26th INTERNATIONAL LUNG SOUNDS CONFERENCE

Berlin, Germany

September 20/21, 2001

PROGRAM

The 26th INTERNATIONAL CONFERENCE on LUNG SOUNDS

Presented by

The International Lung Sounds Association

September 20-21, 2001

Berlin, Germany

FINAL PROGRAM & ABSTRACTS

Organization

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Head, Section Pediatric Pulmonology
Zentralkrankenhaus
Bremen
Germany

Address of the International Lung Sounds Association

Raymond L.H. Murphy, M.D.
1153 Centre Street
Boston, MA 02130
Phone: (617) 983-7000, ext 1968
FAX: (617) 522-4156
e-mail: rmurphy@faulknerhospital.org

GENERAL INFORMATION

Conference Venue:
Thursday, September 20th - Hotel Mercure Tempelhof
Friday, September 21st - Hotel IBIS Berlin Mitte

Official Language:
English

Registration:
Registration will be held at the Hotel IBIS Berlin Mitte on Thursday, September 20th from 07:00 - 08:00.

Registration Fees:
Participants $150 (paid on site) spouses/companions $100
Students – no charge (proof of studentship required)

Certificate of Registration:
Participants will receive a certificate of registration

Posters & Presentations:
Posters will be on display on September 21st at the Hotel IBIS throughout the day. The poster discussion will begin at 15:00 on September 21st. The time for each poster or presentation is 15 minutes, including discussion.

Coffee Breaks & Lunch:
Coffee breaks and lunch will be served each day at the meeting venue and are included in the registration fee.

Social Evening:
Dinner will be served at the "Bar jeder Vernunft" on September 20th at 19:00. Return bus transfer will be available from the Hotel IBIS at 18:30.

Sponsorship:
Sponsorship by Jäger Tönnies, Würzburg, is gratefully acknowledged.

ILSA CONFERENCES
List of Presidents

1st	Oct 1976	Boston, MA Raymond Murphy
2nd	Sept 1977	Cincinnati, OH Robert Loudon
3rd	Sept 1978	New Orleans, LA William Waring
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24th	Oct 1999	Marburg, Germany Prof Peter von Wichert
25th	Sept 2000	Chicago, IL David Cugell
26th	Sept 2001	Berlin, Germany Hans Pasterkamp

PROGRAM

26th Annual Conference
International Lung Sounds Association
Berlin, Germany
September 20/21, 2001

Conference Location:
Thursday, September 20th

Hotel Mercure Berlin Tempelhof Airport
Hermanstraße 214/216
12049 Berlin
Tel: (030) 62 78 00

Conference Location:
Friday, September 21st

Hotel IBIS Berlin Mitte
Prenzlauer Allee 4
10405 Berlin
Tel: (030) 44 33 30

Thursday, September 20th
Hotel Mercure Tempelhof

Registration at Hotel IBIS	*0700 - 0800*
Bus Transfer	*0800 - 0830*
Welcome Address	*0845 - 0900*

Signal Processing (09:00 – 10:15)
Chairing: J.E. Earis & F. Dalmasso

The wavelet transformation for the detection of pathological lung sounds
V. Gross, et al., Marburg, Germany, and Thessaloniki, Greece

Classification of lung sounds by wavelet networks
Y.P. Kahya, et al.; Istanbul, Turkey

Selective bispectrum slicing: A novel method for robust system reconstruction of wheezes and stridors
L.J. Hadjileontiadis, et al.; Thessaloniki, Greece, and Marburg, Germany

Multiparametrical computer estimation of respiratory system status
V.T. Grinchenko, et al; Kiev, Ukraine

Rank and adaptive algorithms of breath sound classification
V.T. Grinchenko, et al.; Kiev, Ukraine

Break 10:15 – 10:30

Acoustics of Cough (10:30 – 12:00)
Chairing: M. Murphy & H. Pasterkamp

Bioacoustics of cough during bronchial inhalation challenge with methacholine
F. Dalmasso, et al.; Torino, Italy

Fractal dimensions of cough sounds
K.A. Friend, et al.; Morgantown, WV, USA

Tracheal sound and aerosol production during cough
W.T. Goldsmith, et al.; Morgantown, WV, USA

A validated system for automated monitoring of cough sounds
F. Dalmasso, et al.; Torino, Italy

Study on measuring method of cough sound features
A. Murata, et al.; Tokyo, Japan

Reported cough and wheeze: what do parents mean?
S.A. McKenzie; London, UK

Lunch (12:00 – 13:30)

Physiology and Modeling (13:30 – 14:45)
Chairing: N. Gavriely & R. Loudon

Modeling of sound propagation in human bronchial tree
V.G. Basovsky, et al.; Kiev, Ukraine

Aerodynamic (breath) sound of a curved duct
F. Sakao; HigashiHiroshima, Japan

The relationship of lung sound amplitude and duration to volume and flow
F. Davidson, et al.; Boston, MA, USA

Chest wall alterations in acoustic output during high frequency ventilation: The effect of deadspace
M. Goldstein, et al.; Glendale, CA, USA

Acoustic detection of diaphragmatic motion
R. Murphy, et al.; Boston, MA, USA

Break (14:45- 15:00)

Guest Speaker (15:00 – 15:45)
Dr. Peter T. Macklem, Professor Emeritus,
McGill University, Montreal, Canada
Phonospirometry for non-invasive measurement of ventilation

ILSA Business Meeting **(16:00 – 17:00)**

Bus Transfer **(17:00 - 17:30)**

Social Evening and Dinner 18:30

Friday, September 21st
Hotel IBIS Berlin Mitte

Recording and Analysis (08:45 – 10:00)
Chairing: R. Murphy & L. Hadjileontiadis

Reducing noise of accelerometer-type stethoscopic sensors
F. Sakao; HigashiHiroshima, Japan

Bronchophonographia is a method of a lung pathology functional diagnostic in childhood
N. Geppe, et al.; Moscow, Russia

Intrathoracic stethoscope during videoassisted thoracic surgery
T. Suzuki, et al.; Yokohama, Japan

Reproducibility of crackle counts in normals and patients with stable fibrosing alveolitis
J. Earis, et al.; Liverpool, UK

Standardization of computerized respiratory sound analysis: review of the European task force (CORSA)
A. Sovijärvi; Helsinki, Finland

Break (10:00 – 10:30)

Clinical Studies (10:30 – 12:00)
Chairing: A. Sovijärvi & V.T. Grinchenko

Lung sound patterns in common pulmonary disorders
R. Murphy, et al.; Boston, MA, USA

Power spectral analysis of lung sounds in patients with emphysema and in normal subjects
H. Nakano, et al.; Fukuoka, Japan

The evaluation on the efficacy of the phonopneumograph in the non-invasive diagnosis of interstitial pneumonia
H. Ono, et al.; Tokyo, Japan

Expiratory crackles in bronchial obstruction may be strongly associated with expiratory wheezes
H. Melbye; Tromsø, Norway

Integration of auscultation and telecommunication technologies
C. Druzgalski; Long Beach, CA, USA

"Breath by breath" - An educational video for parents of young children
D. Zielinski, et al.; Winnipeg, Canada

Lunch (12:00 – 13:30)

Airway Obstruction (13:30 – 14:45)
Chairing: S. Kudoh & D. Frazer

Nocturnal wheezing and sleep
B. Reinke, et al.; Marburg, Germany

Acoustic monitoring of pediatric croup in the emergency department
A. Klein, et al.; Haifa, Israel

"Expiratory wheeze" in a patient with "vocal cord dysfunction"
S. Ishikawa, et al.; Boston, MA, USA

Normal breath sound analysis for the evaluation of small airway obstruction
M. Takase, et al.; Tokyo, Japan

The acoustic properties of stridor
N. Gavriely, et al.; Haifa, Israel

Break (14:45 – 15:00)

Poster Discussion (15:00 – 16:30)
Chairing: S. Ishikawa & Y.P. Kahya

Long-term recording of lung sounds in patients with pneumonia and bronchial breathing
K. Mack, et al.; Marburg, Germany

Nocturnal wheezing and antiobstructive therapy
U. Koehler, et al.; Marburg, Germany

Objective measurement of lung sounds in chronic obstructive lung disease
R. Murphy, et al.; Boston, MA, USA

Objective measurement of wheezes and crackles in congestive heart failure and bronchial asthma
R. Murphy, et al.; Boston, MA, USA

Measurement of snoring before and after palatoplasty
J.E. Earis, et al.; Liverpool, UK

How regional are lung sounds?
H. Kiyokawa, et al.; Winnipeg, Canada

Closing Remarks 16:30 - 16:45

ABSTRACTS

AUTHORS INDEX

THE WAVELET TRANSFORMATION FOR THE DETECTION OF PATHOLOGICAL LUNG SOUNDS

V. Gross[1], L. Hadjileontiadis[2], Th. Penzel[1], U. Koehler[1], P. von Wichert[1], C. Vogelmeier[1]
[1]*Dept. of Medicine, Div. Pulmonary and Crit. Care Med.; Philipps-University Marburg, Germany*
[2]*Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece*
www.lung-sound.de

Introduction: Wavelet transformation based analysis is a good tool for detecting and analyzing discontinuous (crackles) and continuous (bronchial breathing) pathological lung sounds. Normally, lung sounds were analyzed with Fast Fourier Transformation (FFT). We developed a combined method of frequency band analysis using Wavelet Transformation (WT) to extract parameters from lung sound recordings that could detect typical pneumonia lung sounds (crackles, bronchial breathing) .
Methods: The lung sounds of patients with one-sided pneumonia were recorded simultaneously with two air-coupled microphones at standardized airflow. The exact pneumonia position was chosen by auscultation and by x-ray analysis. A symmetric position to the median-sagittal plane was kept in all cases as control. The signals were prefiltered with an antialaising-filter and digitized with 12 bit resolution and a sampling rate of 5512 Hz. After that the respiratory-signals were analyzed with WT based frequency band analysis (MATLAB 5.3, wavelet-toolbox, Daubechie Wavelet with 8 coefficients). We computed parameters to detect bronchial breathing and crackles sound patterns.
Results/Conclusion: 20 Patients with one-sided pneumonia and typical pathological lung sounds (bronchial breathing, crackles) were investigated. Our parameters based on wavelet transformation are able to detect typical pneumonia lung sounds at an early stage of the disease in all 20 patients.

CLASSIFICATION OF LUNG SOUNDS BY WAVELET NETWORKS

YASEMIN P. KAHYA* and METE YEĞINER**
*Dept. Elec. Eng., Boğaziçi University, Bebek 80815, Istanbul, Turkey; **Biomedical Eng. Institute, Boğaziçi University, Bebek, 80815, Istanbul, Turkey

The wavelet networks (WNs) can be used for diagnosing the respiratory diseases. In this paper, it is shown that WN is feasible for classifying the healthy subjects and patients. Our database consists of obstructive patients and healthy subjects. The respiratory sound signals taken by two microphones and flow signal were simultaneously recorded by data acquisition hardware. One respiratory cycle is considered for each person and they are separated into two parts, expiratory and inspiratory phases. These two phases are then divided into three subphases. Our classification method is based on the features extracted by wavelet transforms but additional features are also used to enhance the performance of the classifier and to get comparative results. Our classifier is an Artificial Neural Network (ANN) with single hidden layer. It is trained by the backpropagation algorithm. The classifier is applied to each subphase. Decisions taken for each one are combined to reach to the final result for that subject.

SELECTIVE BISPECTRUM SLICING: A NOVEL METHOD FOR ROBUST SYSTEM RECONSTRUCTION OF WHEEZES AND STRIDORS

L. J. Hadjileontiadis[1], F. A. Papadopoulou[1], C. D. Saragiotis[1], G. I. Tremoulis[1], V. Gross[2], Th. Penzel[2]

[1]*Dept. of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece (http://psyche.ee.auth.gr)*
[2]*Dept. of Medicine, Div. Pulmonary and Crit. Care Med.; Philipps-University Marburg, Germany (www.lung-sound.de)*

Nowadays, several nonparametric system reconstruction methods based on higher-order spectra are reported in the literature. Focusing on the use of third-order spectrum spectra, namely the bispectrum, there are two choices: either to utilize the whole bispectrum information or to use one-dimensional (1-D) bispectral slices. The latter is adopted in this paper, based on the work initially proposed by Pozidis and Petropulu [*IEEE Trans. on Signal Processing*, vol. 46, no. 12, pp. 3360-3377, Dec. 1998]. By applying a system reconstruction method based on preselected 1-D bispectral slices it potentially allows us to avoid regions where bispectral estimates exhibit high variance or regions where they are expected to be zero, such as in the case of bandlimited systems and additive Gaussian noise. Under this perspective, a successful selection of bispectral slices could be achieved when based on the characteristics of the corresponding power spectrum. In that way, the high amplitude samples are revealed and thus result in the appropriate selection of 'good' bispectral slices.

Wheezs and stridors are ideal candidates for the application of the aforementioned system reconstruction method, since their power spectra exhibit prominent peaks in the region of 400-800 Hz. Consequently, the use of bispectrum from the slices of that region provides an enhanced tool for system reconstruction of the associated pathology that produces the abnormal lung sounds. Experimental results from the application of the proposed method on wheezes and stridors drawn from two preclassified lung sound databases prove that the characteristics of the system that is associated with the underlined pathology (such as asthma) could be revealed, giving rise to a more accurate description of the generation mechanisms of the pulmonary dysfunction. Due to the employment of higher-order spectrum the method exhibits a robust performance even in noisy cases. Application of the proposed method on an expanded database with clinical lung sound recordings is currently in progress.

This work was partially supported by the Institution of State Scholarships of Greece (I.K.Y.) and the German Academic Exchange Program (DAAD), under the Greek-German Scientific Collaboration Programme 'IKYDA 2000 2001'.

MULTIPARAMETRICAL COMPUTER ESTIMATION OF RESPIRATORY SYSTEM STATUS

Victor T. Grinchenko, Anatoliy P. Makarenkov, Aleksandr G. Rudnitskii.
Institute of Hydromechanics of National Academy of Sciences, Kiev, Ukraine

Efficiency of computer diagnostics of lung diseases determinative depends on overcoming difficulties connected with large individual variability of the lung sound characteristics. Potentially opportunity of overcoming of the specified difficulty is caused by high information density of respiratory sounds. This allows to enter into consideration the large number of parameters describing a status of the respiratory system. The given presentation is devoted to formation of some feature set of determining parameters and testing of their information completeness. The parameters are not directly connected with traditionally used in medical practice. The researches were carried out in the Kiev children clinical hospital. Training set of patients was formed from 25 healthy children in the age of from 7 till 14 years. The examined set was formed from 26 children of the same age group with various respiratory diseases. The six most diagnostic useful parameters were selected at the basis of one and two channel registration and processing of signals. On the basis of entered parameters an algorithm has been developed to solve the problem of dichotomy: ill - healthy. This gives a way for computer monitoring of patients with lung dysfunctions.

RANK AND ADAPTIVE ALGORITHMS OF BREATH SOUND CLASSIFICATION

Victor T. Grinchenko, Vladimir V. Krizhanovsky

Institute of Hydromechanics of National Academy of Sciences, Kiev, Ukraine

The computer diagnosis of lung diseases is grounded on using of algorithms of the breath sound classification. To use the adaptive algorithms one has to possess a large value of initial information concerning the types of diseases and registration system characteristics. In the presentation some sorts of the adaptive and rank classification algorithms to solve the dichotomy problems: ill – healthy are discussed. The algorithms under consideration use the information about power spectral density (PSD) of the breath sound. The monotonic decrease in level with growth of frequency is very important features of the PSD of the healthy patients. Existence of a pathology produces different sorts of disturbances in the monotonic behavior. This difference is used to construct the new adaptive and rank algorithms. The testing of the algorithms is carried out on the breath sound data for the healthy patients and the patients with bronchitis and pneumonia. In the presentation it is shown that the rank algorithms are comparable on efficiency to adaptive algorithm. They do not require training records of breath sound and are steady against transformations of scale.

BIOACOUSTICS OF COUGH DURING BRONCHIAL INHALATION CHALLENGE (BIC) WITH METACHOLINE

F. Dalmasso, E.Isnardi, L.Sudaro , R.Mantovano, R.Bellantoni.

Division of Pneumology, Patophysiology and Bioacustic Respiratory LAB. Mauriziano Umberto I Hospital TURIN **-ITALY**

BIC with Methacholine (MCh) cause cough frequently. Aim is to assess incidence, timing and acoustic properties of cough during the BIC-MCh carried out according to SEPCR1983. 68 Patients (Pts),53 males,15females, average age 34.2 ±16.2 have been assessed for cough between manoeuvres of FEV1, by CorderTC-m-59v. The signal analysed by "SPECTRA LAB-FFT System" was estimated in timing, total and single duration of "Bursts", frequency (F) of total and single one burst frequency, domain by FFT and by sonogram.. 39 Pts, (57%) were positive to the test and 29 (43%) were negative. 15 Patients (22%) have coughed during test and 3 of them (20%) were positive.

Cough's duration (m ± SD)

	Total	BIC +	BIC -
ms	317.07 ± 119.6	280.83 ± 57.6	324.25 ± 104.8

	I Burst	II Burst	III Burst
Ms	90.7 ± 63.8	160.02 ± 77.8	109.63 ± 37.7
n Pts	15	15	11

Cumulative dose (m ± SD) stimulanting cough

	Total	BIC +	BIC -
mg/ml	0.33 ± 0.4	0.03 ± 0.0	0.38 ± 0.4
Timing (min)	> 0.15 < 6	≤ 1	> 4 , < 6

Cough's frequency spctrum (F) and relative peaks (p)

	Fp1 (Hz)	Fp2 (Hz)	Fp3(Hz)	Fmax(Hz)
m	458	1641.71	2682.70	3011
	±	±	±	±
sd	119.03	416.73	358.14	618.17

The acoustic pattern of the spectrum is characterized by a peak with a maximum of intensity about 500 Hz and with two or three peaks and with a maximum of frequency about 5.000 Hz. The pattern of the spectrum with two peaks is the most frequent . Ther'is not significant difference (p<0.02) between the mean values of the spectra of coughs sounds of TPBA+ and TPBA- subjects.

Cough's blows from BIC are characterised from a total duration < 500ms. In series with 2 bursts, blows turn out < 250 ms. In 73% of Pts the cough is constituted by 3 bursts. Provocation of cough could occur by the Aδ receivers (RAR) in the Pts with BIC+ and via receivers C in BIC- Pts. Cough's BIC are similar to those of cough asthma and asthma due to exercise.

FRACTAL DIMENSIONS OF COUGH SOUNDS

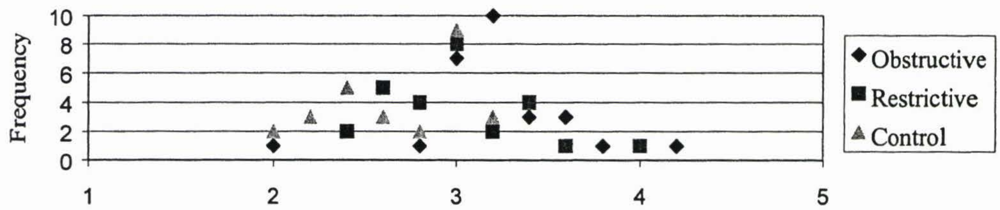
K.A. Friend, W.T. Goldsmith, W.G. McKinney,
J.S. Reynolds, S.A. Watkins, D.G. Frazer

National Institute of Occupational Safety and Health
Health Effects Laboratory Division
Engineering and Control Technology Branch
Developmental Engineering Research Team
Morgantown, WV

This research examines the variations in fractal dimensions of cough sounds of patients with lung disease and controls with no known pulmonary pathology. Cough sounds (n=27 obstructive, n=27 restrictive, n=27 controls) were obtained with a previously described recording system (Goldsmith, et al., Proceedings 3rd International Workshop on Biosignal Interpretation, 1999) from subjects awaiting pulmonary function testing at the West Virginia University Hospital. The power spectrums of the cough sound pressure waves were graphed on log-log scale and the fractal dimensions (slope of the inverse power-law relationship) were determined from linear regression.

The following graph shows the histogram of the fractal dimensions for the three groups. It can be seen that 67% of the obstructive group, 30% of the restrictive patients and 11% of the control group coughs had fractal dimension greater than 3.

Histogram



Preliminary statistical analysis showed parametric data sets, leading to a one way ANOVA that showed a statistically significant difference (P=<0.001) of the mean values among the three groups. A post-hoc all pairwise multiple comparison (SNK) test showed the following values:

Control vs. Obstructive	$P < 0.001$
Control vs. Restrictive	$P = 0.002$
Restrictive vs. Obstructive	$P = 0.028$

These preliminary results indicate the potential utility of this approach.

TRACHEAL SOUND AND AEROSOL PRODUCTION DURING COUGH

W. T. Goldsmith, K.A. Friend, B. Jones,
J. Day, A. A. Afshari, J. Barkley and D. G. Frazer
E&CTB, HELD, NIOSH, Morgantown, WV 26505

A measurement system was designed to examine the correlation between tracheal sounds and aerosol production during exhale maneuvers. The system was enclosed in a chamber and maintained at 37E C to minimize alterations in aerosol characteristics due to condensation-evaporation. Air expired through a disposable mouthpiece entered a spirometer (SensorMedics 762609) which measured the flow and volume of the maneuver. An optical particle analyzer (Grimm 1.108) was used to characterize aerosols between 0.3-20 um which were recovered from the spirometer. Tracheal sounds were recorded with a Larson Davis type 2530 microphone using a modified technique for measuring breath sounds described previously [1]. Custom software was developed to acquire, analyze, display and store the data. The system was evaluated as five healthy volunteer subjects performed three voluntary coughs each into the system after breathing HEPA filtered air for two minutes.

In general, aerosol mass was higher for coughs with increased sound power. Interestingly, one of the subject's particle counts were over an order of magnitude greater than the others despite fairly similar peak flows, volumes, particle mass and tracheal sound amplitudes for all the coughs.

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.

This project is supported in part by FAA IAG 97-11.

A VALIDATED SYSTEM FOR AUTOMATIC MONITORING OF COUGH SOUNDS

F. Dalmasso, R.Mantovano, A.Mazzucato

Divisione di Pneumologia e Lab. Fisiopatologia ed Acustica Respiratoria Ospedale Mauriziano "Umberto I". Torino, Italy.

The *"reported"* cough,above all nocturnal,has repeatedly been found to have poor agreement with the *"recorded"* cough particularly in children and adolescent.The usefulness of measure and count the cough's sounds is obvious..Various apparatus have been used by sticking sensors to the chest and abdominal wall for accurate detection of sounds.Aim of the study is to provide validation to an *"automatic"* system to count cough by a 'free field' microphone in a 'single-bed' room..In 15 Patients with COLD, cough was monitored for each patient from 6 to 8 hours; in 6 during the night,in 9 during the day. The used system consists of: 1.) A portable Integrating Sound Level Meter providing Leq and real time frequency by FFT (L&D,Provo,USA). 2.) Software N&V works (Spectra MI,I) for subsequent analysis. 3 .) Audio Card File for acquisition, pattern recognition of emitted sounds.The automatic count of cough's events was based on : a.) Time duration (180-2200 ms). b .) Relative intensity in dB, depending on background noise. c .) Spectrum peaks (at about 560, 2290 ,5800 Hz) according our data in COLD coughs. The *"VALIDATION"* of the 'automatic' apparatus was obtained by comparison of : 1.) The simultaneous tape recorder .2 .) Two acoustic expert observers. 3 .) Audio Card.The Agreement of the measures between used systems was evaluated with "K" coefficient of Cohen and the test of Bland –Altman (Δ±2SD).

Method	n° Cough's blows	K coef. Cohen	Bland-Altman
Phonometer LD 824	138	+ 0.8	0.6
Tape Recorder DAT	137	+ 0.7	0.6
Observer 1	134	+ 0.7	0.5
Observer 2	133	+ 0.7	0.5
N& V System	144	+ 1	0
Audio Card	144	+ 1	0

The newly described "automatic "system seem reliable apparatus for coug monitoring for up to 24 h, enough for clinical and researche purposes in particular in sleep studies for snoring and cough measure.

Study on measuring method of cough sound features

Akira Murata1), Atsuo Shibuya2), Nao Ohta2), Hiroshi Ono1), Shoji Kudoh1)
1) The 4th Department of Internal Medicine, Nippon Medical School, Japan
2) Japan Women's University, Tokyo, Japan

For the purpose of developing a cough monitor, we analyzed cough sounds acoustically and searched parameters to discriminate the cough sounds from the other sound (voice and noise sounds).

The cough sounds from 5 subjects (3 patients with acute bronchitis and 2 healthy subjects) were recorded using DAT recorder simultaneously through a bone conductive microphone attached to their external ear canal and an electlet condenser microphone in free air (method 1), and the cough sounds from 2 subjects with acute bronchitis_were recorded during sleep, by IC recorder with 8 KHz sampling interval through the throat microphone attached on their necks and an electlet condenser microphone in free air (method 2).

To extract the characteristic of cough sounds, we transformed the sound waves to sound level (amplitude), from which a duration of each cough, a period of time from initial deflection to the maximum sound level, a slope of initial deflection, sharpness of amplitude curve were measured. And we analyzed the sounds with discriminative function to extract cough sounds using these parameters (method 1). And we analyzed the cough sound during sleep by the same method and categorized them into 6 kinds of patterns. And then we made algorisms to discriminate cough sounds using the 6 kinds of parameters.

As a result, we could discriminate cough sounds from the recorded sounds with a probability of 82 % in method 1 and with 90% in method 2.

Reported Cough and Wheeze: what do parents mean?

S.A. McKenzie
Consultant Paediatrician
Royal London Hospital
Whitechapel, London E1 1BB

Persistent and isolated cough (PIC) used to be considered asthma [1]. Audio-visual studies have shown that parents report accurately whether their child is coughing or not, are able to say whether cough gets better or worse but not by how much. These studies have also shown that children often cough during sleep[2], and that sleep is no shorter than that reported in children who do not cough. Thus parents can be assured that sleep is not as disturbed as they perceive. The accurate reporting of cough and its change suggest that accurate cough counting may not always be necessary in a clinical trial.
Clinical and epidemiology studies have shown that PIC is quite unlike asthma and should not be treated as such[3-5].

As well as cough, epidemiology questionnaires ask parents about wheeze. We have shown that many parents have a different understanding of wheeze than doctors[6] and that audio-visual tapes can help[7]. Parents locate sounds better than describing them. At least 30% of all parents use other words for wheeze and about 30% label other sounds as 'wheeze'.

For epidemiology studies, the misclassification of wheeze may not matter because if respondents over and under-report, prevalence may be similar. For clinicians however, making an accurate diagnosis of asthma is not as easy as it might seem. As the gold standard for asthma, should we improve our understanding of reported sounds accompanying breathing i.e. keep the history of cough, wheeze and shortness of breath, or should we take an objective measurement of airways hyperresponsiveness?

1 Chang AB. Isolated cough: probably not asthma. *Arch Dis Child* 1999;80:211-213.
2 Fuller P, Picciotto A, Davies M, McKenzie SA. Cough and sleep in inner-city children. *Eur Respir J* 1998;12:426-431.
3 Kelly YJ, Brabin BJ, Milligan PJ, Reid JA, Heaf D, Pearson MG. Clinical significance of cough and wheeze in the diagnosis of asthma. *Arch Dis Child* 1996;75:489-493.
4 Wright AL, Holberg CJ, Morgan WJ, Taussig LM, Halonen M, Martinez FD. Recurrent cough in childhood and its relation to asthma. *Am J Respir Crit Care Med* 1996;153:1259-1265.
5 McKenzie SA, Bridge PD, Healy MJR. Airways resistance in pre-school children with wheeze and cough. *Eur Respir* 1999;15:833-838.
6 Cane RS, Ranganathan SC, McKenzie SA. What do parents of wheezy children understand by "wheeze"? *Arch Dis Child* 2000;82:327-332.
7 Cane RS, McKenzie SA. Parents' interpretations of children's respiratory symptoms on video. *Arch Dis Child* 2001;84:31-34.

MODELING OF SOUND PROPAGATION IN HUMAN BRONCHIAL TREE

Vladimir G. Basovsky, Viktor T. Grinchenko, Olga. I. Vovk, Igor. V. Vovk
Institute of Hydromechanics of National Academy of Sciences, Kiev, Ukraine

The understanding of features of sound propagation in the bronchial tree enables to increase efficiency of data processing about the breath sound registered on surface of body. Acoustical and mathematical model of a single airway, which takes into account the wall elasticity, has been used to study the sound propagation process. The general solution of the acoustical problem for a single airway allows to develop an algorithm of the sound calculation in the bronchial tree with interaction effects between neighboring airways. The acoustical characteristics of the bronchial tree are given in the frequency range 20 to 2000Hz. It was shown that the input impedance of the bronchial tree is similar to the impedance of the acoustical wave guides of the finite length with a sequence of resonances and antiresonances. The calculated data have been compared with known experimental ones. The model used to compare importance of the two processes of sound energy dissipation: losses in the visco-elastic walls and losses from the radiation in the surrounding tissues. The phase velocity of the sound wave in the bronchial tree was calculated. The sufficient dependency of the phase velocity on frequency and the place of the bronchial tree was shown.

AERODYNAMIC (BREATH) SOUND OF A CURVED DUCT

Fujihiko SAKAO
School of Engineering, Kinki University
Takaya, Higashihiroshima, Japan 739-2116

Aerodynamic sound generated by flow in curved ducts was observed and compared with that of a straight duct. The ducts are of square cross-sections. One of the side walls is made soft to permit sound transmission outside. The sound is observed outside wall just like the human breath sound. The aim of this experiment is to model breath sound with the neck bent by, e.g., use of a pillow: In such situation, the breath sound is known to be enhanced usually.

The sound observed with a microphone 2cm off outside the soft wall is increased in general by duct curvature, suggesting effects of unsteady flow separation on the inner wall. There is, however, some irregularity.

Low frequency components seemed not to change with the duct curvature. It is beyond 1kHz where the sound is increased by curvature. With the duct of soft wall on the outer (of curvature) side, however, the observed sound is found to be *decreased* by the curvature in low frequencies, while over other ranges, remain the same as the straight duct. This fact can be related with the configuration where the average sound-source to microphone distance may be larger than the straight case. Taking this fact into consideration, the features of experimental observation could be explained reasonably.

THE RELATIONSHIP OF LUNG SOUND AMPLITUDE AND DURATION TO VOLUME AND FLOW

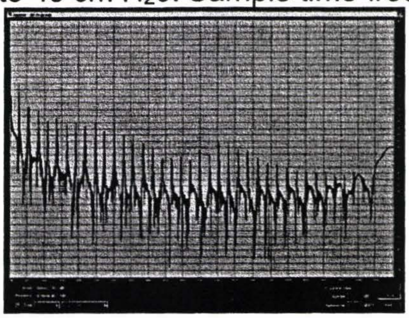
F. Davidson, C. House, V-A Power, C. Wilson and A. Vyshedskiy
Faulkner and Lemuel Shattuck Hospitals, Boston, MA, USA

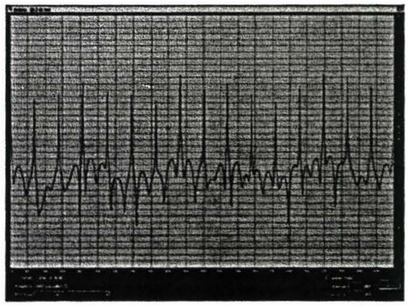
Purpose: To study the relationship of lung sound amplitude to volume and flow.
Methods: Normal subjects inhaled preset flows and volumes from a T Bird ventilator via a mouth piece while lung sounds were recorded at 14 chest sites and at the trachea using a multi-channel lung sound recorder (Stethographics Mod.301). The input flow rates were .4, .6, .8, 1.0,1.2 and 1.4 Liters per minute. Volumes were .4, .8 and 1.2 Liters. A running average root mean square value (RMS) was calculated at each site during each inhalation and exhalation. The RMS was multiplied by the duration of the signal to estimate acoustic power at each site.
Results: Except at the 0.4L/min flow rate, the average sound amplitude (RMS) increased with increasing flow (Figure 1). As the volume delivered by the ventilator increased, the average inspiratory amplitude was relatively stable for flow rates in the physiological range (.4, .6 and .8 L/min). At higher lung volumes amplitude increased with increasing volume as the flow rates increased (Figure 2). Acoustic power (average RMS x time) consistently increased with increasing volume (Figure 3). Inspiratory time, measured acoustically, decreased with increasing flow rates and increased with increasing volumes. Examples of sound patterns in several lung diseases will be presented which show regional variation in sounds with regional pathology. These include a patient with sarcoidosis and a bulla, a patient with a bulla before and after resection and a patient with marked elevation of a hemidiaphragm.
Conclusion: These observations provide support for the concept that lung sounds provide useful information about global and regional ventilation.

CHEST WALL ALTERATIONS IN ACOUSTIC OUTPUT DURING HIGH FREQUENCY VENTILATION (HFV): THE EFFECT OF DEADSPACE.

Mitchell Goldstein, Philip Sorkin, Joseph Correnti, Glendale Memorial Hospital, Glendale, CA

The introduction of deadspace to the HFV circuit is trivialized. Many institutions attach in-line catheters, "extenders", and "positioners". Since HFV is described as "deadspace" ventilation, little information exists on the effect of deadspace itself on ventilation. Changes in deadspace may be clearly discernable using time-frequency domain analysis of acoustic transmission at the chest wall. A test lung was ventilated with an InfantStar 950 using HFV. An Andrea microphone was attached to the exterior of the test lung and connected to a PC with an M-Wave sound card sampling at 22kHz. Sampling was conducted using P_{AW} of 10 cm H_20, frequency 10Hz, and flow 10 lpm. Deadspace was varied from 25 to 0cc. Amplitude was varied from 10 to 40 cm H_20. Sample time-frequency domains are presented below:





Figures 1 and 2: 40 cm amplitude shown with 25 and 0 cc deadspace, respectively.

Changes in amplitude peaks and frequency of peak elements are evident from these figures. The changes in the FFT during time-frequency domain analysis are distinctive and quantifiable for increased deadspace ventilation.

ACOUSTIC DETECTION OF DIAPHRAGMATIC MOTION

R. Murphy, V-A Power, R.Paciej and A. Vyshedskiy
Faulkner Hospital, Boston, MA, USA

While diaphragmatic motion can usually be detected by percussion by experienced clinicians, fluoroscopy is used when there is doubt or more objective documentation is warranted. To determine whether the motion of the diaphragm could be detected acoustically, subjects with no history of lung disease and who had normal pulmonary function were studied using a 16 channel lung sound analyzer. Microphones were placed in a 4x4 array over the lower right back. An acoustic signal was introduced at the mouth both at total lung capacity (TLC) and at residual volume (RV). The acoustic signal was clearly seen in all channels at TLC, but was not seen or was markedly diminished in the lower, central microphones at RV. Results are consistent with diaphragmatic motion being detected by lung acoustical analysis. The technique is easy to perform and avoids radiation exposure. It is less expensive than fluoroscopy and can be done at the bedside.

REDUCING NOISE OF ACCELEROMETER-TYPE STETHOSCOPIC SENSORS

Fujihiko SAKAO
School of Engineering, Kinki University
Takaya, Higashihiroshima, Japan 739-2116

A contact stethoscopic sensor of accelerometer-type is known to be sensitive to noise traveling along its lead cable: Occasional touching or frictional movement on the cable may cause a very large noise. For this reason, sometimes a long span of the cable is kept in the air: It must be fairly inconvenient in practical applications. This investigation is aimed at establishing a way how to prevent such noise from disturbing the sensor output.

A simple way to cut off noise traveling along the cable to the sensor is to set a large mass in the midway of the cable. By experiments, this was proven to be indeed effective, especially for the high frequency components. A mass of only 5 grams attached to the cable can reduce the noise even by more than 10dB's. In a practical application of this principle, a pre-amplifier cartridge set near the sensor can serve as the necessary mass.

Another disadvantage of a contact sensor is its relatively high sensitivity to ambient acoustic noises. This might be overcome by covering the sensor together with the skin around it with a massive canopy. This was also proven to be effective, although it may cause some inconvenience for clinical applications.

BRONCHOPHONOGRAPHIA (BPG) IS A METHOD OF A LUNG PATHOLOGY FUNCTIONAL DIAGNOSTIC IN CHILDHOOD

Geppe N., Lisitsyn M., Malyishev V.
Childhood diseases hospital, I.M. Sechenov Moscow Medical Academy, 19 Bolshaya Pirogovskaya str., Moscow, Russia

The purpose: a lung function evaluation by BPG as a method of a complex lung diseases diagnostics at children.

Method: BPG is functional diagnostic method of lung pathology and breath pattern evaluation on the basis of frequency-peak characteristics of a respiratory hums spectrum. The method allows to fixing a temporary curve of acoustic hum arising at respiration with the subsequent mathematical processing and an obstruction and (or) restriction changes evaluation. The amplitude of sound fluctuations in frequency ranges from 0 up to 12,4 kHz (1,2-5 kHz – restrictive zone, 5-12,4 kHz –obstructive zone), with subsequent account of "acoustic breath work" as equivalent of lung work, spent to the act of respiration. The hardware-software complex demonstrates on a PC screen and objectively evaluates respiration sounds characteristics, which are not revealed at physical examination.

Materials: 76 children in the age from 1 till 14 years, with bronchial asthma were surveyed. A control group included 48 children without lung pathology. The physical examination was carried out and the data of BPG and FVC, FEV1, FVC/FEV1 were recorded.

Results: the BPG analysis of surveyed children was carried out in view of all fixed frequencies spectra during several complete respiratory cycles at quiet respiration.

Average parameters of "acoustic breath work" at children not suffering by pulmonary diseases (N=48) were 0,24+/-0,08 mJ (p=0.05) (in obstructive zone). At children with light bronchial asthma (N=31) average parameters of "acoustic breath work" were 1,72+/-1.04 mJ (p=0.05) and after test with broncholitics fault to 0,14 mJ. At children with strong bronchial asthma (N=24) average parameters of "acoustic breath work" were 3,09 mJ, and after test with broncholitics fault to 0,73 mJ.

Conclusions: the BPG method can reach data of routine methods of lung function measurements, to take quantitative assessment of bronchial asthma intensity. The figures of BPG are correlated with clinical data. The BPG allow to evaluating a bronchial obstruction, especially at kids, when ability of routine methods of lung function measurements (FVC) limited.

INTRATHORACIC STETHOSCOPE DURING VIDEO-ASSISTED THORACIC SURGERY

Takashi Suzuki, M.D., Akihiko Kitami, M.D., Shuichi Suzuki, M.D.

Department of Thoracic and Cardiovascular Surgery, Showa University Fujigaoka Hospital, Fujigaoka 1-30, Aoba-ku, Yokohama 227-8501, Japan

We devised an intrathoracic stethoscope for use during video-assisted thoracic surgery of spontaneous pneumothorax. The stethoscope consists of a small electret condenser microphone in a hollow plastic tube. One end of the hollow tube picks up the sound in the thorax, and the microphone set in the other end monitors the sound. To alleviate the interference by standing wave, which is inevitable in the hollow tube, a gauze strip is placed in the tube. The sound is recorded on a digital videotape along with a movie of the surgery. After the stethoscope is introduced into the thoracic cavity, the anesthetist begins to inflate the lung to produce the ventilation sound or leaking sound. Although the visual observation through the video monitor provides the most important information for surgery, the stethoscope also indicates whether or not there is air leakage from a bleb. We have also analyzed the recorded sound by frequency analysis in attempt to comprehend the pathological features of the bleb. This intrathoracic stethoscope may be useful in the future for other purposes, such as, picking up the lung sound of pleural effusion patients during thoracic drainage.

REPRODUCIBILITY OF CRACKLE COUNTS IN NORMALS AND PATIENTS WITH STABLE FIBROSING ALVEOLITIS

John Earis, Nicola Woodhouse, Nick Duffy.
Aintree Chest Centre, University Hospital, Aintree, Liverpool*, UK.

The reproducibility of crackle counts in 3 normals and 3 patients with CFA was investigated (0, 15, 30 and 60 mins on two occasions two weeks apart) to evaluate the possibility of using inspiratory crackle counts (ICC) as a marker of disease activity in CFA. 20sec tidal breathing recordings were analysed by a validated 15 channel automatic cackle counting system (Stethograph). In normals the crackle counts were scanty with <1.8 crackles/ breath. Thus the equipment was not analysing artifactual surface noise as crackles. The 3 patients with CFA had raised ICC: mean15.1± 2.6 SD (range 10.8-19.0), 26.8 ± 11.6 (10.8-44.3) and 15.3 ± 5.5 (7.6-25.3). Breath-by-breath analysis was undertaken for 23 breaths in patient 1 to measure inspiratory time (IT), tidal volume (by pneumotachograph) and ICC of each inspiration. IT was 0.6 to 1.15 sec mean 0.88 +/- 0.17 and TV 402mls to 659 mean 519+/- 87. There was significant correlation between IT and TV against ICC p<0.01 (Spearman Rank). These results suggest that tidal breathing in CFA is variable and this will be reflected in the number of crackles/ breath. Thus either longer recordings or corrections using breath length/volume are needed to standardise a patients crackle counts.

Standardization of computerized respiratory sound analysis; review of the European task force (CORSA)

by Anssi R A Sovijärvi,
Dept. of Clinical Physiology, Helsinki University Hospital, Finland

An European expert group which included over 20 scientists from 7 European countries has recently completed a computerized respiratory sound analysis project (CORSA) the main purpose of which was to review and summarize, in the form of recommended standards, terms and techniques used in the field . The CORSA project was an European Union BIOMED 1 concerted action project and, in addition, a task force of the European Respiratory Society (ERS).
The main product of the project has been published recently (Sovijärvi A.R.A , Vanderschoot J,, Earis, J,Eds..: Computerized Respiratory Sound Analysis (CORSA); recommended standards for terms and techniques. European Respiratory Review 2000,10:77:585-649).
The contents of the task force publication includes e.g. reviews on current methods used for computerized respiratory sound analysis and characteristics of breath sounds and adventitious sounds, definitions of terms for applications of respiratory sounds, including some new and revised definitions and recommended standards for capturing , preprosessing and digitization of respiratory sound signals, and for basic techniques used in sound analysis. The document includes also discussion on future perspectives in the field.
The presentation will critically review and summarize the CORSA document focused on the standardization issue.

LUNG SOUND PATTERNS IN COMMON PULMONARY DISORDERS

R. Murphy, A. Vyshedskiy, V-A Power, C. Wilson, C. House, J. Paciej and D. Bana
Faulkner and Lemuel Shattuck Hospitals, Boston, MA, USA

Purpose: To quantify the prevalence of abnormal sounds a variety of patients with pulmonary disorders.

Methods: A soft foam pad was placed on the backs of these patients while they were lying in the supine position. The pad had acoustic chest pieces imbedded in it and each of these contained a Gentex microphone. The microphones were connected to the Stethograph computer (Stethographics, Inc, Model 301).

Results: The results are summarized in Table1. Normals had very low wheeze and crackle rates. As would be expected wheeze rates were high in bronchial asthma. They were also high in pneumonia and not uncommon in congestive heart failure. The highest crackle rate were seen in interstitial pulmonary fibrosis.

Conclusion: We conclude that there are consistent differences in the acoustical patterns in a variety of common lung disorders that can be detected with a computerized lung sound analyzer. Further work is necessary to demonstrate the clinical utility of these observations.

POWER SPECTRAL ANALYSIS OF LUNG SOUNDS IN PATIENTS WITH EMPHYSEMA AND IN NORMAL SUBJECTS

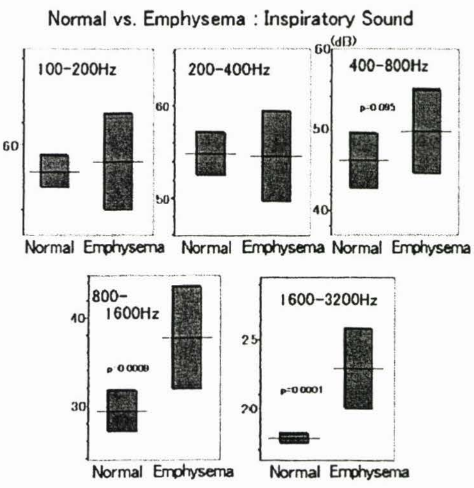
H. Nakano[1], K. Sano[2], J. Maekawa[2], T. Ikeda[1], T. Iwanaga[1], S. Nishima[1],
[1]National Minami-Fukuoka Chest Hospital; [2]Tenri City Hospital, JAPAN

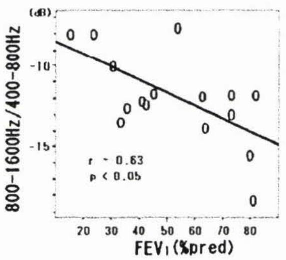
Recently several studies have revealed that there is no difference in lung sound intensity between emphysematous patients and normal subjects at a standardized airflow. However, characteristics of frequency spectra of lung sounds in emphysema have not been elucidated in detail.

In this study we performed power spectral analysis for inspiratory breath sound recorded at six sites on chest wall in 16 patients with emphysema and 8 normal subjects. Power spectra of five octave bandwidths were calculated at various airflows. Linear regression analyses (log power vs. log airflow) were performed to obtain power spectra at a given airflow (1L/sec) in each subject.

The power spectra of two lower bandwidths (100-200Hz; 200-400Hz) were similar between emphysematous patients and normal subjects. However, at higher bandwidths the spectra in emphysematous patients were markedly increased as compared with those in normal subjects (800-1600Hz: emphysema 37.7±5.9dB(mean±SD) vs. normal 29.4±2.4dB, 1600-3200Hz: emphysema 22.9±2.9dB vs. normal 17.8±0.4dB). In patients with emphysema the ratio of power spectrum within 800-1600Hz to that within 400-800Hz was negatively correlated ($r=-0.63, p<0.05$) with FEV1 (%predicted).

In conclusion, increased high frequency spectra may be a characteristic feature of lung sound in patients with emphysema. The difference in spectra from normal subjects is not trivial.





The evaluation on the efficacy of the phonopneumogaraph in the non-invasive diagnosis of interstitial pneumonia.

Hiroshi Ono1), Akira Murata1), Shoji Kudoh1), Atsuo Shibuya2), Torao Muratake3)

1) The 4th Department of Internal Medicine, Nippon Medical School, Japan
2) Japan Women's University, Japan
3) Kenz Mecio Co. Ltd., Japan

Background) The diagnosis of interstitial pneumonia is made based on pathological findings of tissues obtained by bronchoscopes, thoracoscopy, or open surgery. None of these procedures was performed without invasion. To solve this problem, non-invasive techniques are required.

Aim) The objective of this study was to evaluate the efficacy of the phonopneumogaraph in the non-invasive diagnosis of interstitial pneumonia.

Methods) We recorded lung sounds from sixteen patients with a diagnosis of usual interstitial pneumonia (UIP; n=10), non-specific interstitial pneumonia (NSIP; n=3), and cryptogenic organizing pneumonia (COP; n=3). And by using a phonopneumograph we developed, a spectrum analysis of lung sounds during one inspiratory phase was performed

Results) We could observe a specific peak at about 600Hz when analyzing the inspiratory sounds of patients with interstitial pneumonia. Among patients with UIP, the amplitude of that peak seemed higher than that of patients of NSIP or COP. The differences observed among different types of interstitial pneumonia might be due to the increased number of fine crackles and well-transmitted lung sounds in fibrotic lung tissues. These results suggest that this non-invasive analysis of lung sounds is helpful in the diagnosis of interstitial pneumonia.

Expiratory crackles in bronchial obstruction may be strongly associated with expiratory wheezes– a qualitative analysis

Hasse Melbye, Institute of Community Medicine, University of Tromsø, Norway

Crackles may be heard during expiration in patients with bronchial obstruction. Paul Forgacs explained the phenomenon as "passage of a bolus of gas through a lightly closed airway, which opens intermittently when the upstream gas pressure rises above a critical level". The crackles may be heard immediately after an expiratory wheeze. In such cases the wheeze and the crackles may possibly be generated in the same bronchial branch. When the airflow, which maintains the wheeze, weakens, the sound may come at intervals and may turn into crackles or ultra-short wheezes. This is demonstrated by phono- and sprectrograms of patients with obstructive pulmonary diseases. Conclusion: Expiratory crackles and expiratory wheezes may be generated by related mechanisms.

INTEGRATION OF AUSCULTATION AND TELECOMMUNICATION TECHNOLOGIES

Christopher Druzgalski
California State University, Long Beach, CA 90840

Convergence of auscultation and telecommunication technologies provides ever expanding capabilities in the transmission and storage of auscultatoty data as well as a remote assessment of patients' auscultatory signs. As PACS became an integral part of radiographic data handling, similar approaches and the existing technology allow enhanced and distance independent evaluation of cardiovascular and/or pulmonary acoustic signatures.

The uniformity and development of the standards for auscultatory data handling may facilitate broader utilization of a stethoscope as a one of telemonitoring peripherals. Specifically, this project focuses on applicability of new A/D audio hardware, storage devices' requirements, data formats, and standards' compatibility for teleauscultation. The recording of sound at higher bit rates, although it places additional demands on memory requirements, provides higher dynamic range and allows accurate preservation of highly distinct, location dependent, intensity relationships of respiratory sounds. In spite of the large size of auscultatory audio files, new developments in required storage capacity and the transfer speeds available over the phone and cable lines make routine use of teleauscultation feasible. Navigation, within digital respiratory sounds audio files, brings the necessity of dealing with data fragmentation and its effect on short duration nonperiodic respiratory events.

Teleauscultation provides capabilities for consultation and evaluation of peculiar auscultatory findings by a specialist, as it is common with evaluation of radiologic images or variety of physiological signals' recordings. Although this paper focuses on the technical aspects of teleauscultation, it also considers that its practical use is highly influenced by health care policies, and the reality that teleconsultation of patients is already becoming a formalized part of medical practice.

"BREATH BY BREATH" – AN EDUCATIONAL VIDEO FOR CAREGIVERS TO RECOGNIZE RESPIRATORY DISTRESS IN YOUNG CHILDREN.

D. Zielinski, H. Kiyokawa, M. Lowe and H. Pasterkamp, Dept. of Pediatrics, U. of Manitoba, Winnipeg, Canada

Respiratory disease in young children represents the most common reason that leads caregivers to seek medical advice. The assessment of breathing difficulty in infants and toddlers relies to a large extent on physical findings since formal tests of lung function are generally not applicable. Several clinical scores are in use by health care professionals and include respiratory frequency, retractions and use of accessory muscles, breath sound characteristics, and in some scores also cyanosis. To improve the recognition and reporting of respiratory distress by caregivers we prepared a videotape that presents varying degrees of breathing difficulty in children between 6 and 36 months of age. Visual findings of breathing rate and effort were captured from children presenting to the Emergency Room at the Children's Hospital Winnipeg and to the Arviat Health Center, Nunavut. Examples of healthy children were filmed as arranged with their parents. Breath sounds were captured on video with a modified stethoscope that included an electret microphone in order to teach auscultation with particular attention to wheezing. A "Breathing Difficulty Score" was offered as follows ("amber" indicating a need for frequent re-assessment and "red" a need to seek immediate medical advice, with the most severe finding determining the course of action):

	rate	**effort**	**regular sounds**	**extra sounds**
"green"	below 30/min	no retractions	easily heard	none
"amber"	30-60/min	some retractions	decreased	some wheezing, crackles or none
"red"	above 60/min	severe retractions	very difficult to hear	severe wheezing, grunting, stridor, crackles, or none

The initial 2/3 of the approx. 15-min videotape is devoted to the training of observation and listening. In the final portion, several cases of young children with different degrees of respiratory distress are presented for the self-assessment of acquired skills. The video is currently undergoing formal evaluation by parents of young children and also by students in the health care professions.

Supported by the Children's Hospital Foundation of Manitoba and by Merck Frosst Canada

NOCTURNAL WHEEZING AND SLEEP

C. Reinke, V. Gross, Th. Penzel, U. Koehler, J.H. Peter, C. Vogelmeier, *Dept. of Medicine, Div. Pulmonary and Crit. Care Med.; Philipps-University Marburg, Germany*
www.lung-sound.de

Introduction: Sleep, as the most fundamental restorative function of the human organism, can be disturbed in patients with COPD or bronchial asthma. As a consequence, these patients complain of daytime sleepiness, psycho-physiological problems and of depression about three times more often than the average population.

Methods: For the detection of bronchial obstruction we used the established and non-invasive method of acoustical recording and detection of wheezing (*Pulmotrack 1010*). The system continuously records all incidences of wheezing by piezo-electrical sensors at standard positions. Using the recorded data we calculated the wheezing time rate (WTR: percentage of time wheezing per 30sec.) and the wheezing time (WT: time with WTR>5%). In addition, all patients were monitored by a cardiorespiratory polysomnography.

Results/Conclusion: A total of 20 patients with an obstructive airway disease were investigated (11 male and 9 female, mean FEV1 59± 18%). A correlation between appearance of arousal reactions and wheezing was statistically significant ($p<0.05$). A direct correlation between sleep stages and wheezing events was not found.

It seems especially interesting to us, that there were different, individual distributions of wheezing-phases during the night; contradicting the literature, not each patient had an increase of bronchial obstructions only in the morning.

ACOUSTIC MONITORING OF PEDIATRIC CROUP IN THE EMERGENCY DEPARTMENT

Adi Klein[1], Lea Bentur[1,2], and Noam Gavriely[2] Pediatric Pulmonology Unit, Rambam Medical Center[1] and Pulmonary Physiology Unit, Rappaport Faculty of Medicine, Technion, Haifa, Israel.

Background: Croup is characterized by acute shortness of breath, barking cough and progressive inspiratory and expiratory stridor, most often due to a viral infection that results in subglottic swelling and obstruction. If not treated the disease progresses with dyspnea, cyanosis, and exhaustion that may lead to suffocation. We used an automatic wheeze detector and monitor (Pulmotrack® Karmel Medical Acoustic Technologies Ltd. Yokneam Illit, Israel) to assess the acoustic events during treatment of croup in the emergency department. ***Methods***: Breath sounds were recorded and analyzed continuously in 9 children who presented to the Pediatric Emergency Department with croup. The patients were treated with budesonide 2 mg by inhalation. Five phonopneumography sensors were placed over the sternal notch and the thorax. Breath sounds were recorded and monitored continuously while a pediatrician documented a clinical score. The recorded sounds were reviewed off-line to determine the acoustic phenomena during and after treatment. ***Results***: Loud extra thoracic upper airway sounds during both inspiration and expiration were noted initially. The musical component of the stridor sound was often replaced by a narrow band noise. 'Classic' stridor was present later in the course of treatment and was not necessarily a sign of worsening of the patient's condition. ***Conclusions***: The extent of continuous adventitious breath sounds varied during treatment. In some patients an increase in the stridor rate was noted while the patient's condition was actually improving. The acoustic monitoring of croup patients is feasible, but the relationships between the acoustic phenomena and upper airway narrowing require further research.

"EXPIRATORY WHEEZE" IN A PATIENT WITH "VOCAL CORD DYSFUNCTION"

S. ISHIKAWA, F.GOMEZ, A.VYSHEDSKIY, Z. ELMAGHRABY, K.F. MacDONNELL, AND B. CELLI. PULMONARY & CRITICAL CARE, ST ELIZABETH'S MEDICAL CTR DEPT. OF MEDICINE, TUFTS UNIV. SCHOOL OF MEDICINE, BOSTON, MA, U.S.A.

Patients with vocal cord dysfunction have wheezing that is often diagnosed as bronchial asthma. Consequently they are often subjected to improper therapy.

We studied a 49 year old obese white female, who was admitted to the hospital with an exercerbation of dyspnea diagnosed as bronchial asthma. She had had prior pulmonary function tests (PFT) done showing a pure restrictive pattern with normal air flow. PFT could not be done during this admission due to severe shortness of breath. On admission arterial blood gases were: pH7.38, pCO_2 23 mmHg, pO_2 153 mmHg on 3 L/min O_2 via nasal canula. Her respiratory rate was between 20 and 30 per minutes. Her serum bicarbonate was 23 mMol/L.

On physical examination there were bilateral expiratory wheezes and tracheal stridor. A bronchoscopy was done which showed no endobronchial lesions and demonstrated spasm of the vocal cords on exhalation. A chest x-ray showed small lung volumes with no evidence of air trapping.

We were interested in whether lung sounds could indicate the location of the wheeze. A wheeze originating inside the chest would be consistent with asthma, while a wheeze originating at the trachea would be consistent with vocal cord dysfunction. Lung sounds were recorded using 16 channel analyzer (Stethographics Model301). Data was obtained from the trachea and 15 chest sites. A monophonic expiratory wheeze with peak frequency of 600 Hz was present on the trachea and on chest sites close to large airways.

To determine at which microphone the sound arrived first, we compared the phase of the sound at the trachea and the sounds recorded from the chest surface. The cross-correlation function indicated that the sound of wheeze originated at the level of vocal cords.

NORMAL BREATH SOUND ANALYSIS FOR THE EVALUATION OF SMALL AIRWAY OBSTRUCTION: CLINICAL EXPERIENCE WITH ASTHMATIC CHILDREN USING STEROID INHALATION

Masato Takase, Kazuhiko Shirota, Takehide Imai, Toshiko Imai

Department of Pediatrics, Nippon Medical School, Tokyo

We have reported in the past ILSA conferences, that frequency analysis of inspiratory normal breath sounds recorded over the chest is a sensitive and reproducible test to monitor mild small airway obstruction in childhood asthma. We have shown that the spectral edge frequency (SEF: defined as the frequency below which contains 99% of the total power within 150~1,200 Hz) of a flow standardized inspiratory breath sound spectrum (after subtraction of background noise spectrum) increases in relation to decrease in $FEF_{25\text{-}75\%}$ (forced expiratory flow between 25-75% of the vital capacity; a sensitive spirometric measure for the detection of small airway obstruction).

We analyzed lung sound recordings (with 2 contact sensors stuck on the right upper chest and the right lower back) from 20 moderate to severe asthmatic children (11 boys, 9 girls: 6~15 y/o) on steroid inhalation therapy. Lung sound recordings and spirometry before and after bronchodilator inhalation (salbutamol 200 ug) were repeated after 1 year. Method of recording and analysis was identical with our past reports. Five of 7 subjects with normal SEF at baseline retained normal SEF after 1 year. Lower SEF (improvement) was observed in 7 of 13 subjects with increased SEF at baseline. Response of SEF to bronchodilator became larger in all subjects who showed increased SEF after 1 year. Spirometric data and clinical records were used to confirm the reality of these findings.

Our experience indicates that the lung sound analysis would be a good alternative or an adjunct to conventional pulmonary function testing.

THE ACOUSTIC PROPERTIES OF STRIDOR.

Noam Gavriely[1] Adi Klein[2], and Lea Bentur[1,2] Pulmonary Physiology Unit, Rappaport Faculty of Medicine, Technion–Israel Institute of Technology[1], and the Pediatric Pulmonology Unit, Rambam Medical Center[2] Haifa, Israel.

Background: Stridor is a continuous adventitious breath sound (CABS) that originates in the extra-thoracic airways and is associated with substantial narrowing of airway lumen. Stridor is usually inspiratory, but may also be expiratory. The aim of the present study was to characterize the acoustic properties of stridor in children with croup. ***Methods***: Breath sounds of 9 children with croup were monitored and recorded in the Emergency Department with an automatic wheeze detector (PulmoTrack® Karmel Medical Acoustic Technologies Ltd. Yokneam Illit, Israel). The temporal and spectral patterns of the sounds were analyzed off-line using a sonogram in conjunction with auditory evaluation of the data. ***Results***: two types of stridor signals were observed: 1) Narrow band noise (NBN) waveform (i.e. broad peak) was detected in early phases of the croup attack. It was inspiratory and expiratory and it's musical character compatible with Helmholtz resonator type sound. 2) Wheeze-like spectral spikes that are predominantly inspiratory, but may be present during expiration as well. The latter sounds have sharp spectral peaks and they tend to appear later in the course of treatment. The frequency range of the fundamental of both types of stridor sounds was 150 to 400 Hz. Harmonics were observed in some, but not in all stridor events. ***Conclusions***: Stridor is a subtype of CABS. NBN stridor is compatible with a fixed narrow orifice model of sound generation. The Wheeze–like stridor is probably closer in it's mechanism to that of wheezes, namely flutter of the airway walls while the flow is limited. Additional basic research is needed in order to predict the quantitative relationships between the acoustic properties of the stridor and the cross sectional area of the upper airway orifice.

LONG-TERM RECORDING OF LUNG SOUNDS IN PATIENTS WITH PNEUMONIA AND BRONCHIAL BREATHING

K. Mack, V. Gross, T. Penzel, U. Koehler, P. von Wichert, C. Vogelmeier
Department of Medicine, Division Pulmonary and Critical Care Medicine; Philipps-University Marburg, Germany
www.lung-sound.de

Introduction: During the course of a pneumonia there are characteristic changes of transmitted lung sounds. We developed a method based on wavelet-transformation, that enables to detect consolidations of the lung caused by developing and acute pneumonia and can be used as a non-invasive monitoring system for high risk patients.
Methods: Starting on the day of admission to our hospital, we daily recorded (min. 2 weeks) the lung sounds of patients with one-sided pneumonia with 4 air-coupled microphones (Sony ECM 77) simultaneously to the air-flow. The respiratory signals were analyzed by Wavelet transformation (WT, *Matlab 5.3*). The WT-coefficients of the frequency band 345-690 Hz were computed for each respiratory cycle. We calculated the ratio between the two phases for both sides of the lung and calculated the difference between the pneumonia and healthy side (ΔR). We measured the patients again after recovery.
Results: ΔR was significantly increased during the acute infection ($\Delta R_{i1}=0.9\pm0.6$; $\Delta R_v=0.0\pm0.1$ for 218 healthy volunteers, $p<0.05$) and, in the course of recovery, decreased to normal values ($\Delta R_{i2}=0.1\pm0.1$) parallel to x-ray findings and clinical signs.
Conclusion: Our method is a suitable instrument for the early detection and long-term documentation of a consolidation of the lung caused by pneumonia.

NOCTURNAL WHEEZING AND ANTIOBSTRUCTIVE THERAPY

U. Koehler, C. Greib, V. Gross, Th. Penzel, J.H. Peter, C. Vogelmeier
Dept. of Medicine, Div. Pulmonary and Crit. Care Med.; Philipps-University Marburg, Germany
www.lung-sound.de

Introduction: Bronchoconstriction during the night reduces the quality of sleep and can cause life-threatening events. We used a method to detect bronchial obstructions based on acoustical recording of wheezing and compared the wheezing events with sleep stages and arousals. Furthermore we looked for the therapeutic effects of an long-acting β_2-adrenoreceptor antagonist (*Serevent*).
Methods: We recorded 11 patients for three nights at our sleep laboratory. The first night was the control-measurement and the second and third one were the nights under treatment. For the detection of wheezing we used the *Pulmotrack 1010.* The system continuously records all incidences of wheezing by piezo-electrical sensors at standard positions. The wheezing time rate (WTR: percentage of time wheezing per 30sec.) and the wheezing time (WT: time with WTR>5%) were calculated. All patients were also monitored by a cardiorespiratory polysomnography.
Results: 11 patients (3 female, 8 male) were investigated. Our results seem to show that S*erevent* significantly reduces WT (from 45% to 15%, $p<0.05$), the probability of arousal events ($p<0.05$) and increases the percentage of slow wave sleep (from 12% to 17%).
Conclusion: The described method is suitable to monitor patients with bronchial obstructions and to check the quality of antiobstructive therapy.

OBJECTIVE MEASUREMENT OF LUNG SOUNDS IN CHRONIC OBSTRUCTIVE LUNG DISEASE

Murphy, R., Vyshedskiy, A., Power, V-A, Bergstrom, K., Murphy, M.
Faulkner Hospital, Boston MA, Boston College, Chestnut Hill, MA, USA

Introduction

The lung sounds of patients with chronic obstructive lung disease (COPD) have been shown to differ objectively from those of normal subjects using either frequency based or time based analysis. The purpose of this investigation was to determine if a rating scale based on both frequency and time based parameters differed in patients with COPD as compared to normal subjects.

Methods

A 16-channel lung sound analyzer (Stethographics STG Model 301) was used to collect 20 second samples of sound from patients with COPD (n=35) and normals (n=39) during deeper than normal breathing. Seven parameters based on timing, frequency, amplitude, and adventitious sounds analysis were measured. A score was developed based on the findings for each parameter and a total score was calculated for each subject.

Results

The score averaged 2.8 (3.5) for normals; 28.3 (10) for COPD. No normal subject had a score above 11. Only 4 COPD patient (11%) had a score below 16. This score correlated with the percent predicted forced expiratory volume in one second (R=.83, p<.001).

Conclusion

A score based on timing, frequency, amplitude, and adventitious sounds analysis of lung sounds differed significantly in COPD patients as compared to normals and provided clearer separation of COPD from normals than did any acoustic parameters analyzed separately.

OBJECTIVE MEASURENT OF WHEEZES AND CRACKLES IN CONGESTIVE HEART FAILURE AND BRONCHIAL ASTHMA

Raymond Murphy, Faulkner Hospital, Boston MA and Tufts University School of Medicine, Andrey Vyshedskiy, Alberto Ramirez, Gary Brockington, Verna Ann Power, Malavalli Gopal, Jeffrey Cohen, Joseph Paciej, Faulkner Hospital

Objective: To determine whether the frequency characteristics of wheezing differed in congestive heart failure (CHF) as compared to bronchial asthma (BA). **Methods:** We used a 16 channel lung sound analyzer (Stethographics Model 301) to provide automated wheeze and crackle quantification. **Results:** Wheezing was present in 9 of 20 CHF patients. The frequency and rate of wheezing in these patients was compared to that found in 25 asthmatics (Table 1). There were no significant differences in the mean frequencies and wheeze rates between the groups. There was a tendency for inspiratory crackles to be more common in CHF. Five of the 9 CHF patients with wheezing had an inspiratory crackle rate of 5 or more crackles per breath. None of the 25 asthmatic patients had 5 or more crackles per breath. **Conclusion:** Although there were no differences in mean wheeze frequency or rate the presence of inspiratory crackles suggest CHF rather than BA. A larger series of patients needs to be studied to confirm these results. **Comment:** The lack of acoustical measurement differences between CHF and BA wheezing is consistent with the common clinical experience that this wheezing is difficult to distinguish. Crackles can be measured easily at multiple sites even in very ill patients. This offers the promise of differentiating the two conditions noninvasively.

		CHF (n=9)	**Asthma (n=25)**
Wheezing and Rhonchi		avg(std)	avg(std)
Inspiration	Rate (%)	25 (26)	27 (22)
	Frequency (Hz)	260 (160)	297 (140)
Expiration	Rate (%)	28 (36)	50 (30)
	Frequency (Hz)	205 (74)	227 (79)
Crackles (Rales)			
Inspiration	crackles/breath	7 (8)	2 (1)
Expiration	crackles/breath	2 (3)	2 (2)

MEASUREMENT OF SNORING BEFORE AND AFTER PALATOPLASTY

Earis JE, Jones T, Ho M.S.**, Donohue S, Cheetham BMG** Calverley PMA, Swift AC, , Aintree Chest Centre, University Hospital, Aintree, Liverpool*, Dept.Computer Science, University of Manchester**, UK.

Twenty, non-sleep apnoeic patients underwent palatoplasty for heavy snoring. All had sleep studies pre & 1 to 3 months post-operatively, snoring sounds were recorded by a free-field microphone onto a DAT recorder and the first 100 snores identified. Time-domain and spectrographic analysis of the snore waveforms revealed two main patterns *first* a quasi-periodic structure thought to arise from intermittent airway closure (e.g. palatal snoring) and *second* a simple waveform without a clear harmonic structure. Analysis software automatically counted the number numbers of snores/min, avg. duration & power of the snoring episodes. The percentage of periodic sound and the peak to RMS ratio were measured as an index of palatal snoring. These data show considerable inter-patient variation but there was a small reduction in the number of snores per minute from 5.6 to 4 per minute ($p<0.057$) and a change in the overall spectral shape of the waveforms following surgery. No change in the avg. duration or the mean power of each snoring episode was found. The periodicity of the snoring waveform showed significant reduction after surgery (84 to 77%) $p<0.01$. Other than numbers of snores this grouped data shows no major changes in simple indices of snoring after surgery. However, changes in periodicity and spectral shape suggest less of the snoring sound is arising from the palate and the resultant alteration of sound quality may make snoring less troublesome.

HOW REGIONAL ARE LUNG SOUNDS? FURTHER OBSERVATIONS ON BREATH SYNCHRONOUS VARIATIONS OF PHASE AND AMPLITUDE.

Hiroshi Kiyokawa MD and Hans Pasterkamp MD
Dept. of Pediatrics, University of Manitoba, Winnipeg, MB, Canada

New technology allows a detailed view of the chest ("stethoscopy" in the true sense) for regional acoustic assessment. We postulated that changes in airway size and orientation during breathing may result in time and amplitude variations between neighboring sensors on the chest surface. Twice on consecutive days we studied 3 male and 2 female healthy non-smokers, ages 21-50 y. Two contact sensors 35 mm apart in cranial (A) - caudal (B) alignment, recorded sounds over the posterior right upper (RUL), right lower (RLL) and left lower lung (LLL). Target flow (1.2 L/s ± 0.2) and volumes (20-50% and 50-80% of vital capacity) were monitored in a body plethysmograph. Five consecutive respiratory cycles were digitized and analyzed for each subject, site and volume. Sound signals were band-pass filtered (150-300 Hz, 300-600 Hz) before segmentation into 100 ms epochs of 1024 data points. The phase changes of B relative to A ($\Delta\Phi$ in ms) were established by cross correlation and a peak-detection algorithm. The relative sound amplitude changes (20 x log B/A) during breathing were expressed as ΔdB. We found variations of both $\Delta\Phi$ and ΔdB synchronous with breathing in all subjects. These observations were reproducible and most consistent over RLL and LLL at lower frequencies, independent of volume. During inspiration at the lower lobe recording sites, sound at B arrived increasingly late (max. $\Delta\Phi$ = 0.85 ms ± 0.22 at RLL and 0.59 ms ± 0.05 at LLL) and became increasingly loud relative to A (max. ΔdB = 7.4 ± 2.0 at RLL and 7.9 ± 1.7 at LLL). These novel findings may reflect the sensitivity of lung sound measurements to changes in airway spatial orientation and to the position of the diaphragms.