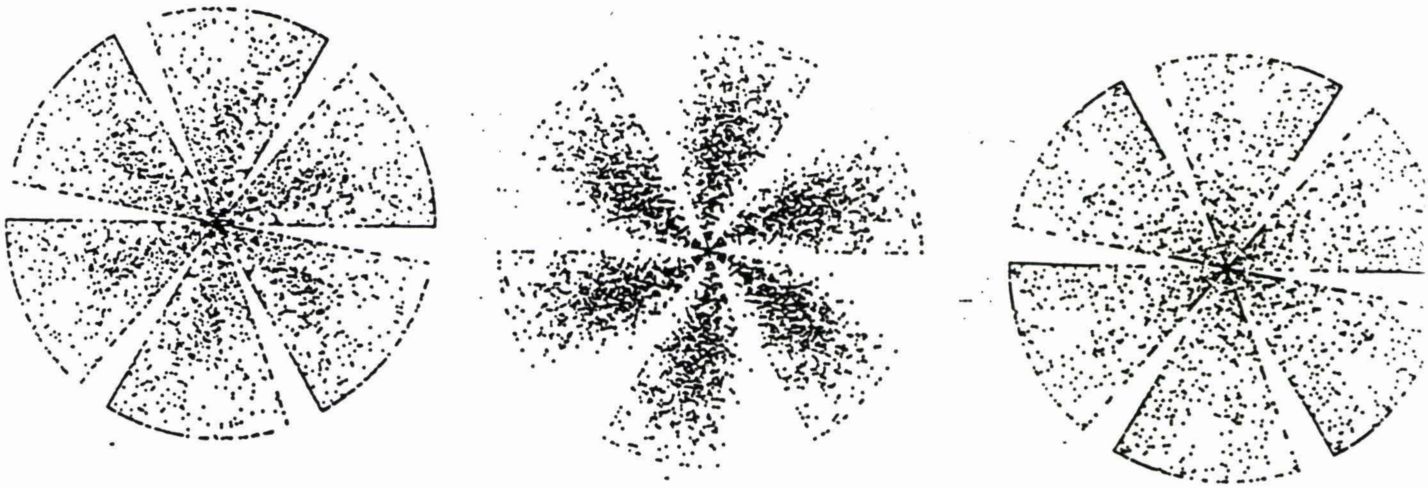
(1) to other observers from the same discipline (e.g., MD vs MD)
(2) to observers from other disciplines (e.g. MD vs Respiratory Therapists, nurses, etc.)
(3) to objective measurements (e.g. Time Expanded Waveform Analysis, Spectral Analysis)
(4) to x-ray interpretation
(5) to pulmonary function test results
(6) and to clinical diagnosis.

We also reviewed related papers on lung sound nomenclature. Interobserver variability ranged from approximately 10% to over 50%. It was greater for qualifying adjectives (56%) and less for presence or absence of simple phenomena such as crackles in asbestos workers (0% to 9%). We conclude that observer variability remains a significant problem. Further efforts to improve the accuracy of auscultation need to be pursued.

LUNG SOUNDS VISUALIZED BY SYMMETRIZED DOT-PATTERNS (SDP)

Frank F. Davidson, Kirsten Bergstrom, Myriam Jean & R. Murphy

SDP, a computerized method for graphic display of acoustic phenomena, has been used to demonstrate differences in speech sounds and heart sounds (1,2). We used this method to determine whether or not lung sounds had distinctive patterns. Lung sounds of patients from an outpatient and inpatient pulmonary practice were recorded using a realistic microphone imbedded in a 3M stethoscopic chest piece and input to an IBM compatible computer after band pass filtering from 80 to 2000 Hz. Sounds were digitizing at 8000 Hz sampling rate and were analyzed using an SDP pogram installed in a high level language program (MATLAB, Mathworks, Natick, MA). Examination of the SDP's of normal tracheal, and vesicular sounds, as well as wheezes, rhonchi, and crackles, show that pattern differences exist in lung sounds that can be displayed using SDP. Examples of the results are shown in Figure 1. The benefits and limitations of this method will be discussed.



Tracheal   Vesicular   Wheeze

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COUGH SOUNDS SPECTRA IN ASTHMATICS: STEROID EFFECTS

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Cough sound spectra were studied in 10 asthmatic subjects while taking steroids and while not taking steroids. Subjects were instructed to make 6 voluntary coughs within 6 seconds. Using a fast Fourier transform spectrum analyzer, sound signals recorded at the neck with a contact microphone were digitized and real time spectrographs were displayed. Cough sound spectrographs of the subjects who had not been taking steroids showed 2 distinct spike complexes. One was within 1 kHz and had peak energy at 543 $\pm$ 45 Hz. The second was between 1 and 2 kHz with peak energy at 1523 $\pm$ 621 Hz. Spectrographs of the subjects, who had been taking steroids and were in a clinically stable state, showed the second high frequency components to be either markedly suppressed or to have disappeared.

MEASUREMENT AND ANALYSIS OF SPECTRAL RESPIRATORY SOUND IN HEALTHY CHINESE. PART ONE IN YOUTHS - 122 STUDENTS

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122 students of the Fu-Dan University, 55 males, 67 females, ages 18-24 years, were examined. Their mean age was 21 $\pm$ 0.958 years. The tracheal breath sounds were sampled during quiet respiration and were analyzed via computer into frequency spectra. The figures of the frequencies distribution and the peak of its waves were shown on the screen. Results: The mean of the main frequency was 146.705 $\pm$ 42.098Hz. It was 155.907 $\pm$ 26.936Hz for males and 139.12 $\pm$ 50.147Hz for females. This was statistically significant ($p < .05$). Peak frequencies were observed with a mean value of 97.109 $\pm$ 3.634. In the males, the peaks averaged 96.796 $\pm$ 3.3. In the females they were 97.292 $\pm$ 3.87. This difference was not statistically significant. As 42 students of this series had a main frequency of 158Hz, 158Hz becomes the normal distribution center of the main frequency of respiratory sound in the healthy youth.

THE KEY WORDS: respiratory sound, acoustic frequency

RESPIRATORY AUSCULTATORY SKILLS AMONG INTERNAL MEDICINE AND FAMILY PRACTICE TRAINEES: A COMPARISON OF DIAGNOSTIC PROFICIENCY

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Purpose: The shift towards managed care in American medicine has recently emphasized the importance of the *Generalist*. Because family practice has long encouraged strong bedside clinical skills, we hypothesized that trainees in family practice might show greater proficiency in physical diagnosis than their internal medicine colleagues.

Methods: We surveyed the pulmonary auscultatory skills of 404 internal medicine and 252 family practice trainees of the mid-Atlantic area. Participants were asked to listen by stethophones to a tape containing 10 respiratory events, directly recorded from patients. Trainees were allowed to listen to each event as long as needed and answered by filling a multiple choice questionnaire.

Results: Trainees' identification scores for the 10 respiratory events ranged between 0-85% for internal medicine (mean = 38.6) and between 0-85% for family practice (mean = 39.6). Although family practice residents had a significantly higher identification rate for the late-inspiratory crackles (22.6% Vs. 15.6%, P=0.024), and the expiratory rhonchus (21.8% Vs. 13.9%, P=0.008), there were no significant differences between the overall *sound-identification* rates of the two groups.

Conclusions: We found very little difference in auscultatory proficiency among internal medicine and family practice trainees. Both groups of residents showed a concerningly low identification rate for 10 commonly encountered respiratory events. Our data suggest the need for a greater emphasis on bedside clinical skills during the training of generalists.