Annual Congress of International Lung Sound Association

Cruising Congress 12.9. – 14.9.2002

Stockholm – Helsinki – Stockholm

Congress venue: Silja Serenade and Biomedicum, Helsinki

Chairman of ILSA:

Prof. Hans Pasterkamp, Winnipeg, Canada

Chairman of local organisation committee:

prof. Anssi Sovijärvi

Helsinki University Hospital

anssi.sovijarvi@hus.fi

Organisation of the Congress

International Lung Sound Association (ILSA)

Scientific committee:

Hans Pasterkamp (chairman)
Raymond Murphy
Steve Kraman
George Wodicka

Local organisation committee:

Anssi Sovijärvi (chairman)
Päivi Piirilä
Terhi Ojala

Sponsors:

Dept. of Clinical Physiology, Helsinki University
Fuchs Medical, Finland
Glaxo Smith Kline, Finland

International Lung Sound Association, Annual Meeting, Stockholm-Helsinki,12.9.-14.9.2002

Program:

-for information call Prof. Anssi Sovijärvi,GSM 358-400-423211 or Dr.Terhi Ojala 358-40-5619622

Thursday, September 12

11:30 – 12:00

Registration at Silja Terminal, Stockholm, Group Travel Desk

12:00 – 13:00

***Lunch on Board**, Buffet restaurant, 6th Deck, Silja Serenade, Stockholm harbor, Silja Terminal*

13:15 – 13:25

***Welcome and Opening Remarks** / Conference Center, 6th Deck, , Silja Serenade*
Hans Pasterkamp and Anssi Sovijärvi

Conference Center, Silja Serenade, 6th Deck:

Session I: Sensors and Measurement Systems

Chairpersons: Noam Gavriely / George Wodicka

13:25 – 13:40
MULTICHANNEL COMPUTERIZED PHONONEUMOGRAPHY
Charleston S., González R., Castellanos P., Aljama T.
Universidad Autónoma Metropolitana-Iztapalapa, Av. San Rafael Atlixco 186,
México City, Mexico

13:40-13:55
A MULTI-CHANNEL TELEMETRY SYSTEM FOR THE ACQUISITION OF RESPIRATORY SOUNDS
Koray Ciftci, Yasemin P. Kahya, Mete Yeginer
Biomedical Eng. Institute, and Department of Electrical Engineering, Bogazici University,
Istanbul, Turkey

13:55 – 14:10
FURTHER ATTEMPTS TO REDUCE NOISES OF AN ACCELEROMETER-TYPE CONTACT STETHOSCOPIC SENSOR
Fujihiko Sakao
School of Engineering, Kinki University, Hiroshima, Japan

14:10 – 14:25
ACOUSTIC MONITORING OF BREATHING IN THE EXTERNAL EAR
Gary A. Pressler, Jeffrey P. Mansfield, Hans Pasterkamp, Steve S. Kraman, Hiroshi Kyokawa,
George R. Wodicka
Department of Biomedical Engineering, Purdue University, West Lafayette, IN, USA
Sound Medical Solutions, Newton, MA, USA
Department of Pediatrics, University of Manitoba, Winnipeg, Canada
VA Medical Center, Lexington, KY, USA

14:25 – 14:40
Coffee Break

Session II: Signal Processing and Analysis

Chairpersons: John Earis / Leontios Hadjileontiadis

14:40 – 14:55
RESPIRATORY AIRFLOW ESTIMATION BY ACOUSTICAL MEANS
Irina Hossein and Zahra Moussavi
Department of Electrical & Computer Engineering, University of Manitoba, Winnipeg, Canada

14:55 – 15:10
AUTOMATIC COUGH DETECTION USING DIGITAL SIGNAL PROCESSING
Hiew YH, Smith JA, Cheetham BMG, Woodcock AA, Earis JE
Computer Science Department, and North West Lung Centre, Manchester, & Aintree Chest Centre, Liverpool, UK

15:10 – 15:25
FRACTAL DIMENSION: A SIMPLE TOOL FOR EFFICIENT DETECTION OF DISCONTINUOUS LUNG SOUNDS
Leontios J. Hadjileontiadis, Ioannis T. Rekanos
Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece
Radio Laboratory, Helsinki University of Technology, Helsinki, Finland

15:25 – 15:40
WAVELET-PACKETS AND HIGHER-ORDER STATISTICS: ON EFFICIENTLY DENOISING DISCONTINUOUS LUNG SOUNDS
I. K. Kitsas, L. J. Hadjileontiadis, V. Gross, Th. Penzel, S. M. Panas
Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece
Dept. of Medicine, Div. Pulmonary and Crit. Care Med.; Philipps-University Marburg, Germany

15:40 – 16:00
Coffee Break

Session III: Databases and Instruction

Chairpersons: John Earis / Leontios Hadjileontiadis

16:00 – 16:15
MARBURG RESPIRATORY SOUNDS (MARS) DATABASE
H. Baran, V. Gross, L.J. Hadjileontiadis, U. Koehler, Th. Penzel
Dept. of Respir. and Crit. Care Med., Philipps-University of Marburg, Germany
Dept. of Electr. and Comp. Eng., Aristotle-University of Thessaloniki, Greece

16:15 – 16:30
THE USE OF VISUAL FEEDBACK FOR THE TEACHING OF PULMONARY AUSCULTATION: MORE IS LESS AND LESS IS MORE
Salvatore Mangione, M.D. and Gregg Lipschik, M.D.
Jefferson Medical College, Philadelphia, PA, USA

16:30 – 16:45
REVIEW IF OF THE I.L.S.A. INTRANET
Hans Pasterkamp
University of Manitoba, Winnipeg, Canada

16:45 – 17:00
Cocktails on Board

17:00
Departure from Stockholm to Helsinki
21:00
A la carte Dinner on Board, Restaurant Maxim, 6 th Deck

Friday, September 13

07:00 – 09:00
Breakfast on Board

09:30
Arrival at Helsinki Harbor, Silja Terminal

09:30 – 10:30
Transportation to Biomedicum Helsinki, Meilahti campus area, incl. tour of Helsinki

10:30 – 10:50
Time for mounting of posters, Biomedicum, seminar room 1-2, ground floor

Location: Biomedicum Helsinki, seminar room 3 , ground floor

Session IV: Sound Generation and Transmission

Chairpersons: Raymond Murphy / Masato Takase

10:50 – 11:05
SOUND SPEED IN THE LUNG MEASURED BY SOUND INJECTION INTO SUPRACLAVICULAR SPACE
R. Murphy, A. Vyshedskiy, J. Shane, D. Bana
Faulkner Hospital, Boston, MA, USA

11:05 – 11:20
SIMULATION OF HUMAN TRACHEA WALLS OSCILLATIONS
Vladimir G. Basovsky , Victor T. Grinchenko, Igor V. Vovk, Olga I. Vovk
Institute of Hydromechanics NAS, Kiev, Ukraine

11:20 – 11:35
THERMODYNAMIC FORMING OF ACOUSTICAL PARAMETERS FOR NORMAL PULMONARY PARENCHYMA
Victor T. Grinchenko, Igor V. Vovk, and Valery N. Oliynik
Institute of Hydromechanics of NAS of Ukraine, Kyiv, Ukraine

11:35 – 11:50
EFFECT OF DEEP INSPIRATION ON FLOW-STANDARDIZED INSPIRATORY LUNG SOUNDS
H. Kiyokawa, J. Gnitecki and H. Pasterkamp
Respiratory Acoustics Laboratory, Manitoba Institute for Child Health, University of Manitoba, Winnipeg, Canada

11:50 – 13:25
Lunch and Poster Viewing,
seminar room 1-2, ground floor
(see list of poster presentations below)

Session V: Discontinuous Sounds and Cough

Chairpersons: David Frazer / Anssi Sovijärvi
13:25 – 13:40
LUNG SOUND ANALYSIS IN ASBESTOS-INDUCED PULMONARY AND PLEURAL DISEASE
Airaksinen J, Kivisaari L, Luukkonen R, Vehmas T, Sovijärvi ARA, Piirilä P
Laboratory of Clinical Physiology and Department of Radiology of Helsinki University Central Hospital, Department of Occupational Medicine and Department of Epidemiology and Biostatistics of the Finnish Institute of Occupational Health, Helsinki, Finland

13:40 – 13:55
AUTOMATED LUNG SOUND ANALYSIS IN PATIENTS WITH PNEUMONIA.
R. Murphy, A. Vyshedskiy, V-A. Power, D. Bana, P. Marinelli, A. Wong-Tse
Faulkner Hospital, Boston, MA, USA

13:55 – 14:10
EFFECT OF OBSTRUCTIVE LUNG DISEASE ON THE INVERSE POWER LAW (1/F^B) BEHAVIOR OF VOLUNTARY COUGHS
D. G. Frazer, K. A. Rosenberry, W. T. Goldsmith, W. G. McKinney, J. S. Reynolds and J. Barkley
Health Effects Laboratory Division, NIOSH, Morgantown, WV, USA

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Address of the Sponsor
14:10 – 14:20
Fuchs Medical, Finland and Jaeger GmbH, Germany ; H-J Smith

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14:20 – 14:40
Coffee Break

Session VI: Sounds in Airway Obstruction

Chairpersons: Päivi Piirilä / Yasemin Kahya
14:40 – 14:55
ACOUSTIC CHARACTERISTICS OF PATIENTS WITH C.O.P.D.
S.Ishikawa, F.Gomez,M.Divo,K.F.MacDonnell,and B.Celli
Pulmonary and Critical Care, St Elizabeth's Medcical Center
Dept. of Medicine, Tufts University School of Medicine, Boston, MA, USA

14:55 – 15:10
ACOUSTIC MAPPING OF THE TIMING OF INSPIRATORY BREATH SOUNDS IN NORMAL SUBJECTS AND PATIENTS WITH C.O.P.D.
D. Barr, S. Jack, N. Duffy, J. E. Earis
University Hospital Aintree Liverpool, United Kingdom

15:10 – 15:25
BRONCHIAL OBSTRUCTION CHANGE FREQUENCY SPECTRA OF LUNG SOUNDS
V. Gross, H. Baran, S. Taplidou, U. Koehler, Th. Penzel
Dept. of Respir. and Crit. Care Med., Philipps-University of Marburg, Germany
Dept. of Electr. and Comp. Eng., Aristotle-University of Thessaloniki, Greece

15:25 – 15:40
SPECTRAL CHANGES IN NORMAL BREATH SOUNDS ASSOCIATED WITH BRONCHODILATOR RESPONSE IN ASTHMATIC CHILDREN
Masato Takase, Kazuhiko Shirota, Takehide Imai
Department of Pediatrics, Nippon Medical School, Tokyo

15:40 – 15:45
Closing remarks

15:50
Bus transportation from Biomedicum to Helsinki Harbor, Silja Terminal

17:00
Departure of Silja Serenade to Stockholm

19:30 – 20:30
ILSA General Annual Meeting, Conference Center, 6th Deck, , Silja Serenade
(Agenda will be sent by e-mail and posted at the Intranet)

20:30
Buffet Dinner on board, buffet restaurant, 6th Deck

Saturday, September 14

07:00
Breakfast on board

09:30
Arrival at Stockholm Harbor

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List of Poster Presentations (13), Biomedicum Helsinki

RELATIONSHIP BETWEEN COUGH EVENTS DURATION AND COUGH EXPIRATORY FLOW-TIME IN RESTRICTIVE, OBSTRUCTIVE DISEASES
F. Dalmasso, E. Isnardi, L. Sudaro, R. Mantovano, A. Mazzucato
Divisione di Pneumologia, Lab. Fisiopatologia ed Acustica Respiratoria, Osp.Mauriziano "Umberto I", Torino, Italy

POTENTIALS AND BARRIERS OF EXTENSIVE AUSCULTATORY DATABASES
Christopher Druzgalski
California State University, Long Beach, CA, USA

DYNAMIC SOUND INTENSITY – FLOW MEASURMENTS DURING COUGH
W. T. Goldsmith, A. A. Afshari, J. Barkley and D. G. Frazer
E&CTB, HELD, NIOSH, Morgantown, WV, USA

ALGORITHM OF SEPARATION CARDIAC AND LUNG NOISES
Grinchenko V.T. , Makarenkov A.P., Rudnitskii A.G.
Institute of Hydromechanics of National Ukrainian Academy of Sciences, Kiev, Ukraine

RANK RESPIROSONOGRAMS OF BREATH SOUNDS
Victor T. Grinchenko, Vladimir V. Krizhanovsky
Institute of Hydromechanics of National Academy of Sciences, Kiev, Ukraine

A RANDOMISED, CONTROLLED CLINICAL TRIAL USING ACOUSTIC PARAMETERS OF SNORING SOUND AS OBJECTIVE OUTCOMES OF PALATAL SURGERY FOR SNORING.
Jones TM, Swift CA, Meau-Shin H, Cheetham B, Calverley P, Earis J
University Hospital Aintree, Liverpool, UK
Department of Computer Science, University of Manchester UK

COMPARISON OF CLASSIFIERS BASED ON WAVELET NETWORKS AND ARTIFICIAL NEURAL NETWORKS FOR RESPIRATORY SOUNDS
Yasemin P. Kahya, Mete Yeginer, Koray Ciftci, Gunseli Kilinc
Department of Electrical Engineering, and Biomedical Eng. Institute, Bogazici University, Istanbul, Turkey
Cerrahpasa Medical School, Istanbul University, Istanbul, Turkey

ACOUSTIC FINDINGS IN PATIENTS WITH CONGESTIVE HEART FAILURE COMPARED TO PATIENTS WITH PNEUMONIA
R. Murphy, A. Vyshedskiy, P. Marinelli, A. Wong-Tse, R. Paciej
Faulkner Hospital, Boston, MA, USA
ACOUSTIC IMAGING OF THE CHEST
R. Murphy, MD and A. Vyshedskiy, PhD
Faulkner/ Brigham and Women Hospitals, Boston, MA, USA

CRACKLE RATE DURING SHALLOW AND DEEPER THAN NORMAL BREATHING IN PATIENTS WITH IPF, CHF, AND PNEUMONIA.
R. Murphy, A. Vyshedskiy, R. Paciej
Faulkner Hospital, Boston, MA, USA

DEVELOPMENT OF CRACKLES DURING SPINAL ANESTHESIA

R. Murphy, A. Vyshedskiy, A. Wong-Tse
Faulkner Hospital, Boston, MA, USA

DETECTION OF PORCINE OLEIC ACID-INDUCED ACUTE LUNG INJURY USING PULMONARY ACOUSTICS

Jukka Rasanen, M.D; Noam Gavriely, M.D., D.Sc.
Department of Anesthesiology, Mayo Clinic, Rochester, MN, USA
Technion – Israel Institute of Technology, Rappaport Faculty of Medicine, Haifa, Israel

TRANSMISSION OF CRACKLES IN PATIENTS WITH INTERSTITIAL PULMONARY FIBROSIS AND CONGESTIVE HEART FAILURE.

Vyshedskiy, A. and Murphy, R.
Faulkner Hospital, Boston, MA, USA

Session I

Sensors and Measurement Systems

MUTICHANNEL COMPUTERIZED PHONONEUMOGRAPHY

Charleston S., González R., Castellanos P., Aljama T.
Universidad Autónoma Metropolitana-Iztapalapa,
Av. San Rafael Atlixco 186,
México City, 09340

Several attempts have been made to avoid the subjectivity of the auscultation method through a more quantitative analysis. The aim of the present work was to develop a system to achieve spatial, temporal and spectral analysis of the respiratory sounds through a more extensive area of the thoracic wall.

We propose a regular-spaced microphone array based on spatial resolution (~5-7 cm) and topographic references. The system acquires up to 64 channels with sampling frequency of 10 KHz, leaving one or more channels for flow signals. It can analyse each channel separately or use the complete set to perform spatial analysis to obtain quantitative characteristics. The system permits multichannel signal display and their representation as acoustical images. These images can be visualised as function of magnitude in time- or frequency-domain. The power spectral information is divided into different bands to evidence frequency behaviour of particular regions.

In normal subjects at standardized flow, we observed repetitive patterns of multichannel and mapping display during inspiratory and expiratory phases. Overall, the acoustical images show a spatial distribution of the sounds that agree with expected regional ventilatory distribution.

The developed system accomplishes standardized criteria for analysis of respiratory sounds, and we conclude that it might be useful to explore breathing activity in healthy and abnormal subjects.

A Multi-Channel Telemetry System for the Acquisition of Respiratory Sounds

Koray Ciftci[1], Yasemin P. Kahya[2], Mete Yeginer[1]
[1]Biomedical Eng. Institute, and [2]Department of Electrical Engineering, Bogazici University, Istanbul, Turkey

This study presents a preliminary approach for the telemetry of respiratory sounds. Increasing the reliability and efficiency of the acquisition process of respiratory sounds is aimed. For this purpose, a system with two separate telemetry transmitters placed on the body of the patient and a remote receiver connected to a PC is developed. A radio frequency link is established between the transmitters and the receiver using frequency modulation. Communication between the PC and receiver is supplied via serial port. To control data acquisition process, a user interface is developed. The receiver can be tuned to any of the transmitters with the help of this interface, which provides the user with the choices of listening, recording and displaying data. A microcontroller is responsible for tuning the receiver according to the commands issued by the computer. The respiratory sounds are filtered by high pass and low pass filters having cut-off frequencies at 80 Hz and 2000 Hz, respectively. A sampling frequency of 5 kHz is selected. Data is digitized by an 8-bit analog-to-digital converter. Performance of the system is tested by measuring its response to some pre-defined signals and by recording respiratory sounds from subjects. Promising results are obtained revealing the feasibility of telemetering respiratory sounds.

Keywords: Telemetry, frequency modulation, data acquisition.

FURTHER ATTEMPTS TO REDUCE NOISES OF AN ACCELEROMETER-TYPE CONTACT STETHOSCOPIC SENSOR

Fujihiko SAKAO
School of Engineering, Kinki University

The investigation on reducing cable-transported noise into an accellerometer-type contact stethoscopic sensor is further extended. As presented last year, attaching a mass onto the cable of the sensor is very efficient for cutting-off the noise traveling into the sensor through the cable. Attempts are on progress to unify such a "mass" with a hard cover for the sensor for preventing room noise from intruding into the sensor. Such a cover may also be a shield to surface waves generated on other parts of the body surface and contaminate the sensor output, because it composes a massive ring on the skin surrounding the sensor.

Effectiveness of those cases or shields was experimentally verified, though not yet completely. It was found that a thin metal cover on the upper surface of the sensor (fixed to the outer case) can reduce considerably the room noise contamination, though it was originaly intended only to reduce electric noise. If this is always effective, then the upper part of the shield may be eliminated, resulting in a ring around the sensor, which may be much more convenient to use. It may be further more convenient if the "ring" can be flexible, as presently being examined by the author.

ACOUSTIC MONITORING OF BREATHING IN THE EXTERNAL EAR

Gary A. Pressler[1], Jeffrey P. Mansfield[2], Hans Pasterkamp[3], Steve S. Kraman[4], Hiroshi Kyokawa[3], George R. Wodicka[1]

[1]Department of Biomedical Engineering, Purdue University, West Lafayette, IN, USA
[2]Sound Medical Solutions, Newton, MA, USA
[3]Department of Pediatrics, University of Manitoba, Winnipeg, Canada
[4]VA Medical Center, Lexington, KY, USA

With a microphone embedded in an acoustically isolating earplug, the external ear becomes a unique location for monitoring breathing that is highly immune to ambient noise. In a preliminary study, 20 healthy male and female subjects were directed to breathe through a pneumotachograph at targeted shallow (3.0 mL/s/kg) and tidal (7.5 mL/s/kg) airflows, normalized to body mass. The resulting breath sounds were recorded with an electret microphone in the distal end of a foam earplug. A breath hold was performed at the end of each recording to measure the background noise. Breath sounds were compared to the background noise in five octave frequency bands between 75 and 2400 Hz. The greatest differences were observed between 150 and 300 Hz where expiratory sounds exhibited a signal to noise ratio (SNR) across all subjects of 6.9 ± 4.2 dB at shallow flows and 14.3 ± 5.5 dB at tidal flows. Inspiratory sounds exhibited SNRs of 6.8 ± 4.1 dB and 15.2 ± 6.5 dB for the same flows, respectively. The breath sounds were band-pass filtered, full-wave rectified, and integrated over time to produce an envelope of sound amplitude. This amplitude envelope was observed to correspond well with airflow, suggesting that quantitative flow information may be obtained acoustically in the external ear.

This work was supported by NIH SBIR Grant 1 R43 HL 59757-01, the NSF Integrative Graduate Education and Research Training (IGERT) Program in Therapeutic and Diagnostic Devices Grant DGE-99-72770, and the Children's Hospital Foundation of Manitoba, Inc.

Session II

Signal Processing and Analysis

RESPIRATORY AIRFLOW ESTIMATION BY ACOUSTICAL MEANS

Irina Hossein and Zahra Moussavi

Department of Electrical & Computer Engineering
University of Manitoba, Winnipeg, MB R3T 2N2
Ihossain@ee.umanitoba.ca, mousavi@ee.umanitoba.ca

Abstract- The purpose of this study was to estimate respiratory airflow by acoustical means. Based on some preliminary results, a linear model was used to estimate respiratory airflow from lung sound's average power. The model was tested using data from then healthy children ages from 5 to 16 years old. Model coefficients were derived from a few breath sound segments with known airflow at medium flow rate and then the model was applied to the rest of lung sound segments to estimate airflow. The estimated airflow was compared with the actual recorded one to calculate the estimation error. The results showed an overall estimation error of 10.2 ± 3.3%. The results also showed that the error at high (low) flow rate was mainly due to a consistent underestimation (overestimation) because the model coefficients were derived from medium flow rate. Therefore, it is suggested to modify the model by applying a scaling factor to compensate for such underestimation (overestimation) error.

Keywords- Lung sound signal, airflow, average power, estimation

AUTOMATIC COUGH DETECTION USING DIGITAL SIGNAL PROCESSING

Hiew YH, *Smith JA, Cheetham BMG, *Woodcock AA. +Earis JE.
Computer Science Department, and *North West Lung Centre, Manchester, & +Aintree Chest Centre, Liverpool, UK

Objective cough detection by manual sound analysis is laborious, even with the assistance of audio editing software in the time domain. The application of advanced digital signal processing (DSP) to the acoustic analysis of cough has many benefits such as counting coughs and distinguish them from other signals, such as speech and background noise. We have applied DSP analysis to the acoustic properties of pathological cough sounds (e.g. asthmatic, cystic fibrosis and cryptogenic fibrosing alveolitis patients). We describe a DSP algorithm which analyses cough and enables long-term objective statistical measurements.

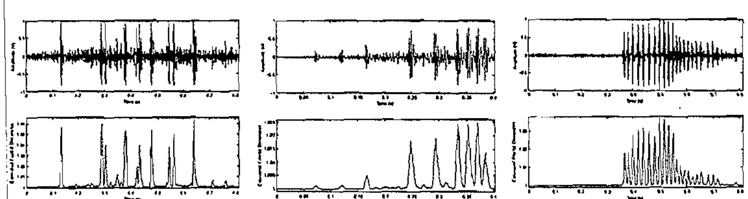
We have applied this algorithm to 35 overnight sound recordings and compared the cough counts to those derived manually using modified wave editing software. The results are expressed in a newly described measurement called "cough seconds" (a cough second is a second in which a cough noise has occurred). This measurement gives a clinical indication of the time spent coughing and improves the accuracy of automatic cough measurements. Compared to manual counting the current version of the Cough Algorithm has a sensitivity of 70.5% and specificity of 98.3%. Each recording takes approximately 60 minutes to process as compared to 4 hours with manual counting.

FRACTAL DIMENSION: A SIMPLE TOOL FOR EFFICIENT DETECTION OF DISCONTINUOUS LUNG SOUNDS

Leontios J. Hadjileontiadis[1], Ioannis T. Rekanos[2]

[1]*Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece (http://psyche.ee.auth.gr)*
[2]*Radio Laboratory, Helsinki University of Technology, Helsinki, Finland (http://www.hut.fi/Units/Radio)*

Detection of discontinuous adventitious lung sounds, i.e., fine/coarse crackles (FC, CC) and squawks (SQ), seems to play an important role in the non-invasive diagnosis of pulmonary dysfunctions, especially when it is based on the auscultation findings. Due to physicians' subjectivity in the interpretation of lung sound recordings, an objective, fast and accurate detector of FC, CC and SQ would, in turn, enhance the diagnostic character of lung sounds and lead to more accurate characterization of the associated pulmonary pathology [e.g., pulmonary fibrosis (PF), interstitial fibrosis (IF), chronic bronchitis (CB), allergic alveolitis (AA)]. In this study we have constructed an efficient technique for detecting FC, CC and SQ in clinical auscultative recordings. The technique is based on a fractal-dimension (FD) analysis of lung sounds. The FD, as a measure of signal complexity, is increased when FC, CC and SQ are present in the recordings and decreased when they are absent (background noise). Analysis of pre-classified lung sounds (FC: 6 cases-PF, IF; CC: 5 cases-CB; SQ: 5 cases IF, AA) drawn from two lung sound databases (Kraman, S.S. *Lung Sounds* 1993, USA: ACCP; Lehrer, S. *Understanding Lung Sounds* 1993, USA: W. B. Saunders Co) demonstrate the efficiency of the proposed method, since it clearly detects the location and the duration of FC, CC and SQ (100% detectability, $p<0.001$), despite their variation either in time duration and/or amplitude (Fig. 1). Since it is not dependent on subjective human judgment, it is robust, and has low computational cost the FD-detector could be easily used in the pulmonary intensive care unit for continuous real-time FC, CC and SQ screening. Application of the proposed method on an expanded database with clinical lung sound recordings is currently in progress.



(a) (b) (c)

Fig. 1. (a) Fine Crackles (upper), FD_{FC} (lower), (b) Coarse Crackles (upper), FD_{CC} (lower), (c) Squawks (upper), FD_{SQ} (lower).

FRACTAL DIMENSION: A SIMPLE TOOL FOR EFFICIENT DETECTION OF DISCONTINUOUS LUNG SOUNDS

Leontios J. Hadjileontiadis[1], Ioannis T. Rekanos[2]

[1]*Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece (http://psyche.ee.auth.gr)*
[2]*Radio Laboratory, Helsinki University of Technology, Helsinki, Finland (http://www.hut.fi/Units/Radio)*

Detection of discontinuous adventitious lung sounds, i.e., fine/coarse crackles (FC, CC) and squawks (SQ), seems to play an important role in the non-invasive diagnosis of pulmonary dysfunctions, especially when it is based on the auscultation findings. Due to physicians' subjectivity in the interpretation of lung sound recordings, an objective, fast and accurate detector of FC, CC and SQ would, in turn, enhance the diagnostic character of lung sounds and lead to more accurate characterization of the associated pulmonary pathology [e.g., pulmonary fibrosis (PF), interstitial fibrosis (IF), chronic bronchitis (CB), allergic alveolitis (AA)]. In this study we have constructed an efficient technique for detecting FC, CC and SQ in clinical auscultative recordings. The technique is based on a fractal-dimension (FD) analysis of lung sounds. The FD, as a measure of signal complexity, is increased when FC, CC and SQ are present in the recordings and decreased when they are absent (background noise). Analysis of pre-classified lung sounds (FC: 6 cases-PF, IF; CC: 5 cases-CB; SQ: 5 cases IF, AA) drawn from two lung sound databases (Kraman, S.S. *Lung Sounds* 1993, USA: ACCP; Lehrer, S. *Understanding Lung Sounds* 1993, USA: W. B. Saunders Co) demonstrate the efficiency of the proposed method, since it clearly detects the location and the duration of FC, CC and SQ (100% detectability, $p<0.001$), despite their variation either in time duration and/or amplitude (Fig. 1). Since it is not dependent on subjective human judgment, it is robust, and has low computational cost the FD-detector could be easily used in the pulmonary intensive care unit for continuous real-time FC, CC and SQ screening. Application of the proposed method on an expanded database with clinical lung sound recordings is currently in progress.

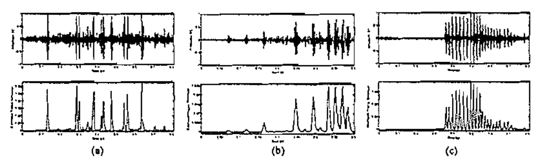


Fig. 1. (a) Fine Crackles (upper), FD_{FC} (lower), (b) Coarse Crackles (upper), FD_{CC} (lower), (c) Squawks (upper), FD_{SQ} (lower).

Session III

Databases and Instruction

Marburg respiratory sounds (MARS) database

H. Baran[1], V. Gross[1], L.J. Hadjileontiadis[2], U. Koehler[1], Th. Penzel[1]
[1]Dept. of Respir. and Crit. Care Med., Philipps-University of Marburg, Germany
[2]Dept. of Electr. and Comp. Eng., Aristotle-University of Thessaloniki, Greece

Respiratory sounds and their relationship with the pulmonary pathology make their interpretation crucial. Current physician education is limited by the low number of available lung sound examples. In contrast to existing lung sound CDs our database contains a multitude of cases. We select typical auscultation findings as well as findings with difficult evaluation. A novelty is the combination between auscultation and lung function results.

We record the breath sounds with our lung sound analyzer (Gross, V. et al. Am J Respir Crit Care Med 2000; 162: 905-909) using the standardized recording protocol of CORSA (Sovijärvi, A et al. Eur Respir Rev 2000; 10:77). The recordings and the parameters of lung function test, auscultation, ICD-10 diagnosis, clinical laboratory results, chest x-ray findings are included. The auscultation phenomena and the respiratory diagnosis are validated by three independent pulmonary experts. Results are integrated into the database when at least two of them confirme. The development of the database was part of the IKYDA lung sound analyzing project.

Today the database contains the results of computerized lung sound analysis (wheezing rate, counts of crackles, parameters of frequency analysis) of more than 2000 recordings from 224 patients (COPD, asthma, pneumonia, lung fibrosis) and 235 healthy volunteers.

Selected cases for teleeducation will be presented on our homepage:
http:// www.lung-sound.de

THE USE OF VISUAL FEEDBACK FOR THE TEACHING OF PULMONARY AUSCULTATION: MORE IS LESS AND LESS IS MORE

SALVATORE MANGIONE, M.D. and GREGG LIPSCHIK, M.D.

PROBLEM STATEMENT AND BACKGROUND: Chest auscultation is suffering from waning proficiency and declining education. To identify better teaching modalities, we assessed the impact of soundwave display on both short and long-term learning.

METHODS: 373 sophomores from two Philadelphia schools were assigned to a 1-hour teaching session on lung auscultation. Students were divided a group with visual feedback and one without. Sound recognition and disease identification were measured both immediately and three weeks after the teaching session. Except for the presence or absence of visual feedback, the content and format of the session was identical for both groups.

RESULTS: Of the 373 participating students, 321 (86.1%) completed both short- and long-term assessment and were therefore included in our final evaluation. Of these, 180 (56%) had access to soundwave display. Students *without* visual feedback had higher short-term *cumulative sound scores* (77.1 vs. 73.3, P = .01) and *sound identification* scores (74.1 vs. 68.5, P = .007), but differed in neither disease identification nor in any of the three long-term scores.

CONCLUSIONS: Supplemental teaching with visual display appears to be more a hindrance than a benefit. Whether teaching sessions longer than one hour might benefit from this modality will need to be evaluated.

REVIEW OF THE I.L.S.A. INTRANET

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On April 11, 2002, the Intranet for ILSA was established at http://www.communityzero.com/ilsa, a service offered by Ramius Corporation, a private company based in Ottawa, Canada. The Intranet is an interactive website that acts as a private meeting place or home for ILSA members. CommunityZero serves as an open channel for organization-to-member and member-to-member communications. Invitations to join were sent by e-mail to 162 recipients on the ILSA address list. Five months later, 93 members have joined the Intranet. Access has remained free of charge since ILSA membership rules have not been finalized. Feedback from members has been generally positive but active participation has not yet reached its full potential, e.g. only 38% have entered their personal information and only 22% have accessed the Intranet within the last month. The possibilities of the Intranet will be presented and potential reasons for the slow adaptation will be discussed.

Session IV

Sound Generation and Transmission

SOUND SPEED IN THE LUNG MEASURED BY SOUND INJECTION INTO SUPRACLAVICULAR SPACE

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Background and Purpose: The speed of sound in the lung changes with changing tissue properties and thus measurement of sound speed has the potential to help in non-invasive diagnosis. Introduction of sound at the mouth for this purpose can be difficult in certain clinical situations such as in the comatose or intubated patient. Accordingly we were interested in a method of measurement speed of sound in the lungs that avoided this problem.

Methods: We introduced a sound, composed of a mix of frequencies from 70Hz to 140Hz, at the supraclavicular space and measured the transit time at multiple microphones placed over the chest wall using a 16 channel lung sound analyzer (Stethographics, Model STG1602). We used the microphone placed next to the speaker as our reference and utilized cross correlation analysis to calculate the transfer times. The sound was "coded" sound, greatly reducing the ambiguity of the crosscorrelation function. In addition, the introduction of sound in the supraclavicular space reduced the problem of sound transmission through bone.

Results: The measured transit time varied from 9ms at the central locations to 13ms at the lung bases. This transit time corresponds to the speed of sound of about 23m/s. This approximation is twice as fast as the speed of sound in the lung parenchyma when test sound is input at the mouth. Our results also indicated that speed of sound increased with increasing lung volume.

Conclusion: Injection of sound into the supraclavicular space allows sound speed measurements in patients unable to cooperate with input of sound at the mouth and provides similar results.

Supported in part by a grant from Stethographics, Inc., ILSA 2002

SIMULATION OF HUMAN TRACHEA WALLS OSCILLATIONS

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The analysis of peculiarities of trachea wall structure is carried out. Possible mechanisms of its excitation is discussed. The acoustical and mathematical models of trachea with elastic walls are developed. These models foresee the possibilities of kinematic excitation of the upper end of trachea and propagation of an elastic wave along the trachea wall. In the wide frequency range a quantitative analysis of modulus and phase of the oscillatory velocity of the trachea elastic wall is performed. These data are compared with those obtained for the acoustical model of trachea with locally responding walls. It is shown that the elastic wall behaves as a delay line, and an elastic wave can propagate along this line in the range of low frequencies ($f < 300$ Hz), having the speed about 10-20 m/s. At higher frequencies the elastic wall behaves like a locally responding surface. It is shown that even relatively low levels of kinematic excitation of the upper end of trachea cause the significant changes in character of the frequency dependence of the trachea wall oscillatory velocity. The analysis of the frequency dependencies of oscillatory velocities of the first seven annular cartilages of the trachea wall is performed. It is found that their levels diminish with the increase of distance of cartilage from the upper end of trachea. The relatively simple technique allowing to estimate real values of the transmission function of the oscillatory velocity from vocal chords to the upper end of trachea is proposed.

THERMODYNAMIC FORMING OF ACOUSTICAL PARAMETERS FOR NORMAL PULMONARY PARENCHYMA

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It is well-known that even the simplest acoustical model of pulmonary parenchyma, introducing the Wood's equation for its sound speed vs the air share in it, demonstrates reasonably good matching with experimental results. In contrary to sound speed, still there are no reliable theortetical or experimental estimates of the sound attenuation in the parenchyma. Our goal was to develop a self-consistent model of acoustical properties of normal parenchyma depending on overall share of the air phase in it.

We treated the parenchyma as a two-phase continuum with air-filled structural elements – alveoles. Due to small mean alveole's cross-size ($\sim$ 0.3 mm) this approximation is valid for practically all frequencies below $10 \div 20$ kHz. Originating from physical studies of the sound propagation through the liquid-air mixtures and the bronchial airflow dynamics, we considered the thermal mechanism as dominating one in forming the parenchyma's acoustical properties (at least, within $100 \div 2000$ Hz frequency band, typical for respiratory sounds).

A thermodynamic model of emulsion (bubbly medium) by Isakovich, 1948, was used as the basic one. It predicts the strong dependence of sound speed and acoustic dissipation from radius of the emulsion's grain. Naturally, in our case this dimension is equivalent to alveole's cross-size, which is a function of capacity of the alveolaris air (share of the air phase in parenchyma).

Obtained results are presented in figure below. The sound speed occurred monotonically increasing with the increase of capacity of the alveolaris air. As to the attenuation coefficient, its behavior is more complex. For shares of the air phase typical for exhalation it demonstrates only slight variation, while "at inhalation" the attenuation decreases the stronger, the more air is accumulated in the alveoles.

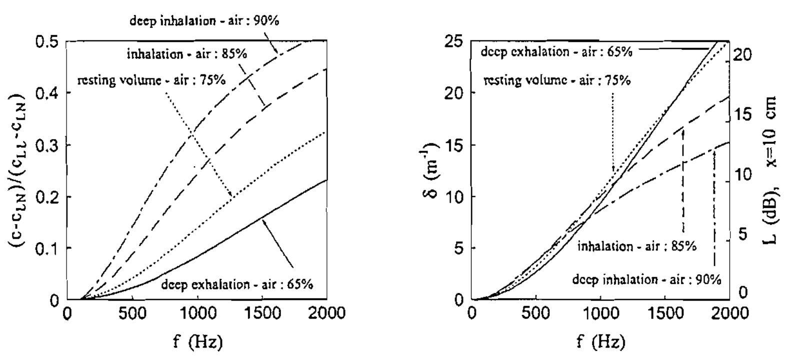

Figure: Sound speed c and the attenuation coefficient δ in parenchyma, where c_{LN} and c_{LL} are isotermic-adiabatic (LF) and adiabatic-adiabatic (HF) sound speeds, $(c_{LL} - c_{LN})/c_{LL} \times 100\ \% \approx 13\ \%$

EFFECT OF DEEP INSPIRATION ON FLOW-STANDARDIZED INSPIRATORY LUNG SOUNDS

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Bronchoconstriction and -dilation change the relation of airflow and lung sounds. We have previously shown that bronchial narrowing by methacholine inhalation reversibly decreases the intensity of basic breath sounds at frequencies below 300 Hz. We have also shown that the flow required to generate inspiratory lung sounds increases during airway narrowing and decreases after bronchodilation. We assume that the tension of airway smooth muscle may have an effect on sound transmission. Since deep inspiration affects smooth muscle tone and causes bronchodilation in normals we postulated that flow-standardized lung sounds would show increased intensity after a deep inspiration. We studied five healthy non-smokers (four males), ages 29-51 y. Flow was measured at the mouth. Lung sounds were detected at the anterior right upper (RU) and posterior right lower lung (RL) using contact sensors. The sound signals were band-pass filtered, digitized and sampled as previously described. The subjects followed a series of breath maneuvers as indicated on a PC screen. These consisted of 1.) slow vital capacity, 2.) shallow breathing (<0.5 L/s for 120 s), 3.) breath hold (5 s), 4.) seven breaths at target flows (1.0-1.4 L/s), 5.) inspiration to total lung capacity, 6.) breath hold (5 s), then back to resting end-expiratory level, 7.) seven breaths at target flow, and 8.) breath hold (5 s). Average spectra of inspiratory sounds obtained from steps 4 and 7 were compared, using background noise information from steps 3 and 8, respectively. After subtracting background noise sound intensity was expressed in dB. We found increased breath sound intensity after deep inspiration (see Table):

	150-300 Hz		300-600 Hz	
	before	after	before	after
RU (n=5)	16.1 ± 4.2	19.0 ± 3.4	2.1 ± 4.9	5.1 ± 5.2 *
RL (n=4)**	14.2 ± 3.0	16.1 ± 4.6	2.3 ± 3.5	6.4 ± 6.6

* $p<0.05$ (paired t-test), ** one subject had artifacts in the RL recording

Further studies are currently underway to enlarge the sample size and to include patients with asthma where no effect or bronchoconstriction would be expected after deep inspiration.

This study was supported by the Children's Hospital Foundation of Manitoba, Inc.

Session V

Discontinuous Sounds and Cough

Lung sound analysis in asbestos-induced pulmonary and pleural disease

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Approximately 50 000 Finnish construction workers were exposed to asbestos during 20th century, and the incidence of asbestos-induced occupational diseases is presumed to rise until year 2010. The aim of this study was to compare lung sounds with findings in high-resolution computed tomography (HRCT) in asbestos-exposed workers (N=590). Based on the HRCT findings, the patients were divided into following groups: emphysema (E), fibrosis (F), combined emphysema and fibrosis (C), pleural thickenings (P) and adherences (A). Using computerized lung sound analyzer (HelSA) phonopneumogram, time-expanded waveform display, Fast Fourier Transform and sonagram spectum analyses were performed from lung sounds recorded from the back basal areas of both lungs. The total crackle count was significantly higher ($p<0.001$) during inspiration in C than in E, F, P or A and the third quartile frequency of the power spectrum (F75) was significantly higher ($p<0.001$) in C than in P, E or F. Root mean square of sound pressure was in inspiration on the left side greater in P than in E or A ($p<0.001$). There were no differences in the crackle waveform characteristics between the groups. In a conclusion, findings in lung sound parameters can help to separate between different asbestos induced lung disorders and emphysema. Patients with combined fibrosis and emphysema were characterized with highest frequencies and most profuse crackling.

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AUTOMATED LUNG SOUND ANALYSIS IN PATIENTS WITH PNEUMONIA.

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Background: Observer disagreement for the physical findings used to diagnose pneumonia is large. To circumvent this problem we have developed a computerized multichannel lung sound analyzer that detects and provides objective quantification of sounds from 16 sites simultaneously.

Objective: To determine whether objectively detected lung sounds in patients with pneumonia are significantly different than those in asymptomatic age matched controls.

Methods: A convenience sample of 62 patients, age 72±18 (mean±SD), in a community teaching hospital who had a clinical diagnosis of pneumonia and 62 controls, age 71±9, were examined with a 16 channel lung sound analyzer (Stethographics, Inc., Model 1602). An Acoustic Pneumonia Score (APS) was generated based on individual acoustic findings detected by the system including rates of wheezing and rhonchi, automatic counts of fine and coarse crackles as well as amplitude measurements of inspiration and expiration.

Results: Inspiratory crackles were present in 76% of these patients as compared to 23% of controls. Expiratory crackles were also more common-57% as compared to 5%. Wheezes and rhonchi were more common in the patients with pneumonia – 36% had wheezing or rhonchi in inspiration and 68% in expiration as compared to 2% and 0% respectfully in the controls. The APS averaged 21±16 in patients with pneumonia and 3±4 in controls, $p<0.0001$. The positive predictive power of a score higher than 6 was 0.90. Its sensitivity was 0.87 and specificity was 0.90.

Conclusion: Lung sound analysis can provide objective evidence supporting the diagnosis of pneumonia. The method is noninvasive and easy to perform even in severely ill patients.

Supported in part by a grant from Stethographics, Inc

EFFECT OF OBSTRUCTIVE LUNG DISEASE ON THE INVERSE POWER LAW ($1/F^{B}$) BEHAVIOR OF VOLUNTARY COUGHS

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Voluntary cough sounds were recorded for groups of normal men (N=27) and women (N=25) and were compared with cough sounds from men (N=27) and women (N=25) with obstructive lung disease. The sound recording system consisted of a mouthpiece attached to a long 1" tube that was terminated with an exponential horn to minimize acoustical reflections. A microphone was mounted tangential to the tube approximately 10" from the mouthpiece to record the sound pressure wave produced during a cough (Goldsmith *et al.*, Proc. of 3rd Int. Workshop on Biosig. Interp., 1999). The calculated power spectrum of each sound pressure wave was shown to follow a $1/f^{\beta}$ relationship with respect to its frequency content (f). A value of β was determined for each power spectrum by linear regression. Results indicated that normal male and female subjects had significantly higher values of β when compared to subjects of the same gender with obstructive lung disease. These findings indicate that there is a more rapid decrease in the high frequency content of coughs from both male and female subjects with obstructive lung disease.

1] Goldsmith WT, JS Reynolds, WG McKinney, KA Friend, D Shahan, and DG Frazer. A System for Recording High Fidelity Cough Sound Measurements. *Proceedings of the 3rd International Workshop on Biosignal Interpretation*, 1999; 178-81.

Session VI

Sounds in Airway Obstruction

ACOUSTIC CHARACTERISTICS OF PATIENTS WITH C.O.P.D.

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We looked for measurable acoustic patterns in the patient with C.O.P.D. that appeared to be different than the patterns seen in persons with other lung diseases or normals.

Fifty consecutive patients who bear clinical diagnosis of C.O.P.D. at Chest clinic were evaluated by Pulmonary Function Tests(Peak Flow, FVC, FEV1, FEV1/FVC ratio) at the same time of physical examination.

Lung sounds were recorded by STG1 System(Murphy) and stored in a portable computer.

31 patients were "obstructive " (O) by PFT (FEV1/FVC : 59.2+/-7.19%, FEV1: 38.0 +/- 6.1% pred.) , 14 patients were "restrictive " (R) (FEV1/FVC: 77.9 +/- 8.83%, FEV1: 65.7+/-8.10 % pred.) and 5 patients had "normal spirometry " (N): FEV1/FVC 87+/-9.30%, FEV1: 95.4 +/- 9.76% predicted)

Ages of these 3 patient groups were: (O):70.8+/-8.42, (R): 68.5 +/-8.25, and (N): 62.8+/-7.92.

We found that the period of Inspiration (I) to Expiration (E) ratio (I/E): were (O): .567+/-.075, (R): .739+/-.0839, and (N): .819+/-.090. Amplitude of the sounds over the chest wll were (O): 37.15 +/- 1.92, (R): 40.3 +/- 2.01, (N): 46.0 +/- 2.14

Presence of Wheeze/Rhonchi on chest were (O): 64.5%, (R): 50%, and (N): 20 % of patients.

With the exception of Bronchial Asthma, significantly reduced I/E ratio is the best parameter that can be used objectively to differentiate patients with C.O.P.D. from other lung diseases or normals.

Acoustic mapping of the timing of inspiratory breath sounds in Normal subjects and patients with COPD

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Breath sounds (BS) at the chest wall are thought to originate from turbulent airflow in larger airways. If this is the case there will be a time-delay between the sound reaching tracheal and chest wall microphones. However, if sound is heard at chest wall before the trachea then sound generation in smaller airways produced at lower flow rates is likely (tracheal sound only occurs when airflow is over 0.3L/s). We have timed the onset of inspiratory sounds (between 80 and 400Hz) at the trachea and at 14 sites over the chest wall using a Stethograph multi-channel recorder in 6 normals and 6 patients with COPD. Sounds were recorded during deep breathing over 20s and the onset of inspiration for each channel calculated automatically when the signal rose 20% above baseline. In Normals the average inspiratory onset at chest wall was -0.01s and in COPD -0.14s earlier than trachea (mean of all channels) ($P>0.05$). These results suggest the BS origin at the chest wall is not the trachea but more distal sites where turbulent flow is induced at lower flow rates. The difference between Normal and COPD may be associated with the increased inspiratory flow resistance in COPD. This observation may help characterise COPD acoustically.

Bronchial obstruction change frequency spectra of lung sounds

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Bronchial obstructions are characteristic for asthma and COPD. An objective, non-invasive method to detect these obstructions in long term is needed for an early and effective treatment. Electronic auscultation and analysis of lung sounds have a great potential for a monitoring of bronchial obstructions.

We recorded lung sounds from patients with COPD or asthma at five different positions with our lung sound analyzer (Gross, V. et al. Am J Respir Crit Care Med 2000; 162: 905-909).

The wheezing rate, crackle counts, median frequencies (F50) and different band powers were calculated for in- and expiration and compared with the results of auscultation and lung function test (FEV1, MEF50, TLC, R, ITGV). We investigated patients with asthma ore COPD and compared them with volunteers from our Marburg Respiratory Sound (MARS) database.

As expected, we found a significant changes in wheezing patients compared to normals. Patients with a decreased FEV1 (<80%) and without wheezing also show changes in frequency spectra.

We conclude, that frequency analysis of lung sounds is a suitable method for a basic, continuous monitoring of bronchial obstruction.

SPECTRAL CHANGES IN NORMAL BREATH SOUNDS ASSOCIATED WITH BRONCHODILATOR RESPONSE IN ASTHMATIC CHILDREN

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Spirometry before and after bronchodilator inhalation often reveals significant improvement in lung function of mild to moderate asthmatics, which indicates the presence of mild and reversible airway narrowing. Such a change in airway configuration must be associated with some changes in the normal breath sounds. We have reported that the spectral edge frequency (SEF: a frequency below which contains 99% of the total spectral power within 150~1,200 Hz) of a flow standardized inspiratory breath sound spectrum (after subtraction of background noise spectrum) is a sensitive indicator of mild airway obstruction in asthmatic children.

We analyzed 34 sets of lung sound recordings (with 2 contact sensors stuck on the right upper chest and the right lower back) from 20 asthmatic children (11 boys, 9 girls: 6~15 y/o), before and after bronchodilator inhalation (salbutamol 200 μ g). Method of recording and analysis was identical with our past reports. Spirometry following each lung sound recording revealed 17 sets of positive bronchodilator response (more than 7% increase in %FEV1). Each set of lung sound spectra was classified according to the patterns of changes in low, medium and high frequency power.

Thirteen of 17 patients (76.5%) had more than 30Hz reduction in inspiratory sound SEF. Further analysis of the changes in each frequency band revealed that the most prominent pattern was increased power in low and medium range frequency band, which may indicate increased local ventilation. The next important change was decrease in high frequency power, which may reflect increase in airway diameter.

Posters

RELATIONSHIP BETWEEN COUGH EVENTS DURATION AND COUGH EXPIRATORY FLOW-TIME IN RESTRICTIVE, OBSTRUCTIVE DISEASES

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Aim of this study was to compare the duration of cough acoustic (CAD) events and expiratory flows and time of cough (CPET;CFET) in restrictive (6 Patients-Pts-) and obstructive respiratory diseases (8Pts). All Pts were invited to give at least four big voluntary coughs before and during the forced expiratory efforts in a pneumothacograph (Lilly MasterLab, Jaeger). The cough sounds in free field, before the test where recorded (cass-corderTCS-100DV SONY) and then analysed by "Spectra Lab-FFT Spectral analysis System" (Poulsbo,WA) and audio card Tahiti for control. The mean values of cough events duration (CAD) before and during expiratory effort (CPEF,CFET) and VC, FEV1, FET were calculated for each patient and then the correlation coefficient of Pearson (P.c.) and Passing & Bablok comparison method were applied between the all measured parameters. The maximum of correlation was found between FET and CFET (P.c.= 0.718) and between CAD and CFET (P.c.= 0.330) in all studied patients. Good correlation was found between CAD and FEV1 when the restrictive and obstructive patients where considered separately. In COLD patients a good inverse correlation (P.c.=-0.264) was found between CAD and FEV1. The total duration of a cough events (from 200 to 2.000ms) in chronic diseases closely correlate with the functional pattern, of the underlain disease. Then the duration of cough's events can be very useful in the diagnostic procedures and in the studies of epidemiology. More data will be necessary to better define the pattern of CAD and increase the P.c. between CAD and the considered diseases.

Potentials and Barriers of Extensive Auscultatory Databases

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The long term monitoring and quantitative evaluation of diagnostic auscultatory events may provide a supplemental tool for the assessment of pulmonary disorders which often represent chronic conditions. However, new capabilities of digital audio and developed new formats do not always coincide with specific technical requirements of respiratory sounds acquisition or long term monitoring.

Specifically, the project focuses on technical requirements, capabilities, and trends in long term storage and assessment of auscultatory data and spectrum of storage schemes and media applicable to respiratory acoustics. A spectrum of storage schemes provides capabilities for a routine collection of auscultatory data from numerous patients, when desirable, although about 5 MB of disk space per minute of audio data is typically required using standard formats. In spite of memory space demands for extensive auscultatory databases, overall memory requirements are below, or comparable to, the level of one terabyte that is needed to store the X-ray films in a large hospital. Further, expanding utilization of *ehealth,* including online diagnosis encompassing an evaluation of auscultatory data, allow practically applicable transmission and storage of associated audio data files in a large patients' population.

Applicable, to lung sounds, capabilities of storage schemes and media, and limitations in management of auscultatory databases, with a particular emphasis on a long term monitoring, are evaluated and discussed.

DYNAMIC SOUND INTENSITY – FLOW MEASURMENTS DURING COUGH

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The sound intensity produced by individuals varies throughout a dynamic respiratory maneuver, such as a cough. To examine this phenomenon, volunteer subjects coughed into a system which measured the flow and sound pressure wave that emanated from the mouth. This system has been described in detail previously [1]. Sound intensity was plotted versus flow for the coughs and differences were noted between control subjects (N = 9) and those with obstructive lung disease (N = 51). In many cases, curves were similar during the initial impulse portion of the cough but began to show disparities after peak flow had been reached. Subjects with obstructive lung disease had a higher percentage of the total cough sound energy occur after peak flow (51.8 %) when compared to control subjects (40.8 %). This resulted in greater hysteresis of the sound intensity versus flow curves for control subjects.

1] Goldsmith WT, JS Reynolds, WG McKinney, KA Friend, D Shahan, and DG Frazer. A System for Recording High Fidelity Cough Sound Measurements. *Proceedings of the 3rd International Workshop on Biosignal Interpretation*, 1999; 178-81.

ALGORITHM OF SEPARATION CARDIAC AND LUNG NOISES

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Electronic recording and computer analysis of respiratory and cardiac sounds from the chest of normal subjects and patients with respiratory and cardiac diseases become a major preoccupation of many clinical research teams.

For those objectives it is important to provide distinguish of sounds generated by cardiac functions from breathing sounds and random interfering noises. Especially, it is important for separate of respiratory sounds, because cardiac sounds are easy to record (they are restricted to a somewhat small geographical region of the chest, low frequency range and can be recorded during breath-holding to prevent interference from respiratory sounds). On the other hand, the weaker heart sounds, which primarily result from abnormal hemodynamic function, diastolic murmurs, coronary stenotic murmurs and the like, are often masked by respiration sounds.

The object of the present work is to provide a method for quickly and accurately distinguishing sounds generated by cardiac functions from breathing sounds and random interfering noises. This method is based on multichannel computer analysis of the noise recordings from different regions of the chest. The two channel was used for distinguish of respiratory sounds, cardiac noises and random interfering noises. Then, using methods of confluent analysis, spectrums of three noncorrelations components (cardiac, respiratory and random noise) were obtaned.

RANK RESPIROSONOGRAMS OF BREATH SOUNDS

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On 26th conference ILSA by us were submitted rank algorithms of the breath sound classification. The algorithms under consideration use the information about power spectral density (PSD) of the breath sound. Advantage of rank algorithms is their tolerance to amplitude scaling factors of the signals. At the same time these algorithms react to changes of the PSD at occurrence of additional breath sounds (crackles, wheezes etc.). The size of changes PSD are essentially depends on duration of additional sounds, which, as a rule, is small. In this connection are used the short-time fourier transform for the forming respirosonogram, for description of the energy in the TF plane.
The specified idea is used in the report for introduction of the rank respirosonogram. For their formation is used the rank processing of the levels respirosonogram. Advantage of this representation is that it is less sensitive to a range of the levels respirosonogram. It allows in a number of cases to improve detection of weak sounds. Besides, offered rank representations allows improve to divide additional sounds. At last, it is convenient for comparison rank respirosonograms among themselves, as changes of ranks of spectral samples, instead of their absolute levels here are taken into account only.

A Randomised, Controlled Clinical Trial Using Acoustic Parameters Of Snoring Sound As Objective Outcomes Of Palatal Surgery For Snoring.

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Thirty-six non-apnoeic snorers were randomised to undergo uvulopalatal elevation palatoplasty or laser palatoplasty.Using a DAT recorder and an infrared camera, four hours of snoring sound and sleeping position were recorded pre-operatively, at 1 to 3 months and 6 and 12 months post-operatively. Records were digitised at 8KHz at 16-bit resolution. Sound files, comprising inspiratory sound of first 100 snores whilst sleeping supine, were analysed using specifically designed software. Snore duration (secs), loudness (dBA), periodicity (%) and energy ratios at the frequencies 0-200Hz, 0-250Hz and 0-400Hz as well as subjective outcomes were measured. Operation type and Body Mass Index (BMI) > or < 30,were investigated as between group variables.

Repeated measures ANOVA demonstrated statistically significant pre and post-operative differences for snore loudness, periodicity and energy ratios at frequencies 0-200Hz, 0-250Hz and 0-400Hz. (p = 0.004, 0.001, 0.001, 0.002 and 0.026 respectively.) No demonstrable difference between type of palatoplasty or between BMI. Poor correlation between subjective and objective data was demonstrated. Depending on outcome measure, 16.7% - 38.9% had no post-operative improvement, 8.3% - 30.5% experienced unsustained improvement, whereas 38.9% – 69.5% enjoyed sustained improvement. Changes in acoustic parameters of snoring sound following palatal surgery are demonstrable but short-lived. Development of methods to target individuals enjoying sustained success is essential.

Comparison Of Classifiers Based on Wavelet Networks and Artificial Neural Networks For Respiratory Sounds

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The computer-based systems for diagnosing diseases have been widely used in the last decades and similar studies have been performed to parameterize and increase the reliability of lung-sound based diagnosis by using computational techniques. In this study, wavelet network (WN) and conventional artificial neural network (ANN) based systems are used and compared for the classification of healthy and two-class pathological sounds which are acquired by two microphones on the chest area along with the air-flow signal. It is shown that the systems based on WNs have more accurate results and, therefore, are more convenient as a diagnosis aid. For each subject, expiratory and inspiratory cycles of data are divided into thirty segments. In WN classifier, the signal is decomposed to five levels using wavelet transforms and the reconstructed signal at each level is represented by AR parameters at the input of the wavelet network along with the volume constant indicating the subphase of the respiratory cycle. For the ANN, on the other hand, the AR parameters obtained from these segments and the volume constant are used as inputs for networks. The classifiers operate on the phases of the respiration separately and a comparison between the results of the two phases indicates that expiration is more useful in diagnosis.

Keywords: Artificial neural networks, wavelet networks, classification.

ACOUSTIC FINDINGS IN PATIENTS WITH CONGESTIVE HEART FAILURE COMPARED TO PATIENTS WITH PNEUMONIA

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PURPOSE: To determine whether there are clinically significant acoustic differences between congestive heart failure (CHF) and pneumonia (Pn).
METHODS: A convenience sample of 62 patients, in a community teaching hospital who had a clinical diagnosis of pneumonia and 40 patients with CHF were examined with a 16 channel lung sound analyzer (Stethographics, Inc., Model 1602). The Stethograph (STG) quantifies a number of acoustic parameters including rates and frequencies of wheezing and rhonchi, automatic counts of fine and coarse crackles, crackle timing and waveform characteristics, as well as the amplitude of inspiration and expiration.
RESULTS: Expiratory crackles occurred more often in patients with PN than in patients with CHF. 45% of the pneumonia patients had over 2 expiratory crackles per breath as compared to 18% of the CHF patients. The crackle waveform relaxation pattern (the ratio of the 2^{nd} half period to the 1^{st} half period of the crackle, R2) was also different between the two groups. R2 averaged over all inspiratory crackles was 2.0 ± 0.4 (mean $\pm$ SD) in PN and 1.3 ± 0.2 in CHF. Six patients with CHF and only 1 patient with PN had an R2 less or equal to 1.1. Eleven patients with PN and only 3 patients with CHF had an R2 equal to or bigger than 1.6. Other acoustic differences included a higher number of crackle zero crossings in CHF and the presence of higher frequency expiratory wheezing in Pn. We developed a score using the acoustic parameters that were different in CHF and Pn. In detecting Pn the total score had a sensitivity of 0.58, a specificity of 0.85 and a positive predictive power of 0.81.
CONCLUSION: Lung sound analysis provides some objective evidence that there are differences in acoustic patterns in Pn and CHF. A perspective study of this score is indicated.
CLINICAL IMPLICATIONS: Automated lung sound analysis may provide some help in distinguishing these common and often diagnostically perplexing conditions. The method is noninvasive and easy to perform even in severely ill patients.

ACOUSTIC IMAGING OF THE CHEST

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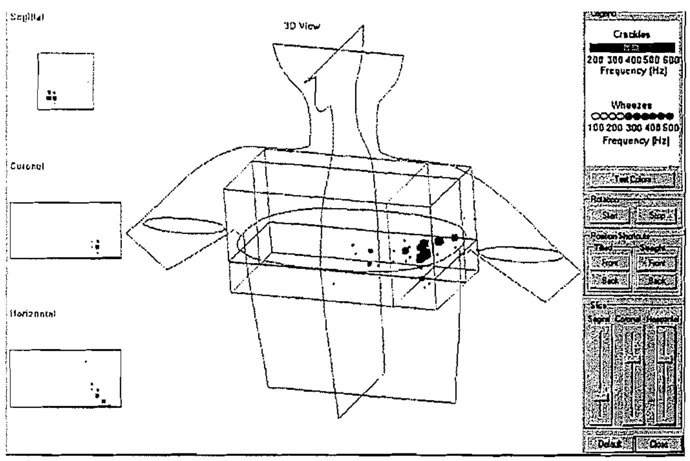
OBJECTIVES: To examine the relationship of the origin of lung sounds to disease processes in the lung.

METHODS: The stethoscope has been used for nearly two centuries to obtain acoustic information from the chest that is helpful in the diagnosis of pulmonary conditions. In recent years computerized methods have been developed to obtain this information more objectively and with greater precision. We have developed a multichannel lung sound analyzer (Stethograph or STG) that allows mapping of normal and abnormal lung sounds.

RESULTS: Using differences in the arrival time of sounds at the various microphones we have been able to provide 3-dimentional displays of sound that correlate with disease processes. Sound origin as detected by the STG correlated with chest X-ray and CT analysis in patients with focal tumors, bronchomalacia, and pneumonia. An example of data obtained from a patient with pneumonia using the STG is shown below. The arrow indicates the location of the abnormal sounds. The chest X-ray of this patient showed a left lower lobe pneumonia.



CONCLUSION: 3D displays of lung sounds correlate with chest X-ray and CT in certain lung conditions. The method has the promise of supplementing information obtained with computerized tomography and/or with magnetic resonance imaging. It has the particular advantage of being noninvasive.

Supported in part by a grant from Stethographics, Inc.

CRACKLE RATE DURING SHALLOW AND DEEPER THAN NORMAL BREATHING IN PATIENTS WITH IPF, CHF, AND PNEUMONIA.

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PURPOSE: To determine the influence of breathing effort and cough on the crackle rate in patients with IPF, congestive heart failure (CHF), and pneumonia (Pn).
METHODS: A convenience sample of 9 patients with IPF, 10 patients with CHF, and 17 patients with Pn in a community teaching hospital were examined with a 16 channel lung sound analyzer (Stethographics, Inc., Model 1602). The Stethograph (STG) automatically identifies and quantifies number of acoustic parameters including the crackle rate (CR). All patients were instructed to perform several breathing maneuvers in the following sequence: normal breathing, deeper than normal breathing, cough several times and repeat deeper than normal breathing, vital capacity maneuver, and repeat deeper than normal breathing. Each breathing maneuver was recorded for 20 seconds.
RESULTS: Inspiratory and expiratory CR were calculated separately. The results are shown in Table 1. Statistically significant changes are shown in bold ($p<0.05$).

	Shallow breathing	1st Deeper than normal		2nd Deeper than normal		3d Deeper than normal
Inspiratory crackle rate (crackles/breath)			Cough		Vital Capacity Maneuver	
Pn (n=17)	**5±5**	6±5		**5±4**		6±6
IPF (n=9)	25±9	24±8		**17±4**		23±6
CHF (n=10)	7±5	7±4		8±4		6±3
Expiratory crackle rate (crackles/breath)						
Pn	**3±4**	4±4		**2±3**		5±6
IPF	4±3	5±6		9±11		7±9
CHF	2±3	3±4		5±5		3±2
	Time →					

CR in each breathing maneuver was expressed in percent of CR during the first "deeper than normal" breathing maneuver. The results are summarized in Table 2.

	Shallow breathing	1st Deeper than normal		2nd Deeper than normal		3d Deeper than normal
Inspiratory crackle rate (%)			Cough		Vital Capacity Maneuver	
Pn (n=17)	**73±39**	100		93±74		92±49
IPF (n=9)	106±36	100		**75±22**		145±41
CHF (n=10)	146±93	100		120±49		89±32
Expiratory crackle rate (%)						
Pn	**54±37**	100		68±102		104±82
IPF	98±108	100		235±209		165±138
CHF	114±135	100		126±59		159±107
	Time →					

CONCLUSION: In patients with Pn CR had a tendency to be effort dependent with few or no crackles heard during shallow breathing. In patients with IPF and CHF a similar CR was identified during shallow and deeper than normal breathing. In patients with IPF and Pn, but not with CHF, CR had a tendency to decrease following the cough. CR in all three conditions did not change significantly following vital capacity maneuver.
CLINICAL IMPLICATIONS: Automated lung sound analysis may provide some clues that may help in distinguishing these common and often diagnostically perplexing conditions. The method is noninvasive and easy to perform even in severely ill patients.

DEVELOPMENT OF CRACKLES DURING SPINAL ANESTHESIA

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Background and Purpose: Atelectasis is known to occur during spinal anesthesia and can cause crackles that can be detected by auscultation. Continuous or frequent auscultation can be difficult or impractical. We were interested in determining if automated lung sound analysis could be used to detect abnormal lung sounds during spinal anesthesia

Methods: A 16 channel lung sound analyzer (Stethographics Model STG1602) was used to detect acoustic data at 14 sites over the posterior and lateral chest of a 69 year old white male undergoing spinal anesthesia during surgery to remove a hydrocoele. The device has electronic microphones imbedded in stethoscope chest pieces, which are in turn imbedded in soft foam for patient comfort and to reduce ambient noise. The operative procedure lasted 45 minutes.

Results: Prior to the procedure no crackles were detected. Fourteen minutes into the operation, fine crackles were detected at most lung sites with accentuation toward lung bases, particularly at the right base. At least 8 inspiratory crackles were identified in the first deep breath following the period of shallow breathing. In 6 recordings separated by at least 2 minutes the STG identified 11 ± 4 (mean $\pm$ SD) inspiratory crackles, range 8 to 17. In every recording after the patient took 3 deep breaths, the crackle count returned to zero.

Conclusion: The waveform characteristics and disappearance on deep breathing are consistent with atelectasis as the cause of these crackles. This presumptive finding of atelectasis would otherwise not have been detected.

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DETECTION OF PORCINE OLEIC ACID-INDUCED ACUTE LUNG INJURY USING PULMONARY ACOUSTICS

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To evaluate the utility of monitoring the sound filtering characteristics of the respiratory system in the assessment of acute lung injury, we injected a multi-frequency broadband sound signal into the airway of five anesthetized, intubated pigs, while recording transmitted sound over the trachea and on the chest wall. Oleic acid injections effected a severe lung injury predominately in the dependent lung regions, increasing venous admixture from 6±1 to 54±8 % ($p < 0.05$), and reducing dynamic respiratory system compliance from 19±0 to 12±2 ml/cmH_2O ($p < 0.05$). A two to fivefold increase in sound transfer function amplitude was seen in the dependent ($p < 0.05$) and lateral ($p < 0.05$) lung regions; no change occurred in the nondependent areas. High within-subject correlations were found between the changes in dependent lung sound transmission and venous admixture ($r = 0.82±0.07$; range 0.74 – 0.90) and dynamic compliance ($r = -0.87±0.05$; -0.80 – -0.93). Our results indicate that the acoustic changes associated with oleic acid-induced lung injury allow monitoring of its severity and distribution.

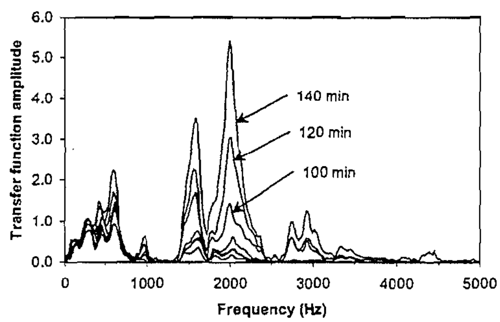

Figure: Multiple graphs of dependent lung Acoustic Transfer Function Amplitude during the worsening of Oleic Acid acute lung injury in one pig. Note the progressive prominence of the transmission peaks around 2 kHz. Arrows and times indicate duration from onset of Oleic Acid administration.

TRANSMISSION OF CRACKLES IN PATIENTS WITH INTERSTITIAL PULMONARY FIBROSIS AND CONGESTIVE HEART FAILURE.

Vyshedskiy, A. and Murphy, R., Faulkner Hospital, Boston MA.

Objective: Patients with IPF have crackles that are often mistaken for the crackles of CHF. Consequently they frequently receive diuretics inappropriately. The goal of this study was to find parameters that could reliably differentiate crackles of IPF from crackles of CHF.

Methods: A 16-channel lung sound analyzer (www.Stethographics.com) was used to collect 20s samples of sound from 40 patients with CHF and 18 with IPF. Some crackles appear at many microphones and others at only a few. To quantify the phenomena of the distance a crackling sound spreads or is transmitted, crackle waveforms occurring within the same 5ms interval were considered to be coming from the same crackle source. Further, the signal containing the highest amplitude crackle (mother crackle) was cross-correlated with the corresponding signals on other microphones (daughters). The ratio of the peak of the crosscorrelation function to the peak of the mother crackle autocorrelation function was calculated. For every crackle family the average of ratios over the chest characterizes the degree of sound transmission from the sound source to the chest - *crackle transmission coefficient* (CTC) – 0 = no transmission,100 = equal transmission to all channels.

Results: CTC averaged 14±4 for IPF and 22±7 for CHF ($p<0.001$). A plot of the CTC vs. frequency yielded a regression line that separated all but 2 of the CHF and 3 of the IPF patients from each other.

Conclusion: We have described criteria that differentiate IPF from CHF patients on the basis of crackle transmission coefficient and frequency. As this type of acoustical analysis is readily done at the bedside, it provides the promise of helping guide diuresis in such patients.

Supported in part by a grant from Stethographics, Inc.