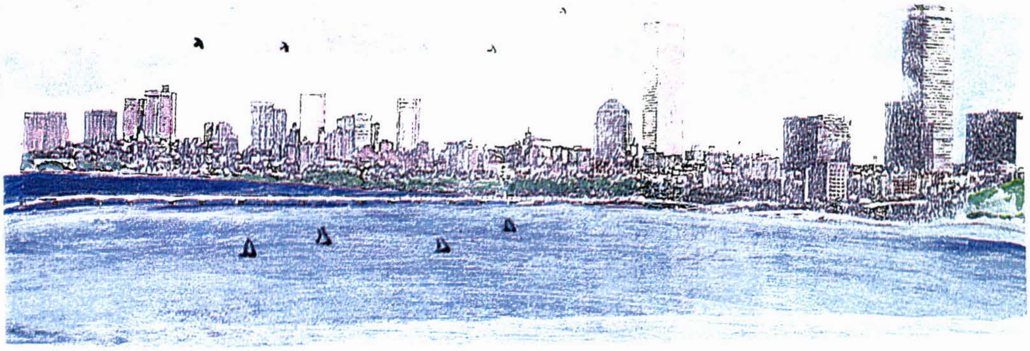
International
Lung
Sounds
Association

Boston, MA   October 14-16, 1998



1998

The 23rd International Conference on Lung Sounds

The 23rd INTERNATIONAL CONFERENCE ON LUNG SOUNDS

第２３回国際肺音学会

Presented by

International Lung Sounds Association

October 14-16, 1998

Boston, Massachusetts

FINAL PROGRAM AND ABSTRACTS

ORGANIZATION

President:	Sadamu Ishikawa, M.D.
Chairman:	Raymond L.H. Murphy, M.D.
Co-chairman:	Robert Loudon, M.D.
Executive Committee:	Noam Gavriely, M.D.
	Steve Kraman, M.D.
	Shoji Kudoh, M.D.
	Hans Pasterkamp, M.D.
	Anssi Sovijarvi, M.D.

The 23rd Conference President

Sadamu Ishikawa, M.D.	St. Elizabeth's Medical Center

Local Organizing Committee

Sadamu Ishikawa, M.D.	St. Elizabeth's Medical Center
Claire Mello	Administrative Assistant, ILSA
Margaret Murphy, RN, Ph.D.	Boston College
Raymond Murphy, M.D.	International Lung Sounds Association
Verna Ann Power, B.A.	Clinical Pulmonary Researcher

Address of The International Lung Sounds Association

Raymond L.H. Murphy, Jr., M.D.
1153 Centre Street, Boston, MA 02130
Telephone: 1-617-983-7000, x1968, Fax: 1-617-522-4156

GENERAL INFORMATION

Conference Venue
Sheraton Hotel, Newton, MA

Official Language
English

Registration and secretariat during the conference
Registration will be held in the Ross Common Room in the Sheraton Hotel on Wednesday, October 14, 1998 from 2:00-3:00 PM
Registration will be held at St. Elizabeth's Medical Center on Thursday, October 15, 1998 from 8:30-8:55 AM

Registration fees
Participants $200, spouses/companions $100, scholarship recipients $100

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

Demonstrations/Posters
Posters will be displayed in the conference room from 8:45am on Friday, October 16th. The poster discussion will begin at 2:00PM. An oral presentation of five minutes and a discussion period of seven minutes is scheduled for each poster presentation

Breakfast, lunch and coffee
Continental breakfast, lunch and coffee are included in the registration fee of active participants at St. Elizabeth's Medical Center on October 15th and 16th

Reception
On October 14th, a reception will be held in the Sheraton Newton Hotel at 5:30PM to welcome the participants and their companions

Banquet
The banquet will be held in the home of Raymond Murphy in Wellesley on Thursday evening from 7:00PM until 10:00PM. Round trip transportation will be provided from the Sheraton Newton Hotel

Sponsors
Boston College
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Tufts University School of Medicine

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J. Earis	B. Fogaty	D. Frazer
N. Gavriely	W. Goldsmith	M. Greenburg
M. Gross	P. Harper	Y. Hashimoto
T. Heimfarth	Y. Hiramine	S. Holford
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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
4th - Sept. 1979 - Chicago, IL - David Cugell
5th - Sept. 1980 - London, England - Leslie Capel & Paul Forgacs
6th - Oct. 1981 - Boston, MA - Raymond Murphy
7th - Oct. 1982 - Martinez, CA - Peter Krumpe
8th - Sept. 1983 - Baltimore, MD - Wilmot Ball
9th - Sept. 1984 - Cincinnati, OH - Robert Loudon
10th - Sept. 1985 - Tokyo, Japan - Riichiro Mikami
11th - Sept. 1986 - Lexington, KY - Steven Kraman
12th - Sept. 1987 - Paris, France - Gerard Charbonneau
13th - Sept. 1988 - Chicago, IL - David Cugell
14th - Sept. 1989 - Winnepeg, Canada - Hans Pasterkamp
15th - Oct. 1990 - New Orleans, LA - David Rice
16th - Sept. 1991 - Veruno, Italy - Filiberto Dalmasso
17th - Aug. 1992 - Helsinki, Finland - Anssi Sovijarvi
18th - Aug. 1993 - Alberta, Canada - Ralphael Beck
19th - Sept. 1994 - Haifa, Israel - Noam Gavriely
20th - Oct. 1995 - Long Beach, CA - Christopher Druzgalski
21st - Sept. 1996 - Chester England - John Earis
22nd - Oct. 1997 - Tokyo, Japan - Masashi Mori
23rd - Oct. 1998 - Boston, MA - Sadamu Ishikawa

PROGRAM

23rd INTERNATIONAL LUNG SOUNDS CONFERENCE

Boston, Massachusetts   October 14-16, 1998

Wednesday, October 14

Sheraton Newton Hotel, Newton, MA

2:00 - 3:00   Registration

3:00 - 5:00   Workshop - European Guidelines for Respiratory Sound Recording and Analysis - CORSA

Chairpersons: J. Earis/J. Vanderschoot

5:30   Reception

Thursday, October 15

8:00	Transportation from Sheraton Hotel to St. Elizabeth's Medical Center
8:30	Registration and Coffee
8:55	Welcome

Session A

St. Elizabeth's Medical Center
Brighton, MA

Chairpersons: N. Gavrielly/R. Loudon

9:00 - 9:20	An Acoustic Model of the Respiratory Tract P. Harper, S. Kraman, H. Pasterkamp, G. Wodicka
9:20 - 9:40	Changing Respiratory Tract Resonances: Description of a Natural Experiment S. Kraman, P. Harper, H. Pasterkamp, G. Wodicka
9:40 - 10:00	Confounding Factors in Lung Sound Analysis K. Shirota, G. Chi-Lem, H. Pasterkamp
10:00 - 10:40	Coffee Break
10:40 - 11:00	Effects of Heart Rate Change on the Measurement of Normal Breath Sound Spectra M. Takase, Y. Inaba
11:00 - 11:20	Discrete All-Pole Spectral Estimation of Upper Airways Sounds B.M.G. Cheetham, D.J. Molyneux, X.Q. Sun, J.E. Earis
11:20 - 12:00	Talk – 'A Clinician's View of Lung Sounds' Bartoleme Celli, Chief of Pulmonary And Critical Care, St. Elizabeth's Medical Center, Professor of Medicine Tufts Univ. School of Medicine
12:00 - 12:20	Photo
12:20 - 1:30	Lunch

Session B

Chairpersons: H. Pasterkamp/G. Wodicka

1:30 - 1:50	Acoustic Analysis of Hoarse Voice M. Trabold, T. Jones, T. Reif, F. Plante, BMG Cheetham, J. Earis
1:50 - 2:10	Frequency, Time and Energy Analysis of Cough Sounds W. Goldsmith, J. Reynolds, A. Afshari, E. Anger, N. Salahuddin, E. Petsonk, H. Abrons, D. Grazer
2:10 - 2:30	Correlation Between Rheological Properties of Productive Cough A. Murata, Y. Hashimoto, Y. Kaneko, Y. Taniguchi, Y. Takasaki, S. Kudoh
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Friday, October 16

Session C

St. Elizabeth's Medical Center
Brighton, MA

Chairpersons: S. Ishikawa/S. Kudoh

9:00 - 9:20	Lung Consolidation and "Egophony" S. Ishikawa, G. Livnat, J. Marquiña, K. MacDonnell, B. Celli
9:20 - 9:40	Age Dependency of Breathing Sounds in Probands Between 20 on 80 Years of Age P.v. Wichert, A. Dittmar, M. Gross, J. Sulzer, T. Penzel
9:40 - 10:00	Characteristics of Lung Sounds in Young Healthy Adults J. Schmelz, V.A. Power, M. Murphy, R. Murphy
10:00 - 10:20	Coffee break
10:20 - 10:40	Automated Detection of Wheezing - A Comparison of Methods M. Greenberg, H. Pasterkamp
10:40 - 11:00	Spatial Distribution of Crackles and Wheezes F. Davidson, R. Murphy
11:00 - 12:00	Special Lecture: 'A Look at How Rocks Crack: The Analysis of Seismic Waveforms John Ebel, Professor of Geophysics, Boston College, Director of Weston Observatory of Boston College
12:00 - 1:30	Lunch
1:30 - 2:00	Business meeting

Session D

Chairpersons: S. Kraman/M. Murphy

2:00 - 4:00 **DEMONSTRATION**

Indrawings and Crackles - a video Demonstration of a possible association
H. Melbye

PulSA: A System to Support Lung Sound Analysis
W. Roque, T. Heimfarth, T. Spengler, H. Valliatti, R. Custodio, L. Oliveira

Karmel Lung Sound Device
N. Gavrielly

POSTERS

Time-Dependent Fractal Dimensions of Lung Sounds
W. Roque, L. Oliveira, R. Custodio, H. Valliatti

The Relationship Among Nocturnal Wheezing Count, Peak Expiratory Flow Rate and Asthmatic Symptoms in Nocturnal Asthma
H. Kiyokawa, M. Yonemaru, K. Minemura, H. Kusumoto, N. Yanagisawa, Y. Hiramine, Y. Ichinose, K. Toyama

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M. Bahoura, M. Hubin

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J. Thompson, R. Doubleday, T. Sheridan

Lung Sounds in Congestive Heart Failure: A Case Report and a Challenge
R. Murphy, K. Bergstrom, V.A. Power

4:00 - 4:15 Closing Remarks
D. Cugell

4:30 Steering Committee Meeting

ABSTRACTS

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12:20 - 1:30	Lunch

AN ACOUSTIC MODEL OF THE RESPIRATORY TRACT

Paul Harper[1], Steve S. Kraman, M.D.[2], Hans Pasterkamp, M.D.[3], and George R. Wodicka, Ph.D.[1]

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

With the emerging use of tracheal sound analysis to detect and monitor respiratory tract changes such as those found in asthma and obstructive sleep apnea, there is a need to quantify the links between the attributes of these easily measured sounds and the underlying anatomy and pathophysiology. Thus, we have developed a model of the acoustic properties of the entire upper respiratory tract (subglottal plus supraglottal airways). The respiratory tract is represented by a transmission line acoustical analogy with varying cross sectional area, yielding walls, and dichotomous branching (up to the 10th generation). Individually, the supra and subglottal portions of the model predict the distinct locations of the spectral peaks (formants) from speech sounds such as/ah/as measured at the mouth and the trachea, respectively, in healthy subjects. When combining the supra and subglottal portions to form a complete tract model, the predicted peak locations compare favorably with those of tracheal sounds measured during normal breathing in the same subjects. In addition, the model predicts both the direction and magnitude of the relatively small spectral shifts that occur in tracheal sounds during a neck flexion/extension maneuver, indicating that these acoustic parameters are sensitively tied to respiratory tract length and radius.

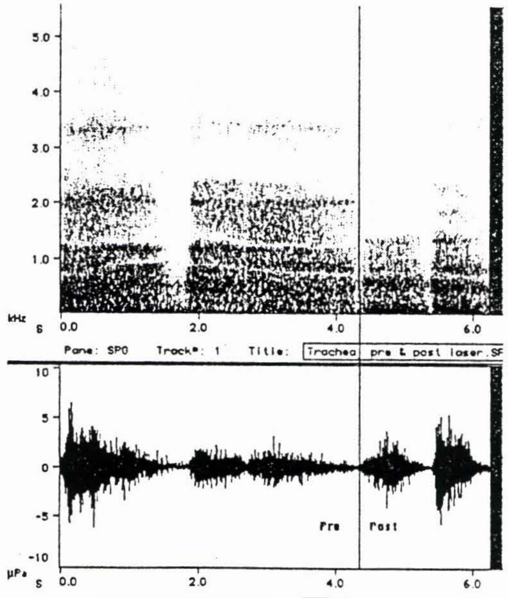
CHANGING RESPIRATORY TRACT RESONANCES: DESCRIPTION OF A NATURAL EXPERIMENT

Steve S. Kraman[1], M.D., Paul Harper[2], Hans Pasterkamp[3], M.D., and George R. Wodicka, Ph.D[2]

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

A 67 year-old male came to the hospital with a history of dyspnea on exertion and cough progressing to severe shortness of breath at rest over several weeks. Physical exam revealed stridorous sounds in inspiration and expiration heard at the mouth and over the trachea. Spirometry revealed severe airway obstruction in expiration and probably inspiration. Bronchoscopy revealed a large mass above and arising from the main carina. This mass obstructed the distal trachea expect for a narrow (~2mm) circumferential space between the mass and the tracheal wall. Breathing sounds were recorded from in front of the mouth and at the suprasternal notch both before and after laser ablation of the mass.

Before ablation, the tracheal sound's predominant pitch was noted to rise during inspiration and fall during expiration. The variable resonances and antiresonances disappeared after laser ablation of the mass (**Fig**). We postulate that the tracheal mass behaved as a dynamic acoustic obstruction and thereby altered the distal boundary condition and resonance behavior of the respiratory tract during breathing.



CONFOUNDING FACTORS IN LUNG SOUND ANALYSIS

Kazuhiko Shirota, Georgina Chi-Lem, and Hans Pasterkamp
Dept. of Pediatrics, University of Manitoba, Winnipeg, Canada

The analysis of lung sounds has traditionally focused on the frequency range with the greatest power, i.e., below approx. 500Hz. However, the effect of confounding factors such as cardiovascular and muscle sounds on lung sounds at low frequencies is well recognized. Since threshold detection algorithms, e.g., for the determination of critical flows to generate breath sounds[1], depend on detailed knowledge about such confounding factors, we expanded our work to define the effect of lung volume and recording sites on cardiovascular and background noise. We studied 11 healthy volunteers (ages 20-39y, 5 females). Heart sounds were recorded using 4 contact transducers attached to the skin with double-sided adhesive tape: precordially at the left sternal border, over both posterior bases (RLL and LLL) and over the anterior right upper lobe (RUL). We selected 4 lung volumes: maximum inspiration (I max), resting end-inspiration and expiration (I tidal and E tidal) and maximum expiration (E max) for this study. Heart sounds were recorded for at least 20 sec during breath-hold at each volume. Digitization and computer analysis of sound signals and simultaneously recorded ECG were as previously published[2]. On D/A playback, epochs without extraneous noise were analyzed to obtain average spectra of 1st and 2nd heart sound and of background noise after exclusion of heart sounds. Subtraction of background spectra from heart sound spectra was used to estimate heart sounds without muscle and other extraneous noise. We calculated the average power in 4 frequency bands (5-75, 75-150, 150-300, 300-600 Hz) and compared the results with repeated measures ANOVA. During tidal breathing (i.e., at I tidal and E tidal) the 2nd heart sound was significantly louder than the 1st at 150-300 Hz over RUL, RLL and LLL.

---

[1] G. Chi-Lem, Y. Inaba, et al. Am. J. Respir. Crit. Care Med. 157: A540, 1998

[2] H. Pasterkamp, R. Fenton, et al. Am. Rev. Respir. Dis. 131:61-64, 1985

Background without heart sound at 75-150 Hz was loudest at maximal breathing excursions (i.e., at I max and E max) at all recording sites. Our findings confirm a significant contribution from non-respiratory sound sources to the spectra of low-frequency acoustical signals on the chest. This may explain some ambiguous results in earlier studies of respiratory sounds that were limited to frequencies below a few 100Hz. We suggest using higher frequency sound analysis when feasible and to be cautious in the interpretation of lung sound spectra at low frequencies.

Drs. Shirota and Chi-Lem are fellows of the Manitoba Lung Association

EFFECTS OF HEART RATE CHANGE ON THE MEASUREMENT OF NORMAL BREATH SOUND SPECTRA

Masato Takase, Yaoki Inaba
Dept. of Pediatrics, Nippon Medical School, Tokyo, Japan

Spectral changes in normal breath sounds recorded at the chest wall, have proved to be a sensitive indicator of mild airway narrowing. A decrease in low frequency power, together with an increase in high frequency power results in the increase of median frequency and spectral edge frequency during inspiration. Exercise induced asthma (EIA) could also be detected by these changes during exercise challenge. However, the possible effects of heart rate change following exercise on the measurement of normal breath sound spectra, have not been investigated in the practical setting.

We examined the effects of heart rate increase after exercise in five healthy adults with normal lung function. Breath sounds were recorded before and after exercise (>50% increase in heart rate), using two accelerometers (EMT-25C, Siemens), at the right upper anterior (RUA) and the right lower posterior (RLP) chest. Subjects breathed at a target flow of 1.5 l/s for ten breath cycles, and held their breath at end-expiration. Averaged fast Fourier transformation analysis provided mean power within 4 octave bands (P1: 75-150Hz, P2: 150-300Hz, P3: 300-600Hz, P4: 600-1200), median frequency (F50) and spectral edge frequency (F99) within the 150-1200Hz range for inspiratory and expiratory phases (flow range 1.2-1.8l/s), with and without the subtraction of averaged breathhold spectra.

After exercise, significant changes in breathhold spectral power up to 300Hz were observed in all subjects. Subtraction of the averaged breathhold spectra from the averaged inspiratory or expiratory spectra would be necessary in order to reduce the effects of changes in cardiovascular sounds.

DISCRETE ALL-POLE SPECTRAL ESTIMATION OF UPPER AIRWAYS SOUNDS

B.M.G. Cheetham, D.J. Molyneux, X.Q. Sun*, J.E. Earis**
University of Manchester, UK
*Voxware Inc., Princeton, NJ 08540, USA
**Aintree Chest Centre, Fazakerley Hospital, Liverpool UK

Previously reported work on inverse filtering applied to quasi-periodic upper airways signals such as voiced sounds represented the spectral envelope by an auto-regressive model whose parameters were calculated by linear prediction (LP) analysis. It is known that he accuracy of the traditional LP analysis is affected, especially for higher pitch-frequencies, by the under-sampling of the spectral envelope in the frequency-domain, by pitch-period variation (jitter) and by the influence of spectral fine structure due to long term correlation. The phase-response of the LP inverse filter is also fundamentally inaccurate owing to a necessary minimum-phase assumption. Reduced accuracy will affect the estimation of vocal tract resonances (formants) and Also glottal excitation waveforms (produced by vocal cords) as required for our studies. The accuracy can be improved by a spectral magnitude estimation technique known as discrete all-pole modeling (DAP) and an improved phase model based on assumptions about the sound waveform at the glottis.

Given FFT derived measurements of power spectral density, P_1, $P_2 \ldots . P_L$ at the discrete frequencies ω_1, $\omega_{2, \ldots} \omega_L$, DAP aims to produce an all-pole power spectrum $P(\omega)$ which minimizes a distance measure between $P(\omega)$ and the given power spectral densities only at the discrete frequencies. Conventional LP analysis minimizes a continuous distortion measure and is therefore affected by the spectral energy between the discrete frequencies, which leads to inaccuracy. A new form of DAP has been applied which is simpler and may reduce the computation time and reliability of a former method.

To obtain an accurate representation of the glottal waveform, an accurate phase spectrum as well as a magnitude spectrum is required. Traditional LP analysis assumes that voiced sounds may be modeled by a pseudo-periodic sequence of impulses e(n) driving a glottal filter G(z), an all-pole vocal tract filter V(z) and a lip-radiation filter L(z). The combination of these three filters is the "vocal system" filter H(z) which is assumed to be minimum phase. However, G(z) which simulates the glottal pulses produced by the opening and rapid closing of the vocal cords, is not minimum phase, and this leads to error in the LP phase model and distortion to the shape of the LP residual signal. Two ways of reducing this phase error have been investigated: one is to approximate the impulse response of G(z) by a Rosenberg pulse and an alternative, based on the observation that such a pulse resembles the time-reversed impulse response of a 2^{nd} order all-pole filter, is to correct the LP derived model by augmenting it by a second order "all-pass" transfer function.

To investigate DAP, segments of artificial voiced sounds were generated by exciting a sixth order all-pole digital filter with an impulse train. Pitch periods in the range 2.5ms-12.5ms were used, and simulated formants were produced typical of a range of different vowel sounds. The pitch-periods were grouped into "short" (2.5ms-5.6ms), "medium"(5.6ms-8.1ms) and "long" (8.1ms-12.5ms). The discrete IS and the log spectral distortion (LSD) measures were used to measure the differences between the estimated and true spectra at the pitch harmonics. The error measurements obtained for each set of pole positions were averaged for each of the three pitch-period ranges. In all cases, the order of the all-pole estimation was six, i.e., the same as that of the synthesis filter. These tests demonstrated how spectral accuracy varies with pitch-period, the accuracy being largely independent of pitch. The accuracy of traditional LP improves significantly as the pitch-period increases. A means of deriving a phase spectrum from the estimated magnitude spectrum has also been investigated, and is expected to benefit from increased accuracy in the all-pole model. Experiments using real voiced sounds confirm the promise of these techniques.

The use of discrete all-pole modeling and corrections to the phase-spectra thus obtained to compensate for the inaccuracy of the minimum phase assumption leads to a spectral estimation technique which provides a considerably more accurate method of analyzing upper airway sounds than traditional auto-regressive modeling.

Session B

Chairpersons: H. Pasterkamp/G. Wodicka

1:30 - 1:50	Acoustic Analysis of Hoarse Voice M. Trabold, T. Jones, T. Reif, F. Plante, BMG Cheetham, J. Earis
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ACOUSTIC ANALYSIS OF HOARSE VOICE

M. Trabold, T. Jones, T. Reif, F. Plante*, B.M.G. Cheetham**, J.E. Earis

Aintree Chest Centre, University Hospital, Aintree, Liverpool, UK
*University of Liverpool, UK, **University of Manchester, UK

A change in the quality of the voice (hoarseness) is a well recognized symptom of laryngeal disease. Objective analysis, by computer, of voiced vowel sounds enables "jitter (the average percentage pitch-period variation between consecutive pitch-cycles) to be measured by a program performing inverse filtering (to reduce the effect of vocal tract resonance) followed by a standard auto-correlation analysis procedure (to determine periodicity) as described in previous presentations (ILSA Conference 1996). We have evaluated this measure of hoarseness, a) in patients and b) in a group where mild laryngeal oedema resulting in hoarseness was induced by histamine challenge testing.

a) Sixteen female and 9 male patients with hoarse voice of varying severity were investigated (age 24 to 82 years, mean 57). Diagnoses included idiopathic hoarseness, asthma, bronchiectasis, vocal cord polyps, cord paralysis, smoke inhalation and acute laryngitis. In each patient, jitter and mean pitch-period were measured by computer and a subjective assessment of the degree of hoarseness was made using a 10 point visual analogue scale. The severity of jitter varied from below 2% (3 patients) to 19% with 18 patients producing values of jitter above 4%. Significant correlation between estimated jitter and subjective gradation of hoarseness was established (r 0.59). In four patients and two normal subjects, variation in jitter over time was measured and found to be within 4% in hoarse voice and less than 1% in normals. For higher mean pitch-periods, especially in females, there was a tendency for the mean pitch-period to fall with increased values of jitter but this did not reach significance.

b) Four female and one male normal volunteers with ages ranging from 21 to 33 years (mean age 25.2) underwent a standard histamine challenge test. For each patient, the value of jitter during a standard vocal manoeuvre was measured by computer and verified by a number of direct measurements using a laryngograph trace. The values computed before, during and after recovery were 1.03%, 2.64% and 1.18% respectively. The difference in jitter before histamine and after recovery was non-significant. However, the differences between values of jitter measured during histamine challenge and the other values was highly significant ($p > 0,001$). The accuracy of the computer measurements was confirmed using the laryngograph.

This data suggests that jitter is an objective and repeatable measurement of hoarseness of the voice in the clinical setting. The values found during histamine challenge indicate that this is capable of measuring small changes in hoarseness and the clinical results show that the severity of jitter equates to subjective scoring of hoarseness. Thus jitter should prove to be a clinically useful method of assessing severity and monitoring treatment of patients with laryngeal disease.

FREQUENCY, TIME AND ENERGY ANALYSIS OF COUGH SOUNDS

W.T. Goldsmith, J.S. Reynolds, A. Afshari, E. Anger, N. Salahuddin,
E.L. Petsonk, H. Abrons, D.G. Frazer

ECTB, HELD and CIB, DRDS, National Institute for Occupational Safety and Health, and Pulmonary and Critical Care Medicine, WVU School of Medicine, Morgantown, WV 26505

Pulmonary physicians use auscultatory techniques to assist in the diagnosis of lung disorders. Recently, breath and cough sounds have been analyzed using computational methods. We designed a system to record and analyze cough sounds. Subjects coughed into a cylindrical mouthpiece attached to a 1″ metal tube. A ¼″ microphone was mounted at a 90° angle with its diaphragm tangent to the metal tube. A 50′ flexible tube was attached to the metal tube opposite the mouthpiece. Sound Pressure waves generated during voluntary coughs were digitized and recorded using a sound analyzer and a computer. A five pole high pass Butterworth filter was applied to the data to reduce the effects of frequencies below 50 Hz. Cough sound measurements for 21 patients, classified as either controls(n=4), restrictive(n=7) or obstructive(n=10) based on spirometery and plethysmography, were recorded and analyzed. Cough duration was defined as the time during which 0.05 to 99.95% of the cough energy occurred. Maximum energy frequency was the frequency where the maximum amount of energy occurred. The high frequency was the frequency below which 99.95% of the energy occurred during the cough. Cumulative energy, the integral of the pressure was squared, in terms of time and frequency was also examined. A cough sound index (CSI) was derived from the shape of the autocorrelation of the joint time-frequency spectrogram of the cough.

	Control	Restrictive	Obstructive
Duration (msec)	391 ± 44	369 ± 79	544 ± 51
Max En. Freq. (Hz)	285 ± 24	212 ± 24	225 ± 29
High Freq. (Hz)	4428 ± 363	4052 ± 309	3821 ± 235
CSI	-0.97 ± 1.30	-1.37 ± 1.82	5.34 ± 1.97

Patterns were evident between the different disease types. Cough sound analysis successfully classified most subjects by disease type and may be useful in the evaluation of respiratory conditions.

CORRELATION BETWEEN RHEOLOGICAL PROPERTIES OF SPUTUM AND ACOUSTIC PROPERTIES OF PRODUCTIVE COUGH

A. Murata, Y. Hashimoto, Y, Kaneko, Y. Taniguchi, Y.Takasaki, S. Kudoh

Last year we reported that chest discomfort was positively correlated with the duration of 2nd phase of cough sound (P=0.0026). Usually its symptoms and rheological properties of sputum are used in evaluation of expectoration. So we investigated the correlation between the acoustic properties of productive cough and the rheological properties of sputum.

15 patients with chronic airway disease were included in this study. They were instructed to make a voluntary cough to expectorate in a natural manner.

Cough sounds were recorded on a digital audio tape recorder (SONY TVD-7) with an electret condenser microphone (panasonic RP VC3) and analyzed by Sound Scope II (GW Instrument Company, U.S.A.). The cough sounds were divided into two to three phases, and the duration and the root mean square value of each phase of cough sound were also calculated according to the method of Dr. Thorpe et at. Spinability, yield value and ciliary beat transport rate of sputum were measured. The relationship between these factors were analyzed by Speaman's rank correlation.

And we found that ciliary transport rate was negatively correlated with the duration of 2nd phase of cough sound. Though this does not show a significant difference, it suggests the duration of 2nd phase of cough sound can be a potential objective index of expectoration.

METHODS FOR THE VALIDATION OF AUTOMATIC WHEEZE DETECTION (AWD) SYSTEMS

Charles Irving, Tomer Jacobson, Tamar Irving and Noam Gavriely
Karmen Medical Acoustic Technologies Ltd., Tirat Carmel Israel

The need to quantify and track wheezing in asthma and other obstructive airway diseases has motivated the development of Automatic Wheeze Detection (AWD) software algorithms for use in wheeze tracking instruments. These algorithms convert digitized signals from acoustic sensors into a quantitative measure of wheezing (e.g., percent wheeze duration/breath or 30sec). Before these instruments can be used in research and clinical applications, their AWD algorithms must be validated using acceptable methods. We here review several wheeze detection validation methods and present examples. The selection of the most appropriate method depends on the extent to which the wheezes are being qualified.

Validation Against Listening: When wheeze 'presence or absence' or a semi-quantitative wheeze score (none, mild, moderate, severe) is used as the quantification method, physical examination auscultatory skills applied to recorded sounds is perhaps the most appropriate and the ultimate validation standard. It relies on the skilled clinician's ability to detect wheezes as abnormal breath sounds with a musical quality. Its use assures that the validated detection method will provide results consistent with clinical practice. The method is limited by the differences in individual clinician's auditory sensitivities and ability to differentiate wheezes from background noise and artifacts. This problem can be overcome by using a group of clinicians and a set of statistical results to reach a consensus opinion. The performance of the AWD can be compared against the group consensus and to the sensitivity and specificity results for individual clinicians compared to the consensus opinion. This method can be applied to AWD algorithms that detect the presence of wheezes over a fixed period of time, in single or multiple breaths or in inspiratory or expiratory breath phases.

Listening can also be used to obtain a rough estimate of wheeze duration by making on-the-fly estimates of the start and finish of wheezing. However, this method requires a great deal of skill and endurance on the part of the listener. It does not lend itself well to obtaining consensus opinions and is biased by the listener auditory sensitivity and specificity, as well as response times.

Validation Against Listening Combined with Sonogram Inspection (Multimedia Review - MMR): When global wheeze duration is used as the quantification method, standards have to be generated using a more exact method of determining the start and finish times of wheezing during inspiration and expiration. This can be done using an acoustic analysis program that can play the recorded sounds as a cursor moves across a sonogram. The presence of wheeze is verified by listening, while the exact start and finish times of the wheeze are determined by marking the sonogram, preferably using cue marks. The length of the marked segments are then summed to obtain an estimate of wheeze duration with a breath phase, a single breath, a group of breaths or over a fixed time. This type of analysis can be easily performed by a trained technician.

Validation Against Listening Combined with Sonogram Inspection and Image Processing: When wheeze cluster time (the sum of the duration of all individual wheezes in a segment) or wheeze pattern, is used as the quantification method, standards have to be generated using a method for determining the start and finish times of all the individual wheezes. This is done using the MMR method or by tracing the wheezes seen in the sonogram and using image processing techniques to sum the times of all the individual wheezes.

ELECTROGLOTTOGRAPHY AND COUGHS

R.G. Loudon, University of Cincinnati

Electroglottography (EGG) is a non-invasive method for measuring the area between the vocal cords. The output signal has sufficient resolution in time to measure laryngeal movement responsible for phonation with a resolution up to 20 kHz. Most descriptions of cough describe a sudden wide opening of a previously closed glottis, but naturally occurring episodes of coughing often consist of a sequence of discrete coughs, on occasion interspersed with throat clearing, or a sequence of sound and airflow signals separated by incomplete glottic closure. These events can to some extent be named and described by listening to the sound, but EGG may be useful in describing an essential element; the laryngeal participation in expulsive clearance of secretions. Examples of EGG and sound recordings will be used to show differences in patterns encountered.

A MICROPHONE-BASED ACCELEROMETER AND ITS APPLICATION AS A LUNG SOUND SENSOR

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And
**National Tokyo Hospital
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A simple accelerometer-type lung-sound sensor has been devised. It is small (2.5 cm diam), light-weight (2.5g or less), yet has a high sensitivity. It is composed of a small electret condenser microphone attached to a small disk with soft molding substance. This composition is an improved model of the one previously reported at this meeting in Lake Louise. Later investigation revealed that the sensitivity was determined mainly by the change in volume of the cavity facing the microphone.

The calibration test show that this sensor has a good response for the frequency range up to 2kHz, which is not wide but enough for the clinical use.

The recordings taken from the normal and the patients using this sensor will be presented.

COMPUTERIZED LUNG SOUNDS IN A PEDIATRIC PRACTICE

M. Murphy, B. Fogaty, K. Bergstrom, R. Murphy

Use of office visit recording of computerized lung sounds in a pediatric office practice was investigated. Thirty-four children between the ages of 11 months and 17 years, 16 of whom had respiratory complaints, were recorded at 4 sites over the anterior chest wall and then 4 sites over the posterior chest wall. Additionally, one microphone was placed over the trachea during each 10 second recording with the child in the sitting position. Two examiners independently listened to the chest with stethoscopes at the same 9 sites prior to the recordings.

15 of 18 children (83%) without respiratory complaints were found by stethoscope and by the computer to be clear to auscultation at all 8 sites. The remaining 3 were positive for adventitious sounds by computer but not by stethoscope.

Of the 16 subjects with respiratory complaints, 7 were positive for adventitious sounds by stethoscope and by computer. Three were clear to auscultation by both modalities (62.5%). Two subjects (12.5%) exhibited adventitious sounds by computer that were not heard by stethoscope. Four of the 16 subjects (25%) were reported to have abnormal sounds by stethoscope but not by computer.

Of all the subjects studied, there were 9 cases where the human observers and computer did not agree. In 5 of these cases, sounds were recorded by the computer that were not heard by the human observers. In the other 4, the opposite was the case, i.e., abnormal sounds were observed by the human observer and not by the computer.

The reasons for the discrepancy between the observers and the machine are not clear. Evanscence of sounds, human error, electronic artefact or differing sites where the observations were made. In any case, we noted that it was feasible in these children to perform computerized lung sound analysis without significant difficulty.

Further work in this area would be of value because of the ability of the computer to provide objective data and permanent recordings for documentation purposes.

Friday, October 16

Session C

St. Elizabeth's Medical Center
Brighton, MA

Chairpersons: S. Ishikawa/S. Kudoh

9:00 - 9:20	Lung Consolidation and "Egophony" S. Ishikawa, G. Livnat, J. Marquina, K. MacDonnell, B. Celli
9:20 - 9:40	Age Dependency of Breathing Sounds in Probands Between 20 on 80 Years of Age P.v. Wichert, A. Dittmar, M. Gross, J. Sulzer, T. Penzel
9:40 - 10:00	Characteristics of Lung Sounds in Young Healthy Adults J. Schmelz, V.A. Power, M. Murphy, R. Murphy
10:00 - 10:20	Coffee break
10:20 - 10:40	Automated Detection of Wheezing - A Comparison of Methods M. Greenberg, H. Pasterkamp
10:40 - 11:00	Spatial Distribution of Crackles Over the Chest Wall F. Davidson, S. Holford, R. Murphy
11:00 - 12:00	Special Lecture: 'A Look at How Rocks Crack: The Analysis of Seismic Waveforms John Ebel, Professor of Geophysics, Boston College, Director of Weston Observatory of Boston College
12:00 - 1:30	Lunch
1:30 - 2:00	Business meeting

Friday, October 11

Session C

St. Elizabeth's Medical Center
Brighton, MA

Chairpersons: S. Kraman & [illegible]

9:00 - 9:20 [illegible] and Typology
S. Ishikawa, [illegible],
[illegible]

9:20 - 9:40 Age Dependency of Breathing Sounds in Subjects between 20 and [illegible] Years of Age
[illegible]

9:40 - 10:00 Characteristics of Lung Sounds in [illegible] Healthy Adults
[illegible]
R. Murphy

10:00 - 10:20 Coffee Break

10:20 - 10:40 Automated Detection of Wheezing - A Comparison of Methods
M. Greenberg, [illegible]

10:40 - 11:00 Spatial Distribution of Crackles over the Chest Wall
D. Davidson, [illegible], R. Murphy

11:00 - 12:00 Special Lecture: A Look at the [illegible]
The Analysis of Signals by Wavelets
John Gray, Professor of [illegible]
Department of [illegible] University of
[illegible]

12:00 - 1:00 Lunch

1:00 - [illegible] Business Meeting

LUNG CONSOLIDATION AND 'EGOPHONY'

S. Ishikawa, G. Livnat, J. Marquina, K.F. MacDonnell, B. Celli

Tuft Lung Station, St. Elizabeth's Med. Ctr.
Dept. of Med. Tuft Univ. School of Med., Boston, MA

Conditions that decrease the sound absorbing effect of the lung parenchymas such as consolidation or large pleural effusion, tend to increase trachea to chest surface transmission. When this leads to high frequency absorption it produces 'egophony' ('ee' to 'ay' change) over an area of consolidation. Twenty-one consecutive patients (7 patients with lobar pneumonia, 7 patients with bronchopneumonia, 7 patients with large pleural effusion) referred to our pulmonary consultation service were studied.

Patients were asked to say 'ee---ay' and lung sounds were recorded by electronic stethoscope on chest surface over the lung consolidation and contralateral site. Using a fast Fourier transform spectro-analyzer recorded sounds were digitized and real time spectro-graphs displayed.

'Ee' to 'ay' changes were observed in 86% of patients with lobar pneumonia, 57% of patients with bronchopneumonias and 71% of patients with pleural effusion.

We conclude egophony is an acceptable sign of lung consolidation when the lesion is close to the chest surface.

AGE DEPENDENCY OF BREATHING SOUNDS IN PROBANDS BETWEEN 20 and 80 YEARS OF AGE

P.v. Wichert, A. Dittmar, M. Gross, J. Sulzer, Th. Penzel

Dept. of Medicine, Div. Pulmonary and Crit. Care Med., Phillips-University Marburg/Lahn, Germany BalsdingerstraBe 1, D-35033 Marburg

Often it has been said, that breathing sounds heard by auscultation of the lungs change their characteristics with advancing age. To get objective data, we studied 100 adults without lung diseases between
20 and 80 years of age.

Setting

Dept. of Intern. Med. In an University Hospital

Methods

Analysis of lung sounds with a Sony ECM77 microphone using a special capsule. Microphone output is amplified and filtered in an analog way (GEPA bandpass 60-2100 Hz, 48 db/octave). Air flow was analyzed with a Fleisch-pneumotachograph (Hugh Sachs, Freiburg, Germany) and simultaneously presented with the sound on a computer screen to allow breathing at a predefined flow of 1.75 1/sec. We recorded signals from four microphone locations in parallel. All signals were digitized with 5512 Hz and 12 Bit resolution. The data were displayed and analyzed using MATLAB 5.2 software. A time segment of 0.1 sec with constant flow was used for further sound analysis with Fast-Fourier-Transformation. The power spectrum was characterized by mean frequency, maximum value of the spectrum and further characteristics of the frequency distribution.

The absence of lung diseases in the group of probands was checked by history, absence of symptoms, x-ray and lung function.

Results and Discussion

There were only marginal changes of the breathing sound with advancing age. This holds true also for gender and smoking habits in our sample. In healthy persons breathing sounds are not depending of the age. people.

Therefore, a change in the characteristics of breathing sounds indicate an alteration of structure or function of the lungs, also in older

CHARACTERISTICS OF LUNG SOUNDS IN YOUNG HEALTHY ADULTS

Joseph Schmelz, Vera Ann Power, Margaret Murphy, and Raymond Murphy

Using a Multi-Channel Lung Sound Analyzer (MCLSA), we studied the pattern of sounds at 16 sites over the chest of 20 subjects between the ages of 18 and 40. Our objective was to describe the basic pattern of the normal sounds including amplitude, duration and presence of adventitious sounds. Subjects were selected from both the military and civilian populations from a major Southwestern city. All subjects were screened for history of prior pulmonary disease and smoking history using a standardized assessment tool. Subjects were seated with the microphones positioned on the chest as follows: back, 4 (each side); side, 2 (each side); front, 3; and one over the trachea. The MCLSA made it possible to record all 16 microphones sites simultaneously.

AUTOMATED DETECTION OF WHEEZING - A COMPARISON OF METHODS

Matthew Greenberg and Hans Pasterkamp
University of Manitoba, Winnipeg, Canada

Computer-based lung sound analysis depends on the reliable detection of adventitious sounds such as wheezes and crackles. Methods for the automated detection of wheezing are typically based on power spectral. Analysis and peak detection.[1,2,3] Further processing by neural network methods can enhance the detectin of wheezing.[4] A promising technique developed for the HeLSA system uses sonograms and edge detecting image processing (EDIP) algorithms.[5]

There are obvious deficiencies in all of these methods, particularly with regard to the detection of brief or faint wheezes and of those with rapidly changing frequencies. We have applied a spectral prediction analysis (SPA) to improve automated wheeze detection under difficult circumstances. A smoothed prediction of spectral characteristics was used on the established slope of spectral power within the lung sound range, resulting in a frequency dependent threshold. Spectral peaks outside the confidence limits for the predicted spectrum were further analyzed with regard to their connection to related peaks in order to define wheezes.

A comparison of EDIP and SPA methods was performed on a data set of eight recordings that had challenging wheeze characteristics. Auditory wheeze identification by an expert observer was our reference standard. The results were as follows (% sensitivity in brackets):

Recording	Wheezes	detected by EDIP		detected by SPA	
1	5	2	(40)	5	(100)
2	6	4	(67)	3	(50)
3	10	9	(90)	10	(100)
4	13	10	(76)	12	(92)
5	10	6	(60)	10	(100)
6	10	6	(60)	6	(60)
7	6	4	(67)	6	(100)
8	7	7	(100)	7	(100)

In summary, wheezes of rapidly changing frequency and of short duration are more easily detected with SPA than with EDIP. Since these methods take different approaches to wheeze detection, a combination of their individual strengths should be advantageous.

1 R.P. Baughman and R.G. Loudon, Chest 1984, Nov., vol. 86, pp. 718-722

2 T.R. Fenton, H. Pasterkamp, A. Tal, and V. Chernick, IEEE Trans. Biomed. Eng. 1985. Jan., vol. 32, pp. 50-55

3 Y. Shabtai-Musih, J.B. Grotberg and N. Gavriely. J. Appl. Physiol. 1992. Feb., vol. 72, pp. 629-635

4 K.E. Forkheim, D. Scuse and H. Pasterkamp, IEEE WesCanEx Proceedings 1995, pp. 214-219

5 M. Waris, P. Helisto, S. Haltsonen, A. Saarinen and A. Sovijarvi, Technology and Health Care 1998 (in press)

SPATIAL DISTRIBUTION OF CRACKLES OVER THE CHEST WALL

Frank Davidson, Steven Holford, Raymond Murphy

In previous work, we noted that the dispersion of crackles over the chest wall varied from 4.3 to 6.6 cm. Furthermore, 52% of the crackles fell within a 6 x 8 cm area. We were not able to determine the pattern of distribution of the crackles in these studies and assumed that it was circular. In this study, we attempted to determine the pattern of distribution of individual crackles over the chest wall. The motivation for this work is that if the spatial distribution were known, the number of microphones necessary for an automated lung sound analysis could be estimated. In addition, current theories for the mechanism of crackle production could be tested and if true understanding of the underlying pathophysiology of certain lung conditions could be improved.

Materials and Methods

Fifteen microphones were placed in an array configured as follows:
A central microphone surrounded by five microphones arranged in a circle with each microphone 20 mm from the central microphone. A second circle of 9 microphones was placed so that each microphone was 40 mm from the central microphone. These microphones were mounted in hat washers 2cm in diameter and inserted in a rubber template covered by 2" thick foam rubber and hand held at 4 chest locations on patients with a variety of illnesses (IPF, COPD, bronchiectasis, CHF). Ten seconds of data were recorded at each site.

Results

One hundred crackles were examined with respect to their spatial distribution. The majority of crackles had an ovoid rather than circular distribution consistent with the hypothesis of Fredberg & Holford. There was a strong tendency for crackles earlier in inspiration to be more widely distributed than those later in inspiration.

Session D

Chairpersons: S. Kraman/M. Murphy

2:00 - 4:00 **DEMONSTRATION**

Indrawings and Crackles - a video Demonstration of a possible association
H. Melbye

PulSA: A System to Support Lung Sound Analysis
W. Roque, T. Heimfarth, T. Spengler, H. Valliatti, R. Custodio, L. Oliveira

Karmel Lung Sound Device
N. Gavrielly

POSTERS

Time-Dependent Fractal Dimensions of Lung Sounds
W. Roque, L. Oliveira, R. Custodio, H. Valliatti

The Relationship Among Nocturnal Wheezing Count, Peak Expiratory Flow Rate and Asthmatic Symptoms in Nocturnal Asthma
H. Kiyokawa, M. Yonemaru, K. Minemura, H. Kusumoto, N. Yanagisawa, Y. Hiramine, Y. Ichinose, K. Toyama

Time Frequency Based Method for Wheezes Detection
M. Bahoura, M. Hubin

A Computer Guided System for the Accurate Placement of Thoracic Acoustical Transducers
J. Thompson, R. Doubleday, T. Sheridan

Lung Sounds in Congestive Heart Failure: A Case Report and a Challenge
R. Murphy, K. Bergstrom, V.A. Power

4:00 - 4:15 Closing Remarks
D. Cugell

4:30 Steering Committee Meeting

Session 7
Chairpersons: S. Kraman/H. Pasterkamp

12:00 - [illegible]

DEMONSTRATION

Instruments and Consoles - Video Demonstration of a Possible Associated [illegible]
K. Yelke

PULSAR: A System to Support Lung Sound Analysis
C. Moore, T. Reinhardt, J. Spencley, H. Pasterkamp, R. Castedo, G. Oliveira

Vertical Lung Sound Devices
M. Gavriely

POSTERS

Time-Dependent Spectral Quantitation of Lung Sounds
W. Kergus, J. Oliveira, R. Castedo, J. Valletti

The Relationship Among Nocturnal Breathing Sounds, Respiratory Flow Rate and Nocturnal Hypoxemia in Nocturnal Asthma
H. Miyazaki, K. Ishikawa, K. Kinoshita, H. Kumamoto, M. Hasegawa, Y. Kinoshita, Y. Uchiyama, K. Koyama

Lung Frequency Based Method for Wheeze Detection
M. Schwarz, H. Rohm

A Computer Aided System for the Accurate Estimation of Tracheal Acoustical Transducers
J. Zechner, R. Brambauer, J. Martinez

Lung Sounds in Congestive Heart Failure: A First Report of a Trial
P. Murphy, E. Barstow, D.A. Powell

[illegible] Closing Remarks
D. Powell

[illegible] Steering Committee Meeting

PULSA: A SYSTEM TO SUPPORT LUNG SOUND ANALYSIS

W. Roque*, T. Heimfarth, T. Spengler, H. Valliatti, R. Custodio,
L. Oliveira

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PULSA is a computer system under development with the purpose of supporting lung sound analysis. The system has been designed for easy lung sound manipulations. Currently, the system presents the following features: it is able to digitally record the lung sound captured with an electroscope plugged to a sound cardboard on a PC, display the lung sound waveform for nine different sites either simultaneously or individually, acoustically reproduce the lung sound entirely of just a selected part of it, edit the sound waveforms, create and maintain a lung sound data basis for the patients as well as their clinical records, display the lung sound of a patient recorded a different dated to perform a visual and/or acoustic comparison for evolution follow up, or alternatively display the sound of a patient and compare with a sound from a lung sound dictionary to observe deviations, transform the lung sound to the wave or ascii formats, print the patient data records and sound waveforms or send them to a floppy, compute the Fast-Fourier Transform (FFT), display the power spectrum and compute its time-dependent fractal dimensions.

• Present address: Department of Mechanical Engineering, Carnegie Mellon Unversity, Pittsburg, PA 15213, USA

TIME-DEPENDENT FRACTAL DIMENSIONS OF LUNG SOUNDS

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The lung sounds seem to be the result of a turbulent motion due to the flow of a compressive fluid through the human respiratory system. As such, they form a highly complex nonlinear system that can be better investigated with nonlinear signal processing techniques. With the associated time series we can used phase space reconstruction techniques and compute some important invariance dynamical characteristics, like the fractal dimension and Lyapunov exponents. As we have observed, the lung sound time series has a self-affine structure, therefore their time-dependent fractal dimensions (TDFD) can be evaluated according to the critical exponent method (CEM). Applying this method to a set of lung sound samples, the observed TDFD have shown to be constant with value 1.49 for normal samples, despite of the physical characteristics of the patients. In contrast, they have shown a non-constant behavior for abnormal cases, when adventitious sounds are present. In addition, the Lyapunov exponents indicate the presence of chaos in adventitious sounds. These seem to suggest that TDFD may be useful as an acoustic pattern recognition parameter for lung sound classification.

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TIME-FREQUENCY BASED METHOD FOR WHEEZES DETECTION

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The automatic wheezes detection methods are currently based on the identification of a particular shape of peaks in the respiratory power spectrum. These techniques present a high false detection rate caused by the presence of peaks in normal sounds similar to those characterizing wheezes.

In this abstract, we propose a new method for automatic wheezes detection based on the wavelet packets. This method operates in the time-frequency domain including two stages: The first one detects all suspicious peaks in the frequency domain which could characterize wheezes, the second one validates, in the domain, the true wheezes and rejects the false ones.

The proposed detection method consists of decomposing the signal with wavelet packets, to construct an histogram based on function characterizing blocks situated in the useful frequency band. We applied the first detection test to this histogram, which consists to compare all histogram coefficients to empirical threshold. If the test is positive, then we transformed back only the wavelet packets coefficients of the bloc which verify the condition. So, the suspected wheeze is approximately separated from the respiratory sound. The second test is applied to the time waveform in order to validate the true wheezes and rejected the false ones.

A COMPUTER GUIDED SYSTEM FOR THE ACCURATE PLACEMENT OF THORACIC ACOUSTICAL TRANSDUCERS

James Thompson[1,2], Roland Doubleday[1], and Thomas Sheridan[1]
[1]Human Machine Systems Laboratory, Massachusetts Institute of Technology
[2]Department of Anesthesia and Critical Care, Massachusetts General Hospital, Harvard Medical School

To compare lung sounds for a specific patient taken at different times, a method was required to accurately place acoustical transducers at the same location each time data were collected. To accomplish this, a transmitter/receiver system that utilizes the strength of an induced magnetic field was used. This system gives six degree of freedom position information in the form of three Cartesian coordinates and three rotation angles of the receiver with respect to the transmitter. All of the information was given relative to the transmitter that was located at the T1 vertebra. Eight acoustical transducers were sequentially guided to coordinates specified in the initial data collection file for the patient, and these transducers were affixed to the patient with repeatability on the order of 0.1 inches. A graphical user interface was developed to give visual cues to the user to aid in this transducer placement.

LUNG SOUNDS IN CONGESTIVE HEART FAILURE: A CASE REPORT AND A CHALLENGE

R. Murphy, K. Bergstrom, V.A. Power

A 92 year old female presented to the Faulkner Hospital in congestive heart failure. A Swan Ganz catheter was placed to aid in management of her fluid balance. Lung sounds were recorded on three occasions using a multi-channel lung sound analyzer. The results are presented in Table I.

Table 1
Medium to Coarse Crackles
3 Breaths (Inspiration and Expiration)

Date/Time	Right Lateral	Right Posterior	Left Posterior	Left Lateral	Total	PCWP
6/4/96 1:00 pm	0	12	25	0	37	22
6/4/96 3:30 pm	12	7	11	5	30	16
6/5/96 8:15 am	10	9	2	n/a	21	9

As can be seen in this table, crackle counts and pulmonary capillary wedge pressure decreased in a roughly similar manner.

We have collected data on several other patients in whom the abnormal lung sounds have decreased after diuresis. Indeed standard clinical experience tells us that patients in pulmonary edema often have crackles "up to the apices" and that they clear after diuresis.

The study of Deguchi et al [1], showed that the presence of posturally induced crackles was a good predictor of outcomes of patients with myocardial infarction([1]). It has been shown in animal studies that lung sounds change in parallel with pulmonary capillary wedge pressure ([2,3]). We have demonstrated that computerized lung sound analysis can be readily performed in severely ill patients such as those in pulmonary edema on ventilators.

These preliminary observations suggest that lung sound analysis could be of value in the management of congestive heart failure. There are however, a number of confounding variables which present a challenge to lung sound investigators. Pulmonary edema can be present when crackles are not appreciated. Other conditions such as pleural effusion, atelectasis and co-existing pneumonitis are often present and can make the interpretation of lung sound information more difficult. Nevertheless, lung sound analysis has considerable appeal as there are numerous complications of pulmonary artery catheters and lung sound analysis can easily be instituted when the patient first presents in an emergency situation. In contrast therapeutic intervention, such as diuretic or fluid administration, is often necessary before a pulmonary artery catheter can be placed.

The goal of many lung sound investigators is to improve non-invasive diagnosis. The study of the sounds of congestive heart failure, for reasons noted above, is one of the most promising paths to pursue to provide an important clinically useful tool. A multi-centered study could facilitate reaching this goal.

1 F. Deguchi, S. Hirakawa, K. Gotoh, Y. Tagi, S. Ohshima, paper - Long-Term Follow-up of Patients After Recovery From Acute Myocardial Infarction: Prognostic Significance of Posturally-Induced Crackles

2 R.L. Donnerberg, C.K. Druzgalski, R.L. Hamlin et al, Sound Transfer Function of the Congested Canine Lung. Br. J. Dis. CHEST 1980: 74: 23-31