Respiratory Division
Department of Pediatrics
Alberta Children's Hospital
University of Calgary
Calgary, Alberta, Canada

The 18th International Conference on Lung Sounds

Presented by

International Lungs Sounds Association

August 25 - 27, 1993
Chateau Lake Louise
Lake Louise, Alberta, Canada

FINAL PROGRAM AND ABSTRACTS

Organization

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David Cugell, MD	Chicago, Illinois
Filiberto Dalmasso, MD	Torino, Italy
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Hans Pasterkamp, MD	Winnipeg, Canada
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Local Coordinator

Dr. Raphael Beck

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General information

Conference venue

Pipestone Room, Chateau Lake Louise

Official language

English

Registration and secretariat during the conference

Registration wil be held in front of the conference hall on:

Thursday, August 26th	7.30 a.m. - 10 a.m.	
	12.00 noon - 1.30 p.m.	

Registration fees

Participants $200, spouses/companions $50.

Certificate of attendance

Participants, duly registered, will receive a certificat of attendance upon request.

Posters

Posters will be displayed in the conference hall from 8.45 a.m. on August 26th until 5 p.m. on August 27. During the poster session, an oral presentation of five minutes is held for each poster.

Prize for the best poster

Dr. Filiberto Dalmasso (Torino) has donated a prize of 1,000,000 Italian Lire for the best poster. The Steering Committee will judge posters and award the prize.

Hotel accommodation

Chateau Lake Louise
Lake Louise, Alberta, Canada
Phone: 403-522-3511

Lunch and coffee

Continental breakfast, lunch and coffee are included in the registration fee of active participants at the Chateau Lake Louise on August 26th and 27th.

Welcome party

On August 25th, a wine and cheese reception wil be held in the Lakeview Lounge at 7 p.m. to welcome the participants and their companions.

Banquet

There will be a banquet on August 26th in the Sun Room at 8 p.m.

Sponsors

The organizers gratefully acknowledge the generous support of the following companies:

Fisons Pharmaceuticals Canada
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The 18th International Conference on Lung Sounds
Chateau Lake Louise, Alberta, Canada

Program

Wednesday, August 25

3:00 - 5:00	Workshop
7:00	Wine and cheese reception

Thursday, August 26

7:30 - 8:25	Registration and breakfast
8:25 - 8:30	Welcome address - Raphael Beck, M.D.

Session A
Prof. Noam Gavriely M.D. and S.A.T. Stoneman M.D., Chairmen

8:30 - 8:50	An Experimental Evaluation of Two Parts of an Hypothesis for the Vortical Origins of Breath Sounds	Stoneman
8:50 - 9:10	Modelling Fluid Dynamic Flutter in Lung Airways	LaRose
9:10 - 9:30	Comparison of Lung Sounds Recorded in the Esophagus and on the Chest Wall	Sha
9:30 - 9:50	*Coffee Break*	
9:50 - 10:10	Use of Trilateralization in Locating the Origin of Lung Sounds	Murphy
10:10 - 10:30	Interbreath Variance of Lung Sound Spectra and Effects of Data Windows and Flow Gate Tolerances	Pasterkamp
10:30 - 10:50	Repeatability of Breath Sound Parameters in Healthy Non-Smoking Men	Sovijarvi
11:00 - 11:30	Paul Forgac's Contribution to Lung Sound Studies	Loudon
11:30 - 12:00	*Photo*	
12:00 - 13:30	*Lunch*	

Session B
George Wodicka, Ph.D. and Steven Kraman, M.D., Chairmen

1:30 - 2:15	Speech Processing Techniques Applied to the Analysis of Lung Sounds	Cheetman
2:15 - 2:35	Wavelet Transform Based Respiratory Crackle Detection	Guler
2:35 - 2:55	Use of a Derivative Filter for Detection and Analysis of "Crackles"	Rossi
2:55 - 3:15	*Coffee Break*	
3:15 - 3:35	Microphone Air Cavity Depth Effects on Lung Sounds	Wodicka
3:35 - 3:55	Composition & Calibration of New-Type Lung Sound Sensors Based on Microphones	Sakao
4:00	Poster Viewing	
8:00 p.m.	Banquet, Sun Room, Chateau Lake Louise	

Friday, August 27

Session C
Wilmot Ball, M.D and Masashi Mori, M.D, Chairmen

7:30 - 8:30	*Breakfast*	
8:30 - 8:50	Lung Sounds in ARDS	Wichert
8:50 - 9:10	Mycoplasmal Pneumonia: Stethoscopic and Acoustic Properties of Crackles	Dalmasso
9:10 - 9:30	Acoustical Monitoring During Forced Expiration Using Rapid Thoracoabdominal Compression in Infants	Pasterkamp
9:30 - 9:50	Respiratory Sounds Patterns During Methacholine Challenge	Sacco
9:50 - 10:10	*Coffee break*	
10:10 - 10:30	Surface Acoustical Mapping of the Chest During Methacholine Challenge	Pasterkamp
10:30 - 10:50	Lung Sounds During Allergen-Induced Asthmatic Responses Using Airflow-Standardized Phonopneumography	Schreur
10:50 - 11:10	Spectral Characteristics of Cough Sounds in Normal and Asthmatic Subjects	Ishikawa
11:10 - 12:15	Purring, Snoring and Other Sounds of the Night	Prof. J. Remmers
12:15 - 1:30	*Lunch*	

Session D
Shoji Kudoh, M.D. and David Cugell, M.D., Chairmen

2:00 - 2:20	The Relationship Between Snore Frequency and Severity of Obstructive Sleep Apnoea	Spence
2:20 - 2:40	Upper Airways Modelling by LPC Filtering in Heavy Snores and Obstructive Sleep Apnoea	Spence
2:40 - 3:00	Generation of Snoring Sounds - Pressure/Flow/ Sound Studies of Simulated Snores	Beck
3:00 - 3:20	The Changes in Lung Sounds Spectra Due to Route of Breathing (Nose vs. Mouth)	Gavriely
3:20 - 3:40	Lung Auscultation Among Physicians in Training: a Lost Art?	Mangione
3:40 - 4:00	The Teaching of Lung Auscultation in American Internal Medicine & Pulmonary Training Programs	Mangione
4:00 - 4:20	Efficacy of Wireless Stethoscope for Lung Sounds Education.	Murata
4:20 - 5:20	Steering Committee Meeting	

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

Posters

Space for posters is 90 cm width and 150 cm height. Five minutes will be allocated for each presentation, with a maximum of 2 slides.

P1	Differences in Spectral Parameters of Tracheal Breath Sounds by Three Different Spectral Measurement	Charleston
P2	Adaptive Cancelling of Ambient Noise in Lung Sound Measurement	Suzuki
P3	Acoustic Model of Respiratory Airways	Druzgalski
P4	Acoustic Probes for Endobronchial Sounds	Dalmasso
P5	The Dimensions of Cough	Loudon
P6	Two-Dimensional Discriminant Analysis of Cracles in Five Pulmonary Disorders	Sovijarvi

ABSTRACTS

An Experimental Evaluation of Two Parts of an Hypothesis for the Vortical Origins of Breath Sounds.

S.A.T. Stoneman and J.R. Hill

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In an ad hoc presentation at the 1992 Helsinki meeting, a hypothesis was proffered for the generation of normal breath sounds based on kinetic energy exchanges between the flowing air medium and the acoustic fields of the enclosed bronchial tubes. It centred on the premise that during a significant proportion of any respiratory manoeuvre, the internal epithelium of the bronchi presents a corrugated bounding surface to the enclosed flowing air. The corrugations cause localised adverse pressure-gradients to be experienced by the boundary layer attempting to follow the profile of the epithelium, such that a situation is created where the flow separates from the inner, minimum diameter points of the corrugations and vortices are shed into the flow. Vortices create and absorb acoustic energy throughout the acoustic cycle and the phase relationships of the three vectors of the Howe Integral vary (Ref 1). The sounds heard due to air movement in the bronchial system represents the net energy balance of the creation and absorptive processes.

Experiments have been conducted, on rigid corrugated conduits, to test an important aspect of the hypothesis, which is that if periodic energy exchange, due to vortex creation and convection, is the means by which acoustic activity is excited, then the period of the acoustic cycle should have an integer relationship with the convection period of the vortices through the geometric field of the corrugated conduit.

The Strouhal Number (Str No.) is the ratio of the vortex shedding frequency and the flow velocity all times a characteristic dimension. It is a non-dimensionalising parameter, used in flow-induced acoustic resonance research, *inter alia*, to describe possible sources of the resonant energy. The characteristic dimension in the present experiments was shown to be equal to the distance between TWO corrugations. It can be inferred from this that acoustic energy is fed into the acoustic field by a mechanism which is related to the interaction of the vortical activity in the boundary layer and the corrugated surface of the enclosing corrugated conduit.

There have been many published accounts of the energy exchanges in acoustic enclosures (e.g. Ref 2) based on the Howe theory of vortical sound generation, further discussion of which is beyond the scope of this presentation. The present findings are not inconsistent with any aspect of the previous experimental and theoretical published works.

Experimentation has also been conducted to investigate the influence of the acoustic branching which is caused by the bronchial bifurcations on the frequency spectrum of normal breath sounds. It is well documented that acoustic distributions in organ pipe-type systems are mechanically filtered by the presence of side branching. A single bifurcation of a rigid corrugated pipe was investigated (analogous to the trachea and two main bronchi), to establish the influence of the length and openness of one of the side branches of the bifurcation, on the acoustic frequencies generated .

It was found that the organ pipe modal distributions of a corrugated, bifurcating conduit were changed with the conditions in one leg of the bifurcation. The changes were varied with different lengths of branch and for different flow velocities in the branch. It was also found that the presence of a branch which was blocked, changed the frequencies which were excited at different flow velocities in the remaining open leg. This may be a factor for the clinical finding that different pathophysiological condition of the human bronchi manifest different spectral characteristics of lung sounds.

References:

1. *Howe. M., 'On the absorption of sound by turbulence'. IMA J. Appl Maths 32, 187-209.*
2. *Stoneman, S.A.T., Hourigan, K., Stokes, A.N. and Welsh, M.C. 'Resonant sound caused by two plates in tandem in a duct'. J.Fluid.Mech. (1988), vol 192, pp 455-484.*

MODELLING FLUID DYNAMIC FLUTTER IN LUNG AIRWAYS

P.G. LaRose[1] and
J.B. Grotberg[2], Ph.D., M.D.
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and Applied Mathematics
[2]: Departments of Biomedical Engineering
and Anesthesia
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It is generally believed that wheezing lung sounds may be symptomatic of flutter in the lung airways. This has been tested through experimental consideration of flexible air-conveying tubes, and by comparison with theoretical results [1,2]. Previous theoretical investigations have considered the inviscid or inviscid based stability of a fluid flowing through a flexible tube or channel. We incorporate the full effects of fluid viscosity to model air flow in a flexible channel and determine conditions under which the flutter instability is expected to appear. We find, consistent with past work, that decreasing wall mass or flexibility or increasing wall damping or channel width stabilizes the system. Our critical flow speeds are lower than previous results, leading to the conclusion that the geometry of the collapsed tube is significant. The effect of the shape of the collapsed tube cross-section on the flow speeds within the tube is investigated using finite elements methods. It is found that there may be significant variation in flow speed across the cross-section of the collapsed tube. This and additional geometrical effects, such as the constriction introduced by the tube collapse, may account for the differences between the present and previous results.

1. Gavriely, N. et.al., J. Appl. Physiol. 66(5):2251-2261, 1989.
2. Grotberg, J.B. and Gavriely, N., J. Appl. Physiol. 66(5):2262-2273, 1989.

COMPARISON OF LUNG SOUNDS RECORDED IN THE ESOPHAGUS AND ON THE CHEST WALL.

Muneyasu Sha[1], Akito Ohmura[1], Akifumi Suzuki[2], Fujihiko Sakao[3], Masashi Mori[4]

1. Department of Anesthesiology, University Hospital Mizonokuti, Teikyo University
2. Faculty of Science and Technology, Sophia University
3. Faculty of Engineering, Kinki University
4. Department of Pulmonary Medicine, Tokyo National Chest Hospital

The esophageal stethoscope has been used for many years for the simple intraoperative cardio-pulmonary monitoring. We developed a simple esophageal sound monitoring device in which a microphone (ECM-155, SONY) was incorporated into a 24 French esophageal stethoscope tube (Mallincrodt, NY) approximately 5 cm proximal to the balloon at the tip. Another microphone (ECM-155) which was attached to the connecting tube of a stethoscope (3M) 1 cm from the chest piece was placed over the right anterior chest. The recordings were made in the supine position on three patients who were under general anesthesia and mechanical ventilation. The recordings were also made on two normal volunteers who were breathing normally. The lung sounds simultaneously recorded in the esophagus and on the chest wall were compared. The esophageal lung sounds were louder and clearer and their intensity was largest when the microphone was placed near the bifurcation 25 to 30 cm from the front teeth. The power spectra ranged up to 2,000 Hz and had much wider bandwidth compared to those recorded on the chest wall. Coherence between esophageal and precordial sounds was higher in expiration than in inspiration.

Use Of Trilateralization In Locating The Origin Of Lung Sounds

R. Murphy, T. FitzGerald, G. Fleischer and D. Davidson

We used a lung sound analytic system with the capability of obtaining sounds simultaneously from multiple channels to study the origin of lung sounds in normals and a variety of disease states. Arrival times were estimated at each of 6 microphones placed in a triangular configuration and were used to calculate the location of the source of the sounds. Underlying assumptions include the following: 1) The sound originates in one location; 2) A given sound source can be identified at multiple microphones by its characteristic pattern; 3) The speed of acoustic sound in different paths is uniform. The actual speed and transmission paths of sounds in a given patient were unknown and our results, therefore, will be presented with these considerations in mind. Some crackles appeared in only one or two microphones, whereas others appeared in many, consistent with the hypothesis that some crackles are more peripheral and some more central in origin. The squawks observed were "peripheral", wheezes tended to be more "central" using this technique.

Characterizing of lung sounds in terms of their relative site of origin has the potential of presenting a new dimension in terms of their classifications. It has implications for obtaining a better understanding of their mechanism of production and hopefully can be used to help separate differing pathophysiologic states.

INTERBREATH VARIANCE OF LUNG SOUND SPECTRA AND EFFECTS OF DATA WINDOWS AND FLOW GATE TOLERANCES

Yuns Oh and Hans Pasterkamp
Dept. of Pediatrics, University of Manitoba, Winnipeg, Canada

Several parameters used to describe lung sound spectra were evaluated for intrasubject interbreath variability, and used to assess the effect of various data windows and flow-gate tolerances. Three male and 3 female healthy, non-smoking subjects participated, with ages 25 to 35 y, heights 1.60 to 1.90 m, and weights 52 to 70 kg. Lung sounds were recorded with a contact sensor (Siemens EMT25C) at the right lower lobe posteriorly, and airflow was measured at the mouth. The signals were quantized to 12 bits at 10,240 samples/s for the lung sound and 320 samples/s for the airflow. Recordings were obtained over 50 to 60 s and included 12 to 33 breaths. Visual feedback and coaching were used to help breathe at target flows of 15 ml/s/kg (low flow, LF) and 30 ml/s/kg (high flow, HF). To process the data, the airflow signal was averaged over 100 ms epochs. If it fell within the set range (± tolerances of 20%, 10%, or 5%), a Hanning, rectangular, or 5% cosine window was applied to 1024 or 2048 points of the corresponding lung sound segment before FFT analysis. The spectra were averaged to obtain a single representative spectrum for each breath. Sounds at flows of 0 to 0.1 l/s were also processed to obtain a background spectrum (bkgd) for each subject. The spectra at target flows were used to obtain F_{hi} and F_{lo} (the first frequency above and below 200 Hz at which the signal drops to <3 dB above bkgd), P_{max} (the maximum signal/bkgd ratio), F_{max}(the frequency at P_{max}), Q1, Q2, Q3, SE_{99} (the frequencies below which 25%, 50%, 75%, and 99% of the power between 100 and 800 Hz are found), and slope (the slope of a linear regression line of log power versus log frequency between 300 and 700 Hz). Means and coefficients of variation (c.v.) were calculated for each subject and each processing condition. The c.v. were small (<10%) for Q1, Q2, Q3, SE_{99} and slope. P_{max} showed moderate (~10%) variation and F_{max}, F_{hi} and F_{lo}showed large (>20%) variation. To analyze the effects of flow gates and data windows, results were compared by repeated measures ANOVA. The rectangular data window differed from the Hanning and 5% cosine data windows in the means for Q1, Q3, SE_{99} and slope at LF, and for Q2, Q3, SE_{99} and slope at HF. The c.v. was also higher with the rectangular window for SE_{99} and slope at LF, and F_{hi} at HF. Discontinuities at the endpoints of the FFT may produce more power, and greater variation of that power, at higher frequencies with a rectangular window. Varying the FFT data length between 1024 and 2048 points had no appreciable effect on spectral parameters. Flow gate tolerance had an inverse relation to the c.v. of Q2, Q3, SE_{99} and slope at LF, and Q3, SE_{99} and slope at HF. The means of F_{lo}, Q1 and Q3 at LF, and F_{hi} at HF were also affected. Although sampling within a more narrow flow gate might be expected to produce less breath by breath variation, each breath in that case contained so few samples that the variation actually increased. We conclude that Q1, Q2, Q3, SE_{99} and slope are highly reproducible at given flows from breath to breath in normal subjects. A rectangular window should not be used and a flow gate tolerance of at least 10% should be applied in studies of lung sounds.

REPEATABILITY OF BREATH SOUND PARAMETERS IN HEALTHY NON-SMOKING MEN.

Sovijärvi ARA*, Malmberg P*, Kallio K**, Paajanen E**, Katila T**
*Department of Pulmonary Medicine, Lung Function Laboratory, Helsinki University Central Hospital and **Helsinki University of Technology, Finland

Repeatability of breath sound parameters, based on spectral analysis, have been studied in 10 healthy non-smoking men (age 23 - 41, years, mean 33). The breath sounds during 10 tidal breathing cycles were recorded on two successive days between 1 and 2 p.m. (interval 1-3 days) with the subject in sitting position. The sounds were recorded simultaneously with two microphones, one attached on the right posterior chest wall (B & K 4134 condenser microphone) and the other on the right side of the cricothyroid cartilage over the trachea (a piezoelectric contact sensor, PPG no. 102, Technicon, Haifa). The places of microphones were the same on both recording days. The peak expiratory and inspiratory flows during recording were kept at 1.25 l/s monitored with pneumotacograph. The sound and flow signals were recorded into an 8-channel DAT recorder /Teac RD-NT). The data were digitalized with a data acquisition and control unit (HP 3852A) with a sampling rate 12 KHz for sound, and stored on a magneto-optical disk of a Unix work station (HP 9000/330C). The measuring frequency band was 75 - 2000 Hz. The signals were phase-gated, averaged over 10 successive cycles and analyzed using an automatic software developed for the purpose. From the power spectra of expiratory and inspiratory cycles the following parameters were calculated: the median frequency (F50), frequency of maximum intensity (Fmax) as well as the sound intensity (root mean square, RMS). The intraindividual variation of breath sound parameters from recordings on successive days, expressed as the coefficient of variation (CoV) were the following:

a) Inspiratory sounds, trachea; RMS 27%, Fmax 8.7%, F50 6.5%.
b) Inspiratory sounds, chest; RMS 41%, Fmax 5.7%, F50 5.0%.
c) Expiratory sounds, trachea; RMS 33.0%, Fmax 8.2%, F50 6.9%.
d) Expiratory sounds, chest; RMS 47%, Fmax 4.7%, F50 8.5%.

The results indicate, that although flow-controlled standardized breathing was used, the variation of intensity is high, but the parameters derived from the frequency spectra are markedly smaller, both in tracheal and peripheral sounds. Thus, the repeatability of power spectra of averaged breath sounds is good enough to conclude that the method can be developed for clinical purposes.

WAVELET TRANSFORM BASED RESPIRATORY CRACKLE DETECTION

E. Ç. Güler[1], B. Sankur[2], O. Alkin[2], C. D. Mendi[2], Y. Kahya[2], T. Engin[3]

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Crackles are characterised by their short duration and relatively high frequency content. The analysis of crackles needs spatiotemporal filtering since they overlap both in time and frequency. Such a time-frequency expansion of the signal can be implemented via orthonormal wavelet transforms (WT) which decompose an arbitrary signal into a succession of orthogonal subspaces at different scales. This decomposition is enacted using a single prototype function called an analysing wavelet. Fine temporal analysis is done with contracted versions of the wavelet, while fine frequency analysis uses "dilated" versions.

In this work, we have proposed a method for the detection and classification of crackles based on the matched discrete orthonormal WT analysis. The idea behind the method is to increase the crackle / background ratio by expanding the sound signals in the time-scale space, identifying the bands containing crackles and using various linear / nonlinear operations for enhancement. The proposed novel method can be summarized as follows:

(1) The discrete wavelet transform of a length N respiratory sound signal is computed into M octave bands (M is typically 5). As analyzing wavelets, we have used matched wavelets designed with reference to typical crackle waveforms.

(2) In the second step M full-scale waveforms are reconstructed selectively from individual wavelet components each of length N. This represents in fact bandpass filtering operation in the scale space and results in an M-by-N array. This approach has been used because it reveals crackles at different scales, and also avails us of the possibility to apply nonlinear background suppression algorithms in the individual bands.

(3) Finally, the M-by-N matrix of wavelet coefficients at different scales is treated as an image. Since transient phenomena like crackles are expected to show up on more than one scale, then vertical edges in this "image" are

Use of a derivative filter for detection and analysis of "crackles".

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Crackles may show different length or amplitudes but are always characterized by a zone, the initial one, where the signal rises up quickly. In order to evaluate this speed we computed the first derivative (FD) of the signal and from the observation of the absolute value of FD (FDAV) we have noted that crackles are easy to identify; in fact they show a "narrow" zone where FD is "high" in comparison to the contiguous. This is useful in "time-expanded analysis"; in fact the observation of FDAV helps to take decisions when signal and crackles are of the same order of magnitude. Moreover we have seen that, in corrispondence of a crackle, FDAV always shows the same morphologic characteristic, even when it is not an isolated one. This characteristic is: FDAV has at least three peaks that are in corrispondence of the first two deflections of a crackle. This fact have suggested the idea for development of an algorithm for "automatic detection of crackles".
This algorithm is based on the comparison of FDAV with an opportune treshold (T). When FDAV exceeds T we check if, during the following Tw (window) seconds, two condition are verified: (1) FDAV remains over T for at least Tw/2 seconds; (2) there are at least three close peaks within the temporal window Tw : in this way the crackle is detected.
A determinant aspect for the algorithm effectiveness is the choice of T which at present is not completely automatic and it is made for every signal by observing the frequency distribution of FDAV. This last is always concentrated on small values of FDAV but has a tail towards greatest one. T must be a value in this last zone. We have seen that the best results are obtained by choosing values greater than 92%-98% of FDAVs. The choice of Tw is less determinant because it influence only the minimum distance that crackles must have to be detected. Since crackles have length generally less than 20 ms. we have chosen Tw= 5 ms.

Savitzky A., Golag M.J.E: Smoothing and differentiation of data by simplified least square procedures. Analytical Chemestry,36,1627-38, 1964

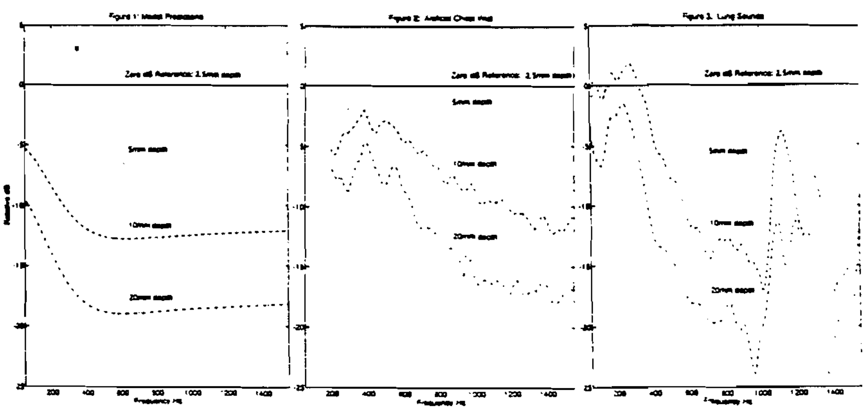
Marchesi C., Tecniche numeriche per l'analisi dei segnali biomedici, Pitagora '92.

MICROPHONE AIR CAVITY DEPTH EFFECTS ON LUNG SOUNDS

George R. Wodicka[1], Steve S. Kraman[2], Gerald M. Zenk[1], Hans Pasterkamp[3]

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

The use of microphones to measure lung sounds is widespread because of their high fidelity, small size, and low cost. An air cavity is placed between the skin and the microphone to convert the chest wall vibrations into a measurable sound pressure. To investigate the importance of cavity depth, an acoustic circuit model of the chest wall-air cavity-microphone interface was developed that represents both the chest wall and the microphone (Sony ECM-155) diaphragm as series resistance-mass-compliance elements connected together via an air conduit. The predicted decrease in sensitivity for an 8 mm diameter cylindrical cavity from a depth of 2.5 (reference) to 20 mm is shown in Fig. 1. The results of measurements using an artificial chest wall with a noise source and of flow-gated lung sounds on a healthy subject performed using a microphone at various cavity depths are summarized in the same relative spectral form in Figs. 2, 3. Although the relative responses are much more complex than the model predictions, there is a clear decrease in sensitivity at higher frequencies for larger cavity depths. This indicates that placing the microphone closer to the chest wall improves the overall high-frequency response of the measurement.



COMPOSITION AND CALIBRATION OF NEW-TYPE LUNG-SOUND SENSORS BASED ON MICROPHONES

Fujihiko SAKAO, Kinki University, Higashihiroshima,
Masashi MORI, Tokyo National Chest Hospital, Kiyose, Tokyo
Hiroshi SATO, Institute of Flow Research, Akasaka, Tokyo

A few kinds of new type lung-sound sensors based on microphones have been devised. Together with conventional stethoscopes and rather conventional air-coupled microphones, they are calibrated with a special calibrating facility simulating a human body surface.

Some of them are variations of air-coupled microphones. They include one with a bellow to enclose the air-volume, which is very convenient for practical use. Among others are accelerometers with microphone and "loading" diaphragm over an air-volume. In acceleration, pressure is build up in the air-volume to make the diaphragm follow the acceleration, and it is sensed by the microphone.

The other type is accelerometer based on sensitivity to acceleration of an electret condenser microphone itself. This type provides a very light-weight, high-sensitivity sensor at high frequencies.

According to calibration results, the air-coupled microphones are displacement-sensitive as expected. The accelerometers are advantageous at higher frequencies, but the diaphragm type ones are infected with some unknown noises. The "acceleration sensitive microphones" are of promising characteristics as far as the calibration results are concerned, though the application to actual lung sound is still on the way.

LUNG SOUNDS IN ARDS

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The diagnosis of ARDS (Adult Respirotory Distress Syndrome) is based on physiological parameters and X-ray findings. Most often the $AaDO_2$ or derivatives of this measure are used to describe the disturbed lung function in ARDS. The direct analysis of the structure of the lung is not possible.
In lung fibrosis a so-called sclerophonia is a constant finding at clinical examination. It is dependent of the stiffness of the structure of the lung and highly diognostic. The question arises wether this finding may also be found in cases of ARDS a disease with o reduced compliance too.

We have investigated by auscultation 25 consecutive cases of ARDS, according to the acceptedcriteria for diagnosis. In all cases we were able ta find an "ARDS-sclerophonia" during the course of the disease. In 21 patients this symptom was present early, it disapears in all surviving patients.

We therefore conclude thot the observer independent "ARDS-sclerophonia" is a good diagnostic tool in ARDS.

MYCOPLASMAL PNEUMONIA:STETHOSCOPIC AND ACOUSTIC PROPERTIES OF CRACKLES

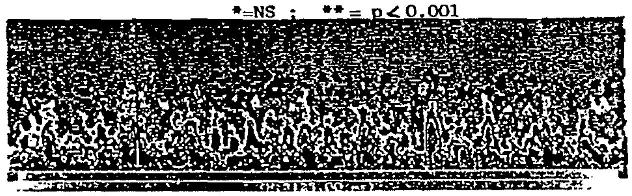
F.Dalmasso,P.Righini,R.Prota,G.Righini*
Divisione di Pneumologia ,Ospedale "Mauriziano Umberto I ",Torino,Italy
***Unità di Acustica,Istituto Elettrotecnico Nazionale "Galileo Ferraris " Torino,Italy**

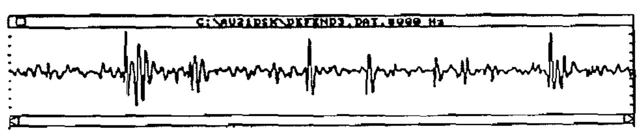
The "Primary Atypical Pneumonia" (PAP) due to the Mycoplasma Pneumoniae (PPLO),is considered atypical also for his variable extension (Minimal ,segmentary diffuse forms) and for his variable stethoscopic findings.
In 38 observed Patients (Pt),we found,on stethoscopic auscultation,adventitious discontinuous lung sounds in 74% of Pt admitted to the hospital.On auscultation , they appeared at early disease and seem to be "fine" and "late" on inspiration and didn't change through the course.
Only with Leptomaki's (1988) our data agree.In six admitted Pt, the lung sounds were recorded simultaneously with the flow at the mouth,by a miniature electret microphone (Sony ECM-144) and then analyzed with "Time-expanded waveform " (IDW;2CD;LDW;TDW) and spectrum (FFT,Sonogram) using a PC with data acquisition card Metrabyte DAS 16

CRACKLES CHARACTERISTICS

	n	IDW	2CD	LDW
Mycoplasmal Pneumonia	6	1.2+0.3	8.4 +1.8	1.8 +0.3
Cryptogenic Fibrosing Alveolitis (CFA)	15	1.3+0.2	7.9 +1.3	1.9 +0.4 *
COPD	18	2.2+0.4	11.8 +1.6	2.7 +0.3 **

*=NS ; **= p< 0.001





The acoustic analysis shows that inspiratory crackles are 'late' (95%),'fine'(93%) through all the course of disease.About the waveform parameters,they don't differ from crackles of CFA,but differ significantly from COPD ones.The crackles in PAP are in higher proportion than in bacterial or viral pneumonia and they are the earliest and most persistent sign lasting 'fine' through the disease.The few coarse and wheezes can show the involment of the largest airways.

ACOUSTICAL MONITORING DURING FORCED EXPIRATION USING RAPID THORACOABDOMINAL COMPRESSION IN INFANTS

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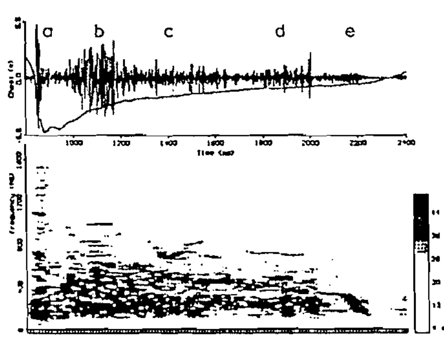
Wheezing during forced expiration occurs in normal adults, provided that flow limitation and a critical transpulmonary pressure are reached. In infants, forced expiration can be achieved by rapid thoracoabdominal compression (RTC), applied at resting end-inspiration with an inflatable jacket. Maximal flows are measured at functional residual capacity. It is uncertain, however, whether flow limitation is reached during RTC in normal infants. Also, partial glottic closure is frequently observed during RTC and produces artifacts, particularly in young infants. We therefore decided to monitor acoustically during RTC in order to document forced expiratory wheeze as an indicator of flow limitation, and vocalization, stridor or grunting related to glottic artifact. Two air-coupled microphones (Sony ECM155) were used, one attached over the anterior left upper lobe and the other placed inside of the face mask. Maximal jacket pressures ranged from 40 to 90 cm H_2O during RTC. Sounds were sampled at 5 kHz per channel while calibrated air flow at the mouth was sampled at 320 Hz. Signal processing included phonopneumography and time base expansion as well as frequency domain analysis. High resolution sonograms were generated from 1024 point FFTs with central data windows of 512 points, applied successively at 12.5 ms epochs. To date, we have studied 6 children: 4 with obstructive lung disease (CF or asthma, ages 2 to 23 months), and 2 normal controls (ages 19 and 28 months). We documented forced expiratory wheeze in 2 infants with obstructive lung disease (see Fig.1) but not in the normal children. Vocalization, grunting or expiratory stridor were often present but not necessarily associated with characteristic disturbance of the flow pattern. We conclude that acoustical monitoring during RTC is both feasible and useful. Further studies are required to assess flow limitation during RTC in normal infants and to define the acoustical characteristics flow generated sounds at the glottis.

Figure 1

Combined display of a phonopneumogram (top) and sonogram (bottom) of lung sounds, recorded over the left upper chest during RTC in an infant with asthma. There is a brief sound burst (a) related to the rapid jacket inflation, lasting < 70 ms. This is followed by a complex, partially musical initial expiratory noise (b). The later parts of expiration contain sequential and at times polyphonic wheezes (c-e).



RESPIRATORY SOUNDS PATTERNS DURING METHACHOLINE CHALLENGE

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Aim of the present study is to investigate the relationship of respiratory sounds and FEV1 during methacholine challenge in order to develop methods and test algorithms. Ten randomly chosen subjects with history of paroxymal bronchoconstriction underwent lung sounds recording during FVC manoeuvre while performing methacholine challenge (cumulative method), starting from 20 gamma and following every four minutes cumulative doses up to 1000 gamma. Methacholine challenge was stopped if a FEV1 drop $\geq$ 20% of basal occurred. Off line analysis starts dividing the sound into inspiration and expiration phases, according to the flow signal. The power spectrum of each phase is computed using an overlapped segment averaging method (each segment 1024 points, overlap 50%) and displayed for inspection. A number of parameters are automatically produced for each phase: the total power bandwidth at 10% of total power (BW, the frequency interval which lies at power exceeding 10% of total power), median frequency (F50, the frequency which separates the power spectrum into 2 equal power areas), and the power in bands 0-640 Hz, 640-1280 Hz, 1280-1920 Hz and 1920-2560 Hz as a percentage of the total power (B1, B2, B3, B4), along with the time duration of the phase. The sound can be reproduced, via D/A converter, for control and validation of results. Results: two patients showed very poor compliance to the test and were excluded by the study. Two subjects resulted negative to the test (group A), completing it without a 20% drop in FEV1, while the other subjects (group B) reached test end-point with methacoline doses between 50 and 600 mg. Only one subject developed audible wheezes during the test. The obstruction process was documented by the variation of FEV1, as percentage of the value at basal conditions (FEV1%). In order to characterize the general degree of obstruction of each patient, FEV1% and the BW, F50, B1, B2, B3, B4 for inspiratory and expiratory phases of FVC, were taken into account in the analysis of results. No relation was evident between FEV1% and the mean spectral parameters in the entire population, both during inspiration and expiration. Pronounced differences are present between subjects in the expiratory phases: group A showed consistently a higher BW and F50 over group B. The wheezing subject scored the lowest expiratory BW and F50. Between inspiration and expiration is present a shift of the sound power towards high frequencies; in group A, this shift is so relevant that the amplitude relation between B1 and B2 in inspiration is reversed in expiration while in group B it is present in a lesser extent and without B1-B2 inversion. The wheezing subject does not show any reduction in B1. In conclusion, the patterns pointed out in the results need a confirmation on a wider sample, especially concerning the group of the negative responses to the test; the shift in frequencies is already present at basal conditions, so a FVC manoeuvre could be sufficient to screen candidates for bronchial obstruction during methacholine challenge, without actually administering the test.

SURFACE ACOUSTICAL MAPPING OF THE CHEST DURING METHACHOLINE CHALLENGE

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We used digital respirosonography during methacholine challenge (MCh) to assess changes in lung sounds before wheeze becomes apparent, and to define the regional transmission of wheeze. Five boys with asthma, ages 10 to 15 y, underwent a standardized MCh while air flow and respiratory sounds were simultaneously recorded. Eight contact accelerometers (EMT25C, Siemens) were attached with double sided adhesive rings, four on the back over the superior segments (A and B) and posterior basal segments of the right and left lower lobe (C and D, respectively), and four in the front over the right and left anterior upper lobes (E and F), over the middle lobe on the right (G) and over the trachea at the suprasternal notch (H). Data were recorded for ≥30 s at baseline and then again at each step of MCh after $FEV_{1.0}$ had dropped ≥5%. Sounds were analyzed at flows of 1 l/s ± 10%. Subjects #3 and #4 had >20% fall in $FEV_{1.0}$ already at the first MCh concentration, and only wheeze at that concentration (MCwz, in mg/ml) could be analyzed. The other subjects had recordings at concentrations before wheeze occurred (MCpre-wz). Results were as follows ($\Delta FEV_{1.0}$ in brackets, BSI = change in normal breath sound intensity relative to baseline, I, E = inspiration and expiration):

Subject	#1	#2	#3	#4	#5
MCpre-wz	**2 (16)**	**2 (6)**	**n/a**	**n/a**	**1 (6)**
inspiratory BSI	↓ C,D,E,H	↓ C, ↑ E,F			↓ A,B,E
expiratory BSI		↑ A,B,C,D,E,F			↑ A,B
MCwz	**4 (46)**	**8 (30)**	**0.25 (81)**	**0.25 (38)**	**2 (29)**
wheeze duration	I > E	I = E	I > E	I > E	I > E
loudest wheeze	H	H	H	E	G
transmitted to	C, A	F, E	F, A	A, C	E

It appears that normal inspiratory lung sounds during MCh may decrease at the lower lobes whereas expiratory sound intensity may increase before $FEV_{1.0}$ falls ≥20% and before wheeze appears. Interestingly, wheeze was more prominent during inspiration and more localized to the right chest in these five subjects. Compared to spirometry, mapping of respiratory sounds during bronchial provocation avoids the problems associated with forced expiratory manoeuvres and appears to be better for the early detection and localization of airway narrowing.

This study was supported by the Children's Hospital of Winnipeg Research Foundation.
Dr. Consunji-Araneta is a fellow of the Manitoba Lung Association.

LUNG SOUNDS DURING ALLERGEN-INDUCED ASTHMATIC RESPONSES USING AIRFLOW-STANDARDIZED PHONOPNEUMOGRAPHY.

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The early asthmatic response (EAR) to inhaled allergens is primarily due to smooth muscle contraction, whereas the LAR also results from inflammatory mechanisms, such as mucosal swelling. We postulated that these distinct mechanisms are of importance in the generation or transmission of lung sounds in asthma. We investigated the influence of EAR and LAR on these sounds using a standardized allergen challenge in 8 mildly asthmatic subjects. Measurement of FEV_1 and recordings of airflow, lung volume changes and lung sounds were performed at baseline (PRE), during the EAR, during the recovery phase at 2 hr (MID), during the LAR at 7 hr, and 10 min after the inhalation of salbutamol at 7 hr (POST). The recordings were made during flow- and volume standardized quiet breathing, and during maximum forced manoeuvres. Airflow-dependent power spectra (FFT) were analyzed for lung sound intensity (LSI), quartile power points ($Q_{25\%}$, $Q_{50\%}$, $Q_{75\%}$), and ratio of wheezy spectra to the total number of spectra (W%). The results were analyzed using ANOVA.

The range of FEV_1 in %fall from baseline was: EAR 21-34%, MID -7-11%, LAR 22-38%, and POST -17-7%. In spite of similar values of FEV_1 ($p \geq 0.156$), LSI during quiet expiration was significantly higher at POST than at PRE for Mic_1 ($p \leq 0.004$), and at POST than at MID for Mic_1-Mic_3 ($p \leq 0.036$), whilst no differences were found between EAR and LAR. During quiet expiration $Q_{25\%}$ was higher at PRE than at POST for Mic_1 and Mic_3 ($p \leq 0.047$), and there was an interaction between $Q_{25\%}$-$Q_{75\%}$ and airflow between EAR and LAR for Mic1 ($p \leq 0.004$) and Mic_2 ($p \leq 0.042$). During forced expiration with decreasing airflow wheezing was more prominent at MID and POST than at PRE for Mic_1-Mic_3 ($p \leq 0.014$), and at LAR than at EAR for Mic_1 and Mic_2 ($p \leq 0.012$).

We conclude that the intensity and pitch of lung sounds, as well as the extent of wheezing, vary during the course of an allergen challenge, even at similar levels of airways obstruction. This suggests that lung sounds reflect differences in the pathophysiology of airway narrowing.

Supported by a grant of the Netherlands Asthma Foundation.

SPECTORAL CHARACTERISTICS OF COUGH SOUNDS IN NORMAL AND ASTHMATIC SUBJECTS.

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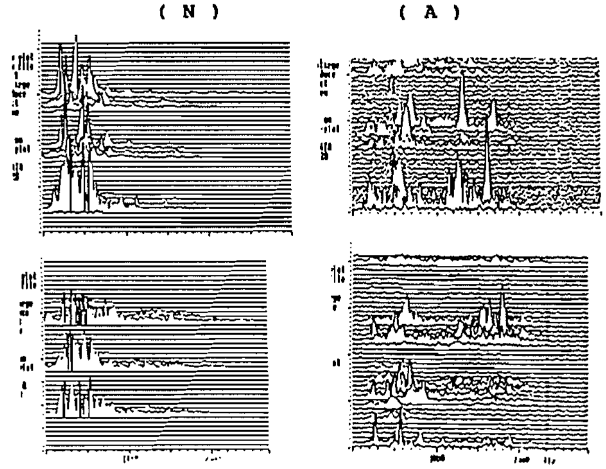
Tufts Lung Station, St Elizabeth's Hospital and Dept. of Medicine,Tufts University school of Medicine Boston Mass.USA

Fifteen Normal and fifteen Asthmatic subjects were instructed to make three voluntary coughs within 6 seconds. Sound signals recorded at the neck with contact microphone, were digitized and real time spectrograph displayed using a fast fourier transform spectrum analyzer.
Normal subjects showed all signals were within 2 kHz.and peak energy around 300 to 500 Hz. (N)
Asthmatic subjects showed two distinct spikes complexes. One of which were within 1 kHz,peak energy around 300 to 500 Hz.The second between 1 and 2 kHz with peak energy around 1.3 to 1.5 kHz. (A)   Cough induced during methacholine bronchoconstriction showed similar spectoral pattern of the asthmatic subjects. Asthmatic subjects who had been placed on steroids and clinically very stable state, failed to show the second component of high frequency spikes of energy although the cough period remained much higher than normal subjects.

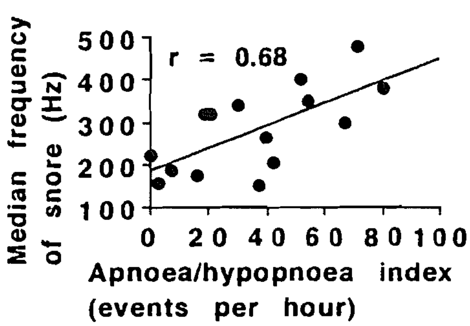
(N) (A)



THE RELATIONSHIP BETWEEN SNORE FREQUENCY AND SEVERITY OF OBSTRUCTIVE SLEEP APNOEA (OSA)

DSP Spence, N Ishaque, G Jamieson, PMA Calverley, JE Earis.

We have previously presented preliminary data examining the frequency content of snores. We have extended our observations to a larger more varied group of patients and examined the relationship between snore frequency and severity of obstructive sleep apnoea as measured by the apnoea/ hypopnoea index. We studied 15 patients refered to our centre for evaluation of heavy snoring and possible OSA. All patients underwent standard polysomnography and computer assisted manual sleep staging. Sounds were recorded by an air coupled microphone over the manubrium sterni and recorded onto video tape. Stage 2 sleep was studied and snores were identified. 30 second periods of snoring were digitised and analysed using an FFT technique.



There was a significant ($p < 0.005$) relationship between snore median frequency and AHI. The reason for this is unclear but may be related to intrathoracic pressure changes or differing sites of upper airway obstruction.

UPPER AIRWAYS MODELLING BY LPC FILTERING IN HEAVY SNORES AND OBSTRUCTIVE SLEEP APNOEA. (OSA)

DPS Spence, K Rees, C Sun, B Cheetham, PMA Calverley and JE Earis

The site of upper airway obstruction in OSA is variable and may involve the soft palate, the hypopharyx or both. The successful surgical treatment of OSA requires that the site of upper airways obstruction is identified and only those patients whose obstruction is at the level of the soft palate are selected. This can be determined by upper airway manometry but this is uncomfortable and positioning of the balloons is difficult.

We have recorded oesophageal, hypopharyngeal and suprapalateal pressures in patients being considered for upper airway surgery in order to determine the site of snoring. The sound signal was detected by a free field directional microphone and all signals were recorded onto an FM tape recorder for subsequent analysis.

The sound signal was analysed by Linear Predictive Coding Techniques (LPC) and an "electronic" model of the upper airway constructed. We will demonstrate a video recording of this airway model and discuss how it may be used to develop a non-invasive method to determine the site of upper airway obstruction.

Generation of snoring sounds - pressure/flow/sound studies of simulated snores.

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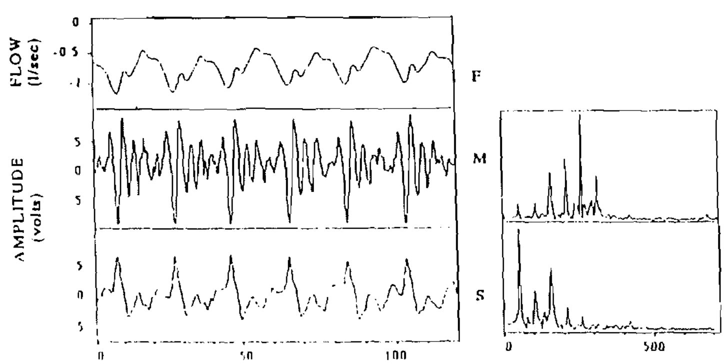
1. Dept. of Pediatrics, University of Calgary, Alberta Children's Hospital, Calgary, Canada.
2. Dept. of Physiology and Biophysics, Faculty of Medicine, Rappaport Family Institute for research in Medical Sciences. Technion - Israel Institute of Technology, Haifa, Israel.

In order to better understand the acoustic mechanism of generation of snoring sounds, we studied simulated snores from 4 male (mean age 35 years, range 29-43) volunteers. They were healthy, non-obese men, with no history of snoring. Two experimental designs were used: a. 3 subjects had mouth flow measured by a Fleisch #2 pneumotachograph, connected to a Validyne differential pressure transducer. Sound was recorded at two locations: 1. Tracheal - a piezoelectric contact sensor (Rappaport Institute) placed 1-2 cm above and slightly to the right of the suprasternal notch. 2. Ambient - an electret-type condenser microphone hung in front of the pneumotachograph, 20 cm from the mouth. Sounds were amplified (x200) and band-filtered (75-2000 Hz). b. 1 subject had supraglottic (distal to vibration site) and nasal (proximal to vibration site) pressures measured in addition to the above. Polythene pressure tubing was placed 17 cm and 1 cm distal to the nostril respectively, and connected to Validyne pressure transducers. Both nostrils were occluded and the subjects were asked to simulate inspiratory snores. All signals were simultaneously digitized with a 12 bit, 8 channel A/D converter (MacADIOS 8ain, GW Instruments) and appropriate software (SuperScope, GW Instruments). Data analysis was performed off-line, and consisted of wave-form analysis of all signals and 1024 point FFT spectral analysis of the sounds.

Results: Snoring sounds were characterized by repetitive sequences of complex sound structures occurring at a frequency of 40-100 Hz. These structures consisted of 2-7 waveforms of higher frequencies (up to 900 Hz) and of consistent appearance. When transformed into the frequency domain, these sound structures appear as multiple, closely spaced peaks of power, centered around the internal frequency of the individual sound structures (comb-like shape). All runs showed parallel oscillations of flow, both pressures and the sound structures in both channels. The highest and sharpest sound-wave deflection always occurred when flow was highest. These data indicate that the snoring sound is produced by a sudden openning of an obstructed lumen, with resulting aero-elastic interactions, similar to those observed in speech. The vibrating structure, however, is located in the supraglottic area.

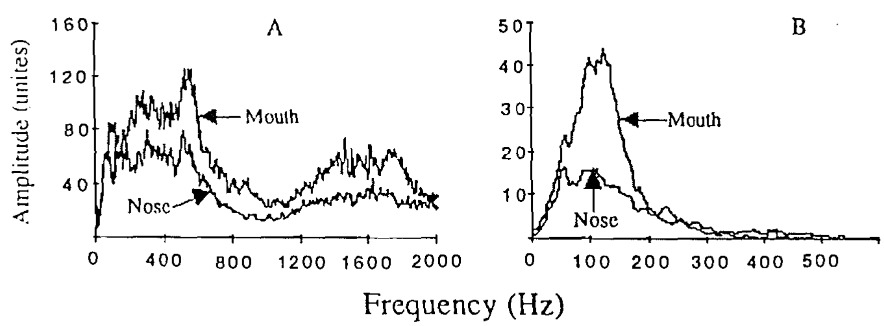


The changes in lung sounds spectra due to route of breathing (nose vs. mouth)

Muhammad Mahagnah, M.D and Noam Gavriely, M.D., D.Sc.

Department of Physiology and Biophysics, Faculty of Medicine and Rappaport Family Institute for Research in Medical Sciences, Technion - Israel Institute of Technology, Haifa, Israel.

We used the phonopneumography (PPG) to examine the changes in lung sounds spectra due to route of breathing, i.e., breathing through the mouth vs. breathing through the nose. We used a special mask (Rudolph mask 2-way # 7900) which contains two one-way valves, each valve ended by a tube. Air flow through the first tube was in the inspiratory direction and through the second tube air flow was in the expiratory direction. Connecting the flow channel of the recording system to the first tube enable us to record the inspiratory direction first when the subject breathed through the mouth with closed nose and then breathed through the nose with closed mouth. Recording the expiratory sounds was done by connecting the flow channel of the recording system to the second tube. The flow rate was hold constant at 1.0 l/s during all the measurements through visual flow feedback.
Respiratory sounds from five young, healthy nonsmoking men age of 23 ± 3 years, were recorded over the trachea and two locations over the chest wall. Each subject was studied while breathing through the mouth and then while breathing through the nose, at the inspiratory and the expiratory phase. The breath sounds were simultaneously picked up by contact sensors placed over each location .The output was amplified and bandpass filtered in the frequency range of 75 - 2000 Hz. The averaged power spectra of the breath sounds were calculated by using a 2048 points Fast Fourier Transform . Each subject was asked to breath several times at controlled air flow of 1.0 l/s until receiving a stable pattern of the spectra.
We found that during breathing through the mouth the amplitude of the respiratory sounds was 2.0 ± 0.52 folds greater than the amplitude during nose breathing without changes in the frequency range. This finding is important for the standardization of the PPG if we wish to use it as a diagnostic tool for examination of airway and lung health.



Averaged amplitude of the inspiratory breath sounds recorded over the trachea (A), and over the anterior upper right chest wall (B) when the subject breathed through the mouth (indicated "mouth") and when the subject breathed through the nose (indicated "nose"). Note that the amplitude of the breath sounds recorded when breathing through the mouth is greater than the amplitude of the breath sounds recorded when breathing through the nose.

LUNG AUSCULTATION AMONG PHYSICIANS IN TRAINING: A LOST ART ?

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We live in times of sophisticated diagnostic technology and declining interest in bedside clinical skills. To evaluate the impact that modern technology and current training practices may have had upon physical diagnosis, we tested the pulmonary auscultatory skills of 124 internal medicine residents, 11 pulmonary fellows and 63 medical students of six University-affiliated programs of the Philadelphia and Pittsburgh area. Most of these physicians had not been exposed to any structured teaching of pulmonary auscultation during their internal medicine or pulmonary training. Participants were asked to listen by stethophones to a tape containing 9 respiratory events, directly recorded from patients and selected out of a pool of 200 sounds. Participants were allowed to listen to each event as long as needed and answered by filling a multiple choice questionnaire. The trainees' accuracy ranged between 0-100% for pulmonary fellows (median = 54.5) and 13.7-82.3% for medical residents (median = 51.6). When compared to medical residents, pulmonary fellows showed a higher identification rate only for the pleural friction rub (72.7% vs. 41.9%, P=0.05) and the end-inspiratory crackles of interstitial fibrosis (45.5% vs. 13.7%, P=0.02). Medical residents did not significantly improve with year of training and were never any better than fourth year medical students. These data confirm recent studies indicating that house officers are prone to making critical errors when doing physical examination. They also suggest that the major burden of preparing future physicians in this time-honored art may now rest mainly on medical schools, and that the deficiencies noted in the performance of physical examinations by students receiving their medical degree (Sox, HC *et al.* J.Med.Educ. 1984; 59 (11 pt 2):139-147) may not be corrected during subsequent training.

THE TEACHING OF LUNG AUSCULTATION IN AMERICAN INTERNAL MEDICINE AND PULMONARY TRAINING PROGRAMS

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Pulmonary auscultation, a time-honored art, is suffering a declining interest caused by competing diagnostic technology and, possibly, inadequate training of physicians. To evaluate the time and importance given to this skill during medical training nationally, we surveyed the 598 directors of all accredited Internal Medicine and Pulmonary programs. On a 6-step scale, all 315 respondents attributed great clinical importance to lung auscultation and expressed desire for more auscultatory teaching during training (5.3 ± 0.9 and 4.5 ± 1.2 respectively). However, only 14.4% of medicine residencies and 11.5% of pulmonary fellowships offered some structured teaching of lung auscultation to their trainees. This included the use of lectures, seminars, audiotapes or other educational modalities. Medicine programs with structured auscultatory teaching were significantly more likely to be non-university affiliated and located in the north-east. Internal Medicine directors assigned more clinical importance to lung auscultation than pulmonary directors (5.5 ± 0.7 vs 5.1 ± 1.1 on a 6-step scale, $P=0.003$) and gave also greater clinical value to the recognition of a selected group of 13 auscultatory findings. This difference was significant in regard to transmitted voice sounds (all P's< 0.02), pleural rub ($P=0.015$), and stridor ($P=0.043$). There was no correlation between directors' year of graduation or subspecialty type, and the importance attributed to pulmonary auscultation. These data indicate that formal auscultatory teaching is rarely offered to post-graduate trainees. Considering that attending physicians are now spending less time in the bedside observation and supervision of trainees, it is possible that deficiencies noted in the performance of physical examinations by students receiving their medical degree may not be corrected during subsequent training.

Efficacy of Wireless Stethoscope for Lung sounds Education

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Auscultation of lung and heart sounds has to be mastered as a basic means of physical examination in medical education program. At present, students use their several stethoscopes for learnig auscultation, but they do not necessary to auscultate the same lung sounds due to sound unstableness and location variability. In some institutions, a special stethoscope in which plural stethoscopes are connected each other by a tube is used for simultaneous auscultation. However, this type of educational stethoscope has some problems, i.e., sound weakening, noise, complications to use, etc.

Recently, we have producted a new FM wireless stethoscope(Kenz Medico Co. Ltd.). This wireless stethoscope is consist of two independent parts, i.e., chest piece(pick-up and transmitter, frequency characteristics; 100～1000Hz) and ear piece(receiver). By means of this wireless stethoscope, plural persons including students or patients can simultaneously auscultate the same sounds with a teaching staff or doctor.

We also studied observer variability to clarify the clinical efficacy of this wireless stethoscope in comparison with an usual stethoscope. Observers auscultated lung sounds of the patients usig both kinds of stethoscope, and illustrated the sound properties without nomenclature. In accordance with the study, we recognized that the wireless stethoscope has better abilities than usual one for lung sounds education.

DIFFERENCES IN SPECTRAL PARAMETERS OF TRACHEAL BREATH SOUNDS BY THREE DIFFERENT SPECTRAL ESTIMATORS

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Although the most common spectral analysis of respiratory sounds has been based on Fourier transform, other techniques that can be tried to derive frequency parameters are the autoregressive (AR) and the adaptive filtering (AF) methods. However, as for each method different assumptions are considered, comparative errors in spectral parameters can ensue. The purpose of the present study was to test the reliability of frequency parameters of tracheal breath sounds when they are derived from different spectral estimators. We processed 77 records of tracheal breath sounds from ten subjects, seated in a plethismographic cabin and breathing through a pneumotachometer at flow ranges between 0.5 to 1.5 l/sec. Measured parameters were weighted mean frequency (WMF), frequency at maximal power (FMP), frequency at 10% of maximal power (F10MP), and frequencies below which 25% (F25PS), 50% (F50PS), 75% (F75PS) and 99% (F99PS) of all the power spectrum occur, while spectral estimators were the periodogram (PG) with the algorithm of Cooley-Tukey, Burg's algorithm for AR modeling and the FTF's algorithm for AF technique. We found by one way ANOVA and analysis of residuals that only F99PS, FMP and F10MP did not present bias or statistical differences ($p>0.05$) among PG, AR and AF techniques. Also, all spectral parameters were statistically not different ($p>0.05$) between AR and AF techniques but F25PS, F50PS, F75PS and WMF measured in power spectra by PG were significatively higher ($p<0.01$) than values coming from AR or AF power spectra. Our results suggest that AR and AF techniques give a more consistent frequency spectral parameters than PG technique, and parameters as F99PS, FMP, and F10MP assure confidence of comparative studies because they were not affected by the power spectrum estimators.

ADAPTIVE CANCELLING OF AMBIENT NOISE IN LUNG SOUND MEASUREMENT

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Tokyo, Japan

Ambient noise such as machine noise and human voice often disturbs lung sound measurement. Ambient noise is transmitted to the microphone measuring lung sound through the chest wall around it. Cancelling of the noise component may be possible by identifying this transfer function. The function, however, may vary with subject and measuring site, so that it should be modified dynamically. We applied adaptive filtering technique to solve this problem. An off-line adaptive noise canceller having a transversal filter was implemented in a workstation. Filter coefficients were controlled by LMS algorithm. Wide-band random noise and human voice were used as ambient noise. Noise corrupted lung sound and ambient noise were simultaniously recorded and then transferred to the workstation. Noise reduction was calculated as the ratio of the power of the canceller output over that of the canceller primary input in the absence of lung sound. Ambient noise was reduced by more than 30dB using a 256-tap filter. Clear lung sound can be heard by D/A convertion of the canceller output. The results show that this method is very effective as a preprocessing tool for the lung sound analysis, and that it is promising to realize an electronic stethoscope with high ambient noise immunity by real-time signal processing.

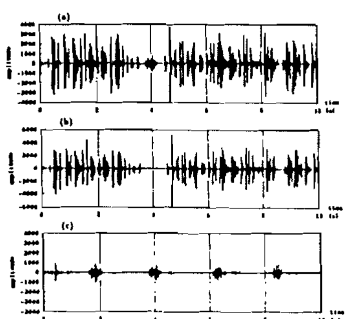

Fig.1 Performance of noise canceller. Ambient noise is human voice. (a)Noise corrupted lung sound. (b)Ambient noise. (c)Canceller output. Adaptation started at time=0s, with all filter coefficients set to 0. Ambient noise is well cancelled and lung sound is clearly discernible.

ACOUSTIC MODEL OF RESPIRATORY AIRWAYS

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The spectral composition of respiratory sounds reflects the status of airways geometry and the dynamic behavior of the respiratory system. Thus a model of the lung structure can be utilized as a tool for studies of respiratory sounds.

A PC based acoustic excitation and transmission model of pulmonary geometry for the evaluation of lumped and distributed acoustical impedances of the pulmonary airways was developed. Specifically, resistive and reactive components of acoustic impedances for a single path, cumulative and accumulated up to a selected level of airways generations are computed. Partitioning of acoustic impedances allows one to evaluate the effect of alterations in lung structure and obstructive changes on the frequency composition of the transmitted sounds. Segmental acoustic analysis on the level of a single airway, as well as a group of airways or a selectable set of airways' generations, provides a tool for an evaluation of acoustic composition and transmission characteristics of respiratory sounds. Acoustic filtering due to specific airways geometry is based on Weibel's lung morphometry and can be extended to filtering by constriction as well as distribution of fundamental frequencies and their harmonics.

The model allows interactive evaluation of the transmission properties and genesis of respiratory sounds. Upon the addition of filtering characteristics of the thoracic wall the simulated data can be validated against clinically obtained auscultatory signs.

ACOUSTIC PROBES FOR ENDOBRONCHIAL SOUNDS

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The frequency content of LungSounds is undoubtedly preserved better through endobronchial detection as possible closer to the generation site. This technique is compatible with the bronchospic practice without further discomfort for the patient. To this goal we have evaluated two possibility: 1) to use the inner channel of the insertion tube of the bronchofiberscope as sound pipe,2) to use the insertion tube itself as a carrier of a miniature electret microphone integral with its tip. The former solution doesn't lay any safety problem but shuts manoeuvrable accessory out; the latter needs a very good electrical insulation of the microphone case and relative circuitry respect to the ground but allows the ordinary manoeuvres. In order to compare the acoustic responses of two systems we have measured their frequency response in laboratory.
Since the former system makes it possible to use an high performance microphone (Sony ECM-144)its response is caracterized principally by the acoustic transfer function of the cylindrical pipe : the phase curve exhibits the typical resonances occuring at regularly spaced frequencies (determined by the pipe lenght), nevertheless the amplitude curve results quite flat ,in a large frequency range,owing to the smoothing of these resonances by the viscous damping of the sound wave in the narrow pipe (2.6 mm)(fig.1). About the latter solution we have verified that the miniature microphones(4x5x2 mm) at present available show a suitable frequency response only at the medium and high frequencies,that's above 500 hz. Even if the phase and amplitude curve in this case seems more regular (fig.2) the frequency limitaton is too severe for an accurate detection of Lung Sounds. The vaweforms are no longer preserved since the microphone acts as first-order derivative circuit.
Therefore the former system is actually preferable from safety and acoustic performance point of view.

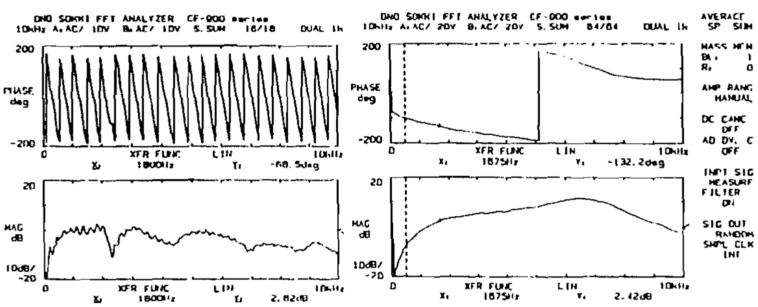

FIG 1 26/05 FIG 2 20/05/93 11:01

TWO-DIMENSIONAL DISCRIMINANT ANALYSIS OF CRACKLES IN FIVE PULMONARY DISORDERS

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*Lung Function Laboratory, Department of Pulmonary Medicine, Helsinki University Central Hospital, **Laboratory of Clinical Physiology, Institute of Occupational Health, ***Department of Epidemiology and Biostatistics, Institute of Occupational Health, Helsinki, Finland

Crackling lung sounds were recorded in the basal back areas of the chest with a microphone simultaneously with airflow at mouth from patients with cryptogenic fibrosing alveolitis (CFA) (N = 10), bronchiectasis (BE) (N = 10), chronic obstructive pulmonary disease (COPD) (N = 10), heart failure (HF) (N = 10), acute pneumonia (AP) (N = 11) and resolving pneumonia (RP) (N = 9). The timing during inspiration was studied phonopneumographically: the beginning of crackling (BC) and the end point of crackling (EC) both related to the total duration of inspiration. The waveforms, initial deflection width, the two-cycle duration and the largest deflection width, of the individual crackles in time-expanded waveform were measured.

Each of the timing parameters was compared with each of the waveform parameters in discriminant analysis. The discrimination property of the measured parameters was good; the significance in BC was the lowest (F-test, $p < 0.05$), in the others $p < 0.0001$. The paired Mahalanobis distance was great especially between the groups CFA, BE, COPD and HF. Also significant differences were detected between BE, COPD and HF with some overlap. HF and BE were close to each other. AP was near BE and far from CFA; RP near CFA and far from COPD and HF. According to the profile of two-dimensional discriminant analysis cryptogenic fibrosing alveolitis is clearly distinguished from the other groups.

The results are in concordance with the authors' previous crackle sound studies (Chest 1991; 99:1076-83 and Chest 1992; 102:176-83). The results indicate that the method can be adapted for diagnostic purposes to separate the features of crackles in different diseases. The method offers a new and visually informative way of analyzing crackling sounds.

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Presented by

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Helsinki

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Marina Congress Center

Katajanokanlaituri 6, Helsinki, Finland

FINAL PROGRAM AND ABSTRACTS

Editors: A. R. A. Sovijärvi, H.- M. Rajala, P. Piirilä, R. G. Loudon and R. L. H. Murphy

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General information

Conference venue

Nordia hall in Marina Congress Center, Katajanokanlaituri 6, Helsinki (Phone: +358-0-135 351).

Official Language

English.

Registration and secretariat during the conference

Registration desk is open at Marina Congress Center:

Monday the 24th August	12 a.m. – 6 p.m.
Tuesday the 25th August	8 a.m. – 6 p.m.
Wednesday the 26th August	8 a.m. – 6 p.m.

Registration fees

Active participants 900 FIM, accompanying persons 450 FIM.

Certificate of attendance

Participants, duly registered, will receive a certificate of attendance upon request.

Posters

Posters will be displayed in Nordia hall of Marina Congress Center from 8.45 a.m. on the 25th August until 5 p.m. on the 26th August. During the poster session an oral presentation of five minutes is held for each poster.

Prize for the best poster

Dr. Filiberto Dalmasso (Torino) has donated a prize of 1 000 000 Italian Lire for the best poster. The Steering Committee will judge posters and award the prize.

Hotel Accommodation

HOTEL GRAND MARINA
Katajanokanlaituri 7, 00160 Helsinki
Phone: +358-0-16 661

HOTEL HOSPIZ
Vuorikatu 17, 00100 Helsinki
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Lunch and Coffee

Lunches and coffee are included in the registration fee of active participants at the Congress Center on the 25th and 26th August.

Welcome party

Welcome party on the 24th August at ravintola SÄRKÄNLINNA, which is situated on an island (called Särkkä) in front of Helsinki. Sponsored by Glaxo Pharmaceuticals Oy. Transportation to the restaurant by boat 7.30 p.m. from Kauppatori, Market place in front of the President's palace, return 10 p.m. from the restaurant.

Banquet

Banquet on the 25th August 8 p.m. at ravintola KALASTAJATORPPA. Price 350 FIM (includes transportation to the restaurant and the dinner). Transportation to the restaurant by bus from the hotels (Grand Marina 7.30 p.m. Hospiz about 7.40 p.m.). Music entertainement by Dixieland Orchestra Gösta.

Sponsors

The organizers wish to thank the following companies for financial support:
Boehringer-Ingelheim
Ciba-Geigy Oy
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Medith Oy
Suomen Astra Oy
The commercial exhibition is located in front of the lecture hall.

EXCURSIONS

Hvitträsk tour for accompanying persons

A 4-hour (11 a.m. – 3 p.m.) tour on the 25th August to the studio-home of Saarinen, Gesellius and Lindgren, the three leading architects from the turn of the century. Lunch will be served at the museum's restaurant. Bus leaves 11 a.m. from the Marina Congress Center. For accompanying persons the tour is included in the registration fee; for the others the price is 240 FIM.

Excursions to Helsinki University of Technology and Helsinki University Central Hospital

Excursions will be arranged on the 27th August (they can be arranged also on other days if needed). Attendance lists will be available at the registration desk.