INTERNATIONAL LUNG SOUNDS ASSOCIATION

25 Years

1976 - 2000

CHICAGO, ILLINOIS

SEPTEMBER 20 - 22, 2000

25th INTERNATIONAL CONFERENCE ON LUNG SOUNDS

The 25th Annual
International Conference
On
Lung Sounds

Presented by:

International Lung Sound Association

September 20-22, 2000

Chicago, Illinois

FINAL PROGRAM AND ABSTRACTS

GENERAL INFORMATION

Conference Venue

Office of Continuing Medical Education of the Northwestern University Medical School, Chicago Illinois

Official Language

English

Registration and secretariat during the conference

Registration will be held at the University on Wednesday, September 20 from 2:00 - 3:00 PM

Registration will also be held on Thursday morning September 21 from 8:30 - 9:00 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

Demonstration/Posters

Posters will be on display in the conference room after 8:45 am on Thursday, September 21, 2000. The poster discussion will begin at 4:00 PM. An oral presentation of five minutes and a discussion period of ten minutes is scheduled for each poster.

Reception

On Thursday evening at approximately 6:00PM, departure from North Pier, 435 East Illinois Street for a dinner cruise.

Sponsors

Boehringer-Ingelheim
Faulkner Hospital
Karmel Medical Acoustics Technology
The Pulmonary and Critical Care Division of the Department of Medicine of Northwestern University Medical School
Stethographics
Tufts University School of Medicine
Mr. Terrence Johnson and "Chicago from the Lake"

The 25th International Conference on Lung Sounds
Chicago, Illinois - September 20-22, 2000

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PROGRAM

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11:45 - 12:00	Enhanced Compression Schemes for the Management of Respiratory Sounds Data - C. Druzgalski
12:00 - 12:20	Photo
12:20 - 1:30	Lunch

Scientific Session B

Chairpersons: Sadamu Ishikawa and Steve Kraman

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10:00 - 10:15	Respiratory Phase Affects the Time Delay of Lung Sounds Between Adjacent Senses - H. Kiyokawa, H. Pasterkamp
10:15 - 10:30	Break
10:30 - 10:45	Tracheal Sounds and Airflow Dynamics in Surgically Treated Unilateral Vocal Fold Paralysis - A. Sovijarvi, A. Saarinen, H. Rihkanen, L. Malmberg, L. Pekkanen
10:45 - 11:00	Physical Modeling of Aerodynamic and Acoustic Processes in Respiratory Ways - V. Grinchenko, O. Vovk, I. Vovk, V. Oliynik
11:00 - 12:00 -	Guest Lecture - 'Emerging Trends in Information Access and Distribution; Medical and Technical Libraries of the Future: The Metamorphosis of Scientific Journals, etc.' - James Shedlock, A.M.L.S.
12:00 - 1:30	Lunch
1:30 - 2:00	Business meeting

Scientific Session D

Chairpersons: Christopher Druzgalski and Robert Loudon

2:00 - 2:15	Stable Modeling: A Novel Tool for Classifying Crackles and Artifacts - L. Hadjileontiadis, A. Giannakidis, S. Panas
2:15 - 2:30	Auditory Detection of Simulated Crackles in Breath Sound - H. Kiyokawa, M. Greenberg, K. Shirota, H. Pasterkamp
2:30 - 2:45	Inspiratory Crackle Rate During Normal, Deeper than Normal, and Deepest Breathing, A. Vyshedskiy, V. Power, K. Bergstrom, R. Murphy

ABSTRACTS

Scientific Session A

Thursday, September 21

8:30	Registration
9:00	Welcoming Addresses

Scientific Session A

Chairpersons: Dave Cugell and Margaret Murphy

9:30 - 9:45	Are Minidisk Recorders Adequate for Lung Sound Research? - S. Kraman, H. Pasterkamp, G. Wodicka
9:45 - 10:00	Observations from an ICU Wired For Sound - R. Murphy, K. Bergstrom, M. Bixby, P. Marielli, V. Power, A. Vyshedshiy
10:00 - 11:00	Guest Lecture - 'Telemedicine in Cardiopulmonary and Critical Care Medicine' - Allen Goldberg, M.D.
11:00 - 11:30	Break
11:30 - 11:45	Tracheal Sounds Analysis as a Tool for Monitoring the Efficacy of Nasal CPAP Treatment in Patients with Obstructive Sleep Apnea - H. Nakano, T. Ikeda, T. Iwanagao, S. Shoji, S. Nishima
11:45 - 12:00	Enhanced Compression Schemes for the Management of Respiratory Sounds Data - C. Druzgalski
12:00 - 12:20	Photo
12:20 - 1:30	Lunch

ARE MINIDISK RECORDERS ADEQUATE FOR LUNG SOUND RESEARCH?

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

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

Digital audio tape (DAT) recorders have become the *de facto* gold standard recorders for lung sounds. The quality of sound recorded on DAT is compact disk (CD) quality with adequate sensitivity from below 20 Hz to above 20 KHz. Microphones appropriate for detection of all lung sounds may be connected to such recorders without the use of filters, thereby assuring recordings as free from distortion as possible. DAT recorders have drawbacks. Although small, they are heavy and the recording mechanism is complex and delicate. The use of tape makes finding one desired track out of many inconvenient. These characteristics can discourage the busy clinician interested in recording lung sounds. A more recent development in portable recording devices is the minidisk (MD) recorder. These recorders are now widely available and have many features that make them attractive to the clinician interested in recording biological sounds. They are inexpensive, small and light, rugged, mechanically simple and record digital data on a small disk in tracks that may be named and accessed directly. Unlike DAT, these tracks may be moved or separately deleted without affecting other tracks. Minidisks hold up to 74 minutes of recorded sound. This represents about as much information as a CD can hold but in 1/5 of the recordable area. This data compression is achieved by use of a system known as Adaptive Transform Acoustic Coding for Minidisk (ATRAC). This coding system makes decisions about what components of the sound would not be heard by a human listener and discards the digital information that represents these sounds. Most of this compression takes place on sounds above 5.5 KHz. As the intended use of these recorders is the storage and reproduction of music, it is unknown whether ATRAC will discard or distort significant portions of lung sound signals. To determine the suitability of MD recorders for respiratory sound research, we compared a variety of normal and pathologic lung sounds, as well as speech, that were digitized directly into a computer and also after recording by two different MD recorders (Sharp model 702 and Sony model MZ-R30) using both time-domain and spectral techniques. <u>Results</u>: Although sounds well above 6000 Hz (speech) were visibly modified by recording on the MD machines, we found no important effect on the spectra or waveforms of typical lung sounds. We conclude that MD recorders may be adequate for lung sound research.

OBSERVATIONS FROM AN INTENSIVE CARE UNIT WIRED FOR SOUND

R. Murphy, A. Vyshedshiy, K. Bergstrom, V-A Power,
P. Marielli, M. Bixby

The Intensive Care Unit at the Faulkner Hospital is wired to allow auscultation to be performed remotely and to permit analysis of lung sounds. The analysis provides objective evidence of abnormalities noninvasively. Cases will be presented to show correlation of the lung sound data with the clinical status of the patients. Typical cases of pneumonia, congestive heart failure (before and after diuresis), interstitial pulmonary fibrosis, bronchial and cardiac asthma, as well as ARDS, will be presented. The course of a patient with pneumonia and ARDS will be discussed in detail. The system is "user friendly" for both the patients and the health care providers and provides useful clinical information not easily obtainable by other clinical modalities.

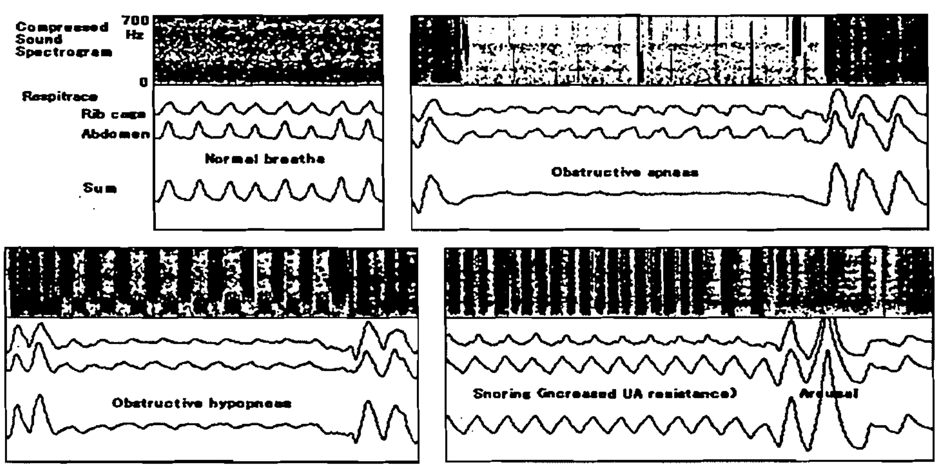
TRACHEAL SOUNDS ANALYSIS AS A TOOL FOR MONITORING THE EFFICACY OF NASAL CPAP TREATMENT IN PATIENTS WITH OBSTRUCTIVE SLEEP APNEA

Hiroshi Nakano, Togo Ikeda, Tomoaki Iwanaga, Shunsuke Shoji, and Sankei Nishima
National Minami-Fukuoka Chest Hospital, Fukuoka, Japan

Nasal continuous positive airway pressure (CPAP) treatment has been established to be the most effective therapy for obstructive sleep apnea (OSA). Prior to the prescription of CPAP treatment the determination (titration) of an optimal CPAP pressure is necessary. Ordinarily the CPAP titration is performed by polysomnographic monitoring at the hospital. And a follow up study is difficult to perform at home. The ideal CPAP efficacy is considered to be the complete elimination of apneas, hypopneas and respiratory effort related arousals (RERAs). We have reported tracheal sounds analysis as a feasible diagnostic tool for OSA, which is available for home monitoring. The aim of this study is to test whether apnea/hypopneas and RERAs can be detected by tracheal sounds analysis during CPAP treatment.

We analyzed tracheal sounds in eight OSA patients during CPAP treatment with polysomnographic recording. Tracheal sounds were acquired by an air-coupled microphone attached on the anterior neck. The signal was digitized using a waveform audio function of a personal computer and the power spectra were calculated by a FFT algorithm on a real time basis every 0.2 seconds. The logarithms of the power spectra were stored in the personal computer and thereafter displayed as a form of compressed sound spectrogram. When the CPAP was properly functioning, continuous noise originating from CPAP machine emerged on the tracheal sound record. In five patients there were periods of insufficient CPAP pressure and episodes of apnea/hypopneas or RERAs occurred. Eighty-nine percent of obstructive apnea/hypopnea events were accompanied by transient attenuation or an absence of CPAP machine noise on the tracheal sound record. The same was observed in fifty-three percent of RERAs, and 40 percent of RERAs were accompanied by snoring sounds with a characteristic feature of gradual accentuation followed by an abrupt disappearance. There were neither apnea/hypopnea events nor RERAs when continuous CPAP noises were dominant on the tracheal sound spectrogram.

We conclude that the tracheal sounds analysis may be a useful tool for the monitoring of CPAP treatment in OSA patients.



Enhanced Compression Schemes for the Management of Respiratory Sounds Data

Christopher Druzgalski
California State University, Long Beach, CA 90840

Continued use of qualitative characterization of auscultatory signs in clinical practice stipulates the need for improved management of digital files representing respiratory sounds' data. In particular, enhanced compression of acoustic signatures of the lungs, by involving MP3 like schemes for increased compaction of diagnostic respiratory sounds data, will allow a reduction of acoustic digital files and improved long term monitoring of changes in respiratory mechanics.

In particular, new compression algorithms allow to squeeze digital audio files by a ratio of 12:1 or even higher for VQF formats. This should elevate some inherent problems associated with the storage, transfer, and comparative assessment of digitized files representing patients' respiratory sounds data. A special consideration is given to the effects of data fragmentation and digital platform compatibility. In particular, the compression and expansion of the audio files representing medical data are often associated with the loss or distortion of peculiar nonperiodic acoustic events. Therefore, fragmentation of data which occurs during the data transfer may affect quantitative analysis. However, properly compressed respiratory sounds' files can enhance efficiency of their storage or transfer over the Internet with increased speed of downloading or transfer.

These factors are essential in on-site management of patients' auscultatory data and very critical in teleauscultation and a broader access to respiratory acoustic data basis. Therefore, proliferation of emerging technologies as applied to compression algorithms and associated hardware provides new opportunities for enhanced management of audio files representing respiratory acoustics.

Scientific Session B

Scientific Session B

Chairpersons: Sadamu Ishikawa and Steve Kraman

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3:30 - 3:45	Adenosine Bronchial Provocation in Infantile Chronic Cough - A Study with Automatic Wheeze Detection - L. Bentur, R. Beck, D. Berkowitz, G. Hasnin, I. Berger, C. Irving, N. Gavriely
3:45 - 4:00	Measurement of Snoring Before and After Palatoplasty - T. Jones, M. Ho, B. Cheetham, J. Earis

SELECTION OF DEFINING PARAMETERS OF LUNG SOUND AT DIAGNOSTICS OF LUNG PATIENTS

Victor T. Grinchenko, Anatoly P. Makarenkov, Alecsandr G. Rudnicky

Institute of Hydromechanics NAS, Kiev, Ukraine, E-mail: vin-igm@gu.kiev.ua

The objective multichannel registration of the breath sound creates the necessary preconditions for development of computer algorithms of lung patient diagnostics. The efficiency of these algorithms is appreciably determined by that as far as the characteristic features for the description of sounds of breath are successfully chosen. The set of characteristic attributes is formed on the basis of data processing both single-channel and two-channel measurements. During clinical researches the diagnostic utility of twelve various parameters of the breath sounds was tested. The researches were carried out in the Kiev children clinical hospital No 6. Training set was formed from 16 healthy children in the age of from 7 till 14 years. The examined set was formed from 17 children of the same age group with various respiratory diseases. The six most diagnostic useful time and frequency attributes were selected. The diagnostic efficiency of every attribute and their system as a whole was tested. Use of set of attributes as a whole has ensured correct diagnostics of diseases and absence of cases of a false alarm. The efficiency of the offered approach to construction of diagnostic algorithms is illustrated with several examples of treatment process monitoring.

Effect of pneumotachygraph on voluntary coughs. Loudon R.G. Professor Emeritus, University of Cincinnati College of Medicine, Cincinatti OH, USA.

As a group interested in the relationships between sound events and respiratory disorders we must accept that cough is one of the loudest and most clinically important of respiratory sounds. The efficiency of cough and its cost in terms of muscular energy or stressful pressures are not readily assessed by any single physiological measurement. One of the major advantages of sound studies is their non-invasive character, and it was hoped that the sound signals would relate to the physiological changes in some consistent way that will help cough sounds to be interpreted in physiological terms. As a first step in an effort to relate the sounds of cough to the associated physiological events we chose to study voluntary coughs in healthy subjects. Esophageal pressure was measured with an esophageal balloon, volume change by a respiratory inductance plethysmograph with chest and abdominal bands, expiratory airflow by a mask and cone pneumotachygraph, and sound by free air and laryngeal microphones. The subjects were asked to make a series of five coughs of increasing intensity, with and then without the pneumotach in place, and repeat this at various lung volume levels and patterns. The signals were recorded on tape and analyzed off-line. An important question in interpreting these observations was whether the instruments used affected the measured variables. Did a pneumotachygraph placed over the subject's face alter their coughs? The repetition by each subject of a series of coughs with and without the pneumotach in place allowed a comparison to be made to test if it did so, and if so in what way and how much. Our results did not show any consistent effect of the pneumotach other than the muffling of the sounds recorded by the free air microphone. The inherent variability in the data make it difficult to rule out minor or inconsistent differences, but our results did not support our expectation that the use of the tight face-mask would affect the force applied during coughs, as reflected in the physiological variables.

SHORT AND LONG TERM LUNG SOUND VARIABILITY IN ASTHMATIC CHILDREN

Masato Takase, Takehide Imai, Kazuhiko Shirota, Yaoki Inaba, Taiyo Imai

Department of Pediatrics, Nippon Medical School, Tokyo, Japan

We have reported that the short-term lung sound variability could be used as a reliable objective measure to assess airway lability in asthmatic children. Ten asthmatic boys (10-13 y/o) with various severity of the disease underwent spirometry and lung sound recordings for three consecutive days. One year later, we conducted the same procedure on nine boys who participated in the asthma summer camp program for two consecutive years. Our objective was to examine the long-term lung sound variability in these asthmatic children.

Recordings were made using two contact-type sensors (Siemens, EMT25C) over the right upper anterior and the right lower posterior chest. The subjects breathed through a pneumotach, targeting at medium flow (15ml/kg/sec±20%). The lung sounds digitized at 10,240 Hz were stored and analyzed on a computer. Average spectra of inspiratory, expiratory and breathhold segments were calculated after applying FFT (fast Fourier transform). Short and long term variability of the lung sound spectra in each subject was examined visually on graphical presentation and statistically using a few spectral parameters. The airway condition at each recording was evaluated with spirometric data obtained after the recording.

Despite the significant physical growth achieved by the participants, the lung sound spectral changes observed seemed to reflect the changes in their spirometric data reasonably well.

Spiro-acoustic bronchial provocation test in adults

Abraham B. Bohadana, MD

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Service de Pneumologie A, CHU de Nancy Brabois, Vandoeuvre-lès-Nancy, France

In recent years, breath sounds have been extensively used to monitor the bronchoconstrictor response in patients undergoing bronchial provocation challenge testing. In the first report on this subject, Avital and colleagues[1] used a stethoscope to show that in 11 out of 15 asthmatic children (aged 6-15 years) the methacholine concentration at which tracheal wheezing first appeared was identical to that at which the forced expiratory volume in one second (FEV1) had fallen by 20% or more. Thereafter, many authors used automated wheeze detection to demonstrate that this acoustic technique was useful in evaluating bronchial responsiveness in asthmatic children. By contrast, in adults, the relationship between wheeze appearance and methacholine-induced fall in FEV1 was found to be less straightforward. Overall, the reported series show that: a) wheezes tend to develop in only a proportion (up to ¾) of subjects whose challenge test is positive by spirometry (fall in FEV1 by 20% or more); b) in a small but significant fraction of subjects wheezes appear one or more steps prior to a 20% fall in FEV1; c) in some subjects wheezes are present at baseline, before the challenge test; d) breath sound intensity may diminish in a significant and reversible way in non-wheezers with a test positive by spirometry. These results - together with considerations on the clinical significance of wheezes - suggest that a "mixed" method of bronchial challenge testing can be contemplated which associates wheeze detection and spirometry. In this study, the pros and the cons of this spiro-acoustic method are examined in the light of its clinical application.

1) Avital A, Bar-Ishay E, Springer C, Godfrey S. Bronchial provocation test in young children using tracheal auscultation. J Pediatr 1989; 112: 591-594

SIMULTANEOUS BREATH SOUND AND FLOW MEASUREMENTS DURING COUGH

W. T. Goldsmith, J. S. Reynolds, A. A. Afshari and D. G. Frazer
E&CTB, HELD, NIOSH, Morgantown, WV 26505

When measuring breath sounds from the mouth, care must be taken to minimize the amount of interference from external and internal sources. A recording system composed of concatenated tubes was designed to record cough sounds from the mouth with high fidelity. Normally, a flow measuring device, such as a pneumotach, is placed near the subject's mouth to record an accurate measurement. In this case, it was anticipated that close proximity of the pneumotach to the microphone would cause reflections and filtering characteristics which would alter the sound measured at the microphone. For this reason the pneumotach was placed near the distal end of the tubing system.

The recording system was coupled to a voltage controlled piston pump capable of generating arbitrary volume waveforms. Noise signals rich in the frequencies of interest were generated to obtain the transfer function of the recording system. An inverse filter was calculated which accounted for flow measurement errors caused by the distal location of the pneumotach.

Eighteen control subjects were asked to cough voluntarily into the recording system. The inverse filter was applied to the pneumotach recordings to provide an accurate measurement of flow from each subject's mouth. Sound intensity was plotted versus air flow from the mouth to examine sound intensity during each phase of the cough.

Study on features of cough sound waves and the detection of cough

Akira Murata1), Atsuo Shibuya2), Hiromi Tanahashi2), Shoji Kudoh1)
1) The fourth Department of Internal Medicine, Nippon Medical School, Japan
2) Japan Women±s University, Japan

For the purpose of developing a cough monitor, we compared effectiveness of two different microphones to analyze cough sounds acoustically and searched parameters to discriminate cough sounds from voice sounds and noise.

The cough sounds from 5 subjects (3 patients with acute bronchitis and 2 healthy subjects) were recorded at sitting position and supine position. We recorded spontaneous cough sounds and voice from the patients and voluntary cough sounds and voice from the healthy subjects on the digital audio tape through 2 channels simultaneously ; one of the channel connected to a bone conductive microphone attached to their external ear canal and another channel to an electlet condenser microphone in free air. Sampling interval was 8kHz. To extract the characteristic waves of cough sounds easily, we decided to analyze the cough sounds by the duration time of coughing, not by frequency. Then we measured duration of each coughing(T), a period of time from initial deflection to the peak of the maximal sound power of cough sound(Tp), a period of time from the peak of the maximal sound power of cough sounds to the end of coughing(Te), and the percentage of Tp in the duration of each coughing(Tp%=Tp/T). We measured four parameters (T, Tp, Te, Tp%) in each voice from the time-expanded waveform analysis.

As the results, we could discriminate cough sounds from the recorded sounds with 87% of probability by using a bone conductive microphone, 84% with an electlet condenser microphone in free air. So we concluded that a bone conductive microphone is suitable in developing a cough monitor. Hereafter we will retest and improve this method of discrimination, develop the software incorporating these four parameters, and examine the effectiveness of this method in clinical trials.

Pulmonary acoustics and esophageal pH monitoring in the evaluation of infantile nocturnal cough

L. Bentur, R. Beck, D. Berkowitz, G. Hasnin, I. Berger, C. Irving and N. Gavriely
Rambam Medical Center, Karmel Medical Acoustic Technologies, and the Rappaport Faculty of Medicine, Technion, Haifa, Israel

Persistent nocturnal cough is a common and troublesome symptom in infants. The differential diagnosis includes gastro-esophageal reflux and asthma. The *aim* of this study was to evaluate the causative relationships between episodes of low esophageal pH and cough spells in 6-24 months old infants. A secondary aim was to define the temporal and acidity thresholds of significance with respect to cough spells. *Methods*: 15 patients were selected based on chief complain of persistent nocturnal cough lasting for more than one month and not responding to conventional treatment. Overnight (8-10 hours) acoustic respiratory monitoring (PulmoTrack® Karmel Medical Acoustic Technologies Ltd. Yokneam Illit, Israel) was performed simultaneously during lower esophageal pH monitoring. *Results*: Two of the subjects (14%) had pH<4.0 for more than 3.4% of the test duration. Seven additional subjects had multiple short episodes of low pH. Nocturnal cough was confirmed in 6 of the patients and 9 of the patients had significant wheezing episodes. In only 1 of the patients cough spells and/or wheezing were temporally associated with esophageal acidity. *Conclusions*: Objective confirmation of nocturnal cough and documentation of nocturnal wheeze are much more common than positive gastroesophageal reflux in young children with persistent nocturnal cough.

Adenosine bronchial provocation in infantile chronic cough – a study with automatic wheeze detection

L. Bentur, R. Beck, D. Berkowitz, G. Hasnin, I. Berger, C. Irving and N. Gavriely
Rambam Medical Center, Karmel Medical Acoustic Technologies, and the Rappaport Faculty of Medicine, Technion, Haifa, Israel

Chronic cough (CC) in babies is often associated with bronchial hyper reactivity (BHR). We performed Adenosine bronchial provocation tests (BPT) in babies with CC. The aim of the study was to assess the extent of BHR and to compare the results when a physician listens with a stethoscope to an automatic wheeze detection (AWD) device (PulmoTrack® Karmel Medical Acoustic Technologies Ltd. Yokneam Illit, Israel). Methods: 15 infants, 6-24 months old with were studied. BPT was done with adenosine in doubling doses ending at 400 mg/ml, or when the physician detected wheezes, cough or drop in SPO2. In parallel, the PulmoTrack® monitored the breath sounds at 5 standard chest locations. Wheeze quantification was compared to the auscultation results. Results: 9 of the patients had positive BPT, but only 4 responded with concentrations under 100 mg/ml. In the patients who responded, rhonchi preceded the onset of wheezing, or were the sole manifestation of bronchoconstriction. In one of the negative and in two of the positive subjects AWD detected wheezes earlier than by auscultation. We conclude that BPT can be used to evaluate babies with CC and that a response can be detected accurately by AWD.

Measurement of Snoring before and after Palatoplasty

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

We report the initial results on six patients from a cohort of fifty patients who have undergone treatment for heavy snoring by palatoplasty. All undertook limited sleep studies pre-operatively, one month and six months post-operatively. Snoring sounds are recorded by a free-field microphone onto a DAT recorder. In addition all patients had simulated snoring recorded prior to surgery.

The digital output from the DAT recorder of the pre-operative and immediate post-operative recordings was read directly into a PC and the first 100 snores are identified by a specially written programme outlined at the ILSA meeting last year. These snores together with a time-base was stored in a separate file and then re-analysed. Time-domain and spectrographic analysis of the snore waveforms revealed two main patterns *first* a predominant quasi-periodic structure with multiple harmonics and *second* a more complex waveform without a clear harmonic structure in the time domain. The first pattern usually arises from palatal snoring and was the commonest pattern seen in simulated snoring while the more complex waveforms are thought to be an interaction of vibrations in pharyngeal palatal and other upper airway structures.

The main analysis software automatically counted the number numbers of snores per minute, average duration (sec/episode) and power of the snoring episodes. A further algorithm measured the percentage of periodic sound in the 100 snores. A new technique subtracted the patients simulated snore waveform from their recorded snoring sounds to give an index (LP gain (dB)) of palatal snoring. The peak to RMS ratio (as described by Osborne et al Clinical Otolaryngology 1999 24, 130-133) was also measured.

The initial results show that following surgery there is no obvious difference in the number or duration of snoring episodes. However, in the 4 patients with comparable data there was a mean reduction of 5.3 dB in the average power of the snoring. In addition there were changes in the overall power spectral shape of the pre and post operative snores. The measures associated with the periodicity of the snoring waveform showed that in the five usable recordings the periodicity fell in 4 (mean 11%) with a small rise of 1.4% in one subject. Palatal snoring should theoretically be associated with a higher value of the LP gain and lower value for the Peak to RMS. In the pre operative values these two parameters were always related (i.e. all patients with high LP gain had a lower peak to RMS). Following surgery the Peak to RMS fell in 4 of the five recordings by an average of 0.46 units.

These preliminary results show that as others have found the basic parameters of the numbers of snores vary little following surgery. However, there was a tendency for reduction in intensity and periodicity of snoring following surgery. Moreover, these results suggest that our measures of palatal snoring are valid and in keeping with other measures such as peak to RMS. However, when all fifty patients results are available firmer conclusion about predictors and outcome measures of surgery will be possible.

POSTERS

Poster Discussion

4:00 - 4:15	Absolute Sensitivity Characteristics of Air-Coupled Microphone - Effect of Coupler Fringe in Contact with Chest Wall - A. Suzuki, K. Nakayama
4:15 - 4:30	Detection of the Malpositioned Endotracheal Tube with the Use of Acoustic Reflectometry - D. Raphael
5:45	Dinner boat cruise. 6:00 departure from North Pier, 435 Illinois Street

ABSOLUTE SENSITIVITY CHARACTERISTICS OF AIR-COUPLED MICROPHONE
Effect of Coupler Fringe in Contact with Chest Wall

Akifumi Suzuki and Kiyoshi Nakayama
Department of Electrical and Electronics Engineering, Faculty of Science and Technology, Sophia University, Tokyo, Japan

It is desirable that lung sounds should be measured and discussed in some absolute unit such as pascal for further progress of lung-sound studies. In the analysis of characteristics of air-coupled microphone, it has been well studied that the microphone shows low-pass frequency response owing to its air-chamber compliance, but it has not been examined how the coupler affects the microphone's response in the pass band. We studied the response in the pass band considering effect of the coupler fringe in contact with chest wall.

In the pass band, the mechanical impedance of air chamber is much higher than that of chest wall; therefore vibration of a measured area on the chest-wall surface is stopped by both the air chamber and the coupler fringe in contact with the chest wall. Incorporating viscoelastic characteristics of the chest wall, we analyzed normal stress distribution on the stopped surface. We then evaluate the effect of the coupler fringe on the microphone response by calculating the ratio of the sound pressure exerted on the air chamber to the stop-surface pressure, i.e., the sound pressure averaged over the stopped surface.

The results show that the stress concentrates on the outer edge on the fringe and that the stress distribution changes with frequency (Fig. 1). The measured sound pressure is therefore lower than the stop-surface pressure and has frequency dependency (Fig. 2). The results of a model experiment well agreed with theoretical predictions based on the mechanical properties of the medium used in the experiment.

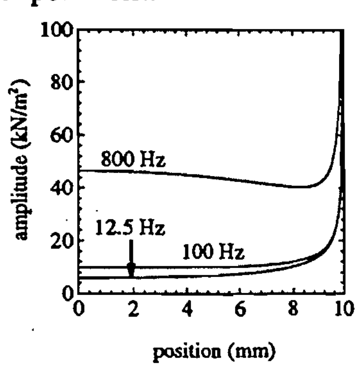


Fig. 1 Normal stress distributions. The outside diameter of the coupler is 20 mm.

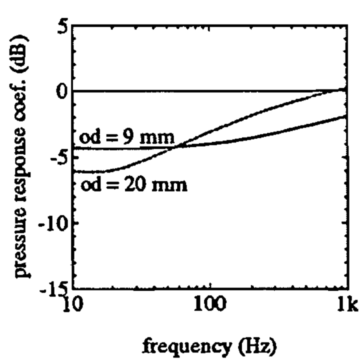


Fig. 2 Effect of the coupler fringe on microphone response. The outside diameters of the coupler are 9 mm and 20 mm. The diameter of the air chamber is 7 mm.

DETECTION OF THE MALPOSITIONED ENDOTRACHEAL TUBE WITH THE USE OF ACOUSTIC REFLECTOMETRY

David T. Raphael, M.D., Ph.D., Associate Professor of Anesthesiology,
LAC-University of Southern California Medical Center, Los Angeles, California 90033;
UMDNJ-Robert Wood Johnson Medical School, New Brunswick, New Jersey

Introduction: Time-domain acoustic reflectometry[1] is a means whereby a 'one-dimensional image' of a cavity, such as the lung or esophagus, can be generated with the image displayed as an area-distance profile. The technique can be used, without resort to capnography, to distinguish readily between an endotracheal and esophageal intubation.[2] Can acoustic reflectometry be used to detect an endobronchial intubation? In a patient undergoing an IRB-approved study involving ETT placement and positioning, an endobronchial intubation in the right mainstem bronchus occurred despite the presence of equal breath sounds. The endobronchial intubation was detected first by acoustic reflectometry, and the diagnosis confirmed by fiberoptic bronchoscopy. With this diagnostic success in mind, a study was initiated to determine the area-distance profile features of an endobronchial intubation in an *in vitro* branching glass model.

Methods: A symmetrical glass model (Witeg Scientific, Anaheim, CA), open at the proximal end, with two orders of bifurcation terminating in four closed distal branches, was studied. Area-distance (A-D) profiles were obtained with a customized computer-based acoustic reflectometer (Hood Labs, Pembroke, MA) characterized by a maximal measurement distance of 50 cm from the distal end of the wavetube. With a 7.0 mm ETT attached to the wavetube, A-D profiles were obtained when the distal end of the ETT, with its cuff inflated, was located in the following positions: (1) the mid-'trachea', (2) in the vicinity of the 'carina', (3) within the 'mainstem bronchus', (4) in the vicinity of the second bifurcation, and (5) within the secondary 'bronchus'.

Results: Advancement of the ETT within a bifurcation results in reduction of the cross-sectional area; further area reduction results if inflation of the ETT cuff seals off any remaining air pathway for the transmission of an acoustic pressure disturbance from the intubated branch to the adjacent unintubated branch. The A-D profile features of an endobronchial intubation, as determined by this model study, are similar to those that were observed clinically in a patient.

Conclusions: Based upon this model study, and pending validation in a larger series of patients, acoustic reflectometry may have a role in the detection of the malpositioned endotracheal tube, either in the form of an esophageal or endobronchial intubation, without resort to capnography and chest roentgenograms.

References: [1]Jackson AC, Butler JP, Miller EJ, Hoppin FG, Dawson SV. Airway geometry by analysis of acoustic pulse measurements. J Appl Physiol 1977;43:523-36.
[2]Raphael DT. Acoustic reflectometry profiles of endotracheal and esophageal intubation. Anesthesiology 2000; 92(5):1293-99.

Scientific Session C

Friday, September 22

Scientific Session C

Chairpersons: Hans Pasterkamp and John Earis

9:00 - 9:15	Experimental Modeling of Breath Sounds with an Obstacle in the Airway - F. Sakao, M. Mori, H. Sato
9:15 - 9:30	"E" - A Changes in Normal, COPD and Asthmatic Patients - S. Ishikawa, M. Murphy, R. Murphy
9:30 - 9:45	The Lung Sound Amplitude and Duration to Ventilator Settings - F. Davidson, K. Bergstrom, V. Power, J. Earis, R. Murphy
9:45 - 10:00	Sound Speed in the Lung As a Function of Lung Volume - T. Bergstresser, A. Vyshedskiy, R. Murphy
10:00 - 10:15	Respiratory Phase Affects the Time Delay of Lung Sounds Between Adjacent Senses - H. Kiyokawa, H. Pasterkamp
10:15 - 10:30	Break
10:30 - 10:45	Tracheal Sounds and Airflow Dynamics in Surgically Treated Unilateral Vocal Fold Paralysis - A. Sovijarvi, A. Saarinen, H. Rihkanen, L. Malmberg, L. Pekkanen
10:45 - 11:00	Physical Modeling of Aerodynamic and Acoustic Processes in Respiratory Ways - V. Grinchenko, O. Vovk, I. Vovk, V. Oliynik
11:00 - 12:00 -	Guest Lecture - 'Emerging Trends in Information Access and Distribution; Medical and Technical Libraries of the Future: The Metamorphosis of Scientific Journals, etc.' - James Shedlock, A.M.L.S.
12:00 - 1:30	Lunch
1:30 - 2:00	Business meeting

THE LUNG SOUND AMPLITUDE AND DURATION TO VENTILATOR SETTINGS

F. Davidson, K. Bergstrom, V. Power, J. Earis, R. Murphy

To investigate the relationship of ventilator settings to automated lung sound analysis, we studied the amplitude of sound over the chest in 2 normal subjects in the upright, supine and prone positions. The subjects breated air from T Bird ventilator at flow rates of 90 L/min and volumes of 400, 800, 1200 and 1600. A multichannel lung sound analyzer (Stethographics, Inc. 2006) was used for these investigations.

RESULTS

The duration of the time amplitude signal was proportional to the volume of air delivered by the ventilator. In the upright position and tidal volume of 800, breath sound amplitude was relatively uniform over the chest. Similar results were found in the supine position. In the prone position, breath sound amplitude was reduced at the left base as compared to the right base. A microphone placed over the upper back on the left consistently showed lower amplitudes than did the two microphones placed on the back at the level of the heart in the supine position. This was reversed in the prone position. These observations provide further confirmation that lung sounds reflect regional ventilation.

SOUND SPEED IN THE LUNG AS A FUNCTION OF LUNG VOLUME

T. Bergstresser, A. Vyshedskiy and R. Murphy

A number of disease processes that affect the lung alter the density of the lung tissue. This in turn affects the transmission of sound in the lung. Accordingly there has been some interest in determining the speed of sound through lung tissue as this may provide information on the density of the lung tissue using noninvasive technology.

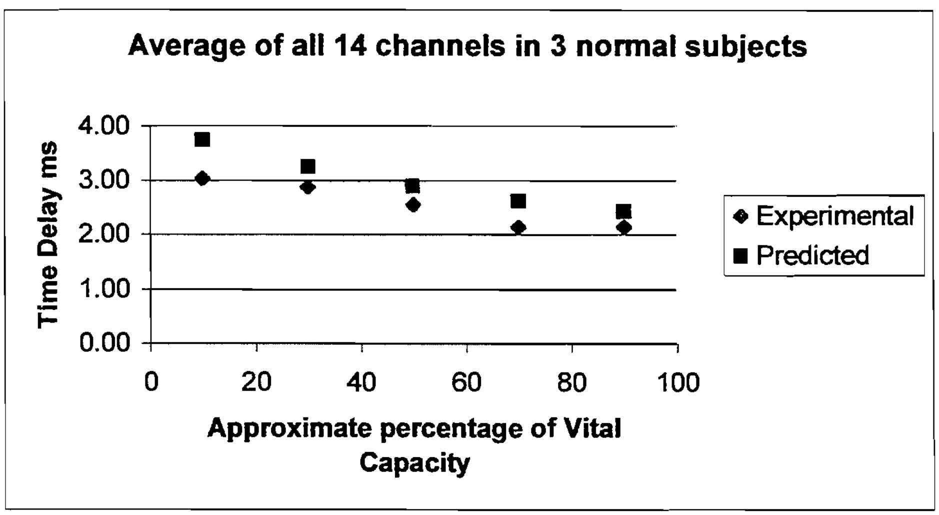
To investigate transpulmonary sound speed we introduced sound at the mouth in normal subjects and measured the arrival time delays at multiple microphones placed over the chest wall using a STG Monitor (Stethographics Inc. Mod 2006). We introduced sound continuously between TLC and RV in healthy subjects while they performed a slow vital capacity maneuver. We used the microphone placed over the neck near the trachea as our reference and utilized cross correlation analysis to calculate the time delays at five evenly spaced intervals from the beginning to the end of the expiratory maneuver.

Sound travel distance was estimated using anatomical landmarks. Figure 1 presents the relationship between the arrival time delays and lung volume. Arrival time delays decreased with increasing lung volume, i.e. sound speed was faster when the lungs were at higher degrees of inflation. Observed relationship between the arrival time delays and lung volume correlated well with that predicted by the following equation:

$$c = \sqrt{\frac{p_a}{p_t}} \frac{1}{\sqrt{v_a(1-v_a)}} \cdot c_{air}$$

v_a is the volume of air in lungs divided by total lung volume, p_a is the density of air, and p_t is the density of tissue.

Figure 1

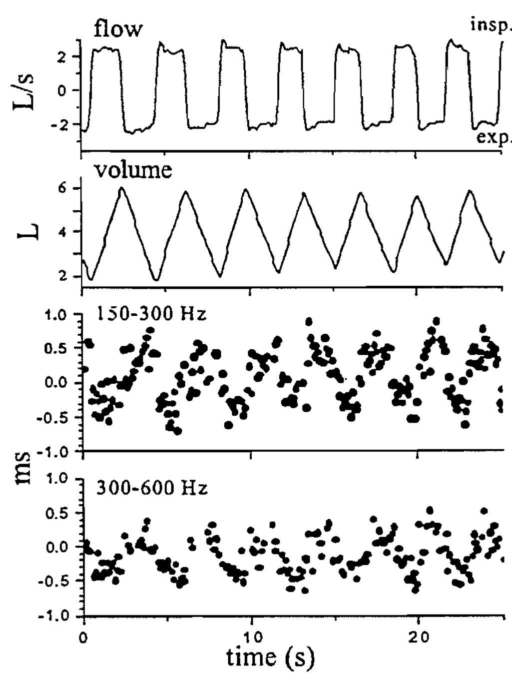


These time delays give an approximate range of speeds between 2.5 and 4 cm/ms. Although evidence has been presented that the transmission of sound introduced at the mouth is predominantly through lung parenchemya, these results are consistant with the hypotheses that the air content of the lung plays a significant role.

Respiratory phase affects the time delay of lung sounds between adjacent sensors.

Hiroshi Kiyokawa, MD and Hans Pasterkamp, MD
Respiratory Acoustics Laboratory, John Buhler Research Centre, University of Manitoba, Winnipeg, Canada.

Much progress has been made in the study of respiratory acoustics since the introduction of computer based measurements. However, the origin of normal lung sounds is still not completely understood. Turbulent gas flow in large airways is assumed to be the major mechanism of sound generation. We considered the change in the orientation and position of large airways during breathing and hypothesized that phase dependent sound delay between two adjacent recording sites on the chest may become apparent at given lung volumes and sensor positions. We studied four healthy male non-smokers, ages 22-49 y. Two contact sensors were attached in cranio-caudal alignment with 5 mm separation distance (35 mm center to center). Three recording sites were chosen at the right posterior chest, 5-7 cm lateral to the spine, at the level of T4, T6 and T9. Subjects sat in a body plethysmograph and breathed through a pneumotachograph while observing target flows and lung volumes on a computer screen (custom written LabView application). At least five complete respiratory cycles at each of three different lung volumes were recorded while subjects were breathing at a target flow of 2.0–2.4 L/s. The volumes were standardized to individual vital capacity (low volume = 20-40% of VC, middle volume = 40-60% and high volume = 60-80%). The sound signal was band pass filtered to extract low (150-300 Hz) and medium frequency (300-600 Hz) information. The filtered signals were divided into 100 ms epochs of 1024 data points each and normalized. The first and last 100 points of each epoch obtained from the caudal sensor were zero padded. Cross correlation and a peak detection algorithm were used to establish a caudal sensor delay (SDcaud). In three of four subjects we found a phasic change in SDcaud synchronous with respiration at one or more lung volumes and recording sites (Subject #1, Figure). SDcaud was mostly negative during inspiration, i.e. the caudal was leading the cranial sensor, but positive during expiration, indicating a movement of the sound source relative to both sites during breathing. Considering a sound speed in pulmonary parenchyma of 25-70 m/s (D. A. Rice, JAP 1983;54:304), the observed variation in SDcaud translates into a change in sound source location of 2.5-7 cm, which may point to medium and large airways. A specific constellation of sensor arrangement and movement of the sound source during respiration is required to observe the phasic change. This may explain inter-individual differences in lung volumes and recording sites at which the phasic change could be observed. Our findings are promising for the further development of multisensor acoustic probes to investigate the respiratory system.



Dr. Hiroshi Kiyokawa is supported by a fellowship grant from the Manitoba Lung Association.

TRACHEAL SOUNDS AND AIRFLOW DYNAMICS IN SURGICALLY TREATED UNILATERAL VOCAL FOLD PARALYSIS

Anssi R. A. Sovijarvi, Antti Saarinen, Heikki Rihkanen, L. Pekka Malmberg, Leena Pekkanen

SUMMARY

The aim of this study was to investigate the changes in tracheal sounds and airflow dynamics in patients who underwent surgical medialization of a unilaterally paralyzed vocal fold. Ten adults with unilateral vocal fold paralysis but no history of pulmonary diseases were included. Vocal fold medialization was performed by an injection of autologous fascia into the paralyzed vocal fold. Recording of tracheal sounds, flow-volume spirometry and body plethysmography were carried out before and four to fourteen months after the operation. The mean number of inspiratory wheezes per respiratory cycle increased from 0.02 (range 0 – 0.10) to 0.42 (range 0 – 0.86) and the mean number of expiratory wheezes per respiratory cycle from 0.03 (range 0 – 0.20) to 0.36 (range 0 – 0.89). The increment was statistically significant ($p = 0.03$ and $p = 0.04$ respectively). The mean expiratory sound amplitude, in terms of root mean square (RMS), increased from 31.5 dB (range 24.0 – 38.0) to 34.9 dB (range 25 – 42) ($p = 0.03$) and the average peak inspiratory flow (PIF) decreased from 4.63 l/s (range 2.84 – 7.51) to 4.03 l/s (range 2.27 – 6.68) ($p = 0.01$). The results indicate that when the paralyzed vocal fold is brought into midline by a surgical procedure, the prevalence of inspiratory and expiratory wheezes increases and sound intensity rises. According to this preliminary data tracheal sound analysis gives additional information for the assessment of the subtle changes in the larynx.

PHYSICAL MODELING OF AERODYNAMIC AND ACOUSTIC PROCESSES IN RESPIRATORY WAYS

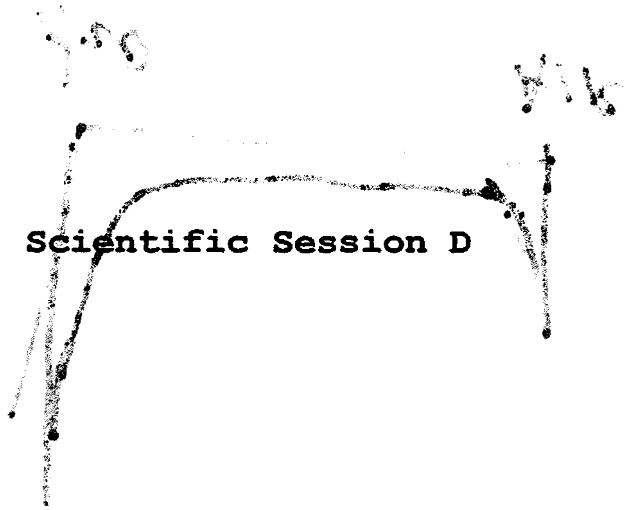
Victor T. Grinchenko, Olga I. Vovk, Igor V. Vovk, Valeriy N. Oliynik
Institute of Hydromechanics NAS, Kiev, Ukraine, E-mail: vin-igm@gu.kiev.ua

The upper part of respiratory tract consists of geometrical elements which can be considered as well known in hydraulics. On the basis of such analogy a physical modeling of upper respiratory tract has been realized. The experimental technique allowing to carry out estimation of aerodynamic resistance and spectra of noise generated by air flow is developed. Both characteristics of flow has been analyzed as functions of geometrical parameters modeling physiology features of the tract. In particular:

-- change of aerodynamic resistance of aperture simulating the true glottis, depending on their sizes and form. The resistance essentially depends on a degree of symmetry of the form of the aperture. The apertures with the form similar to true glottis have the least resistance,

-the change of level of the flow generated noise and character of its spectrum is investigated depending on the area of the aperture, its form, and speed of the flow. The generalization of experimental data specifies existence of the important functional relationships. Among them it is possible to specify the change of frequency spectra with flow velocity and growth of noise level with growth of hydraulic resistance of the aperture. The results are important for understanding lung sound characteristics.

Scientific Session D



Scientific Session D

Chairpersons: Christopher Druzgalski and Robert Loudon

2:00 - 2:15	Stable Modeling: A Novel Tool for Classifying Crackles and Artifacts - L. Hadjileontiadis, A. Giannakidis, S. Panas
2:15 - 2:30	Auditory Detection of Simulated Crackles in Breath Sound - H. Kiyokawa, M. Greenberg, K. Shirota, H. Pasterkamp
2:30 - 2:45	Inspiratory Crackle Rate During Normal, Deeper than Normal, and Deepest Breathing - A. Vyshedskiy, V. Power, K. Bergstrom, R. Murphy
2:45 - 3:00	Lung Sound Analysis Before and After Dialysis - M. Murphy, K. Bergstrom, V. Power, C. Aronstein, D. Cahan, R. Murphy
3:00 - 3:15	Acoustic Monitoring of Crackles and Airway Reopening in Excised Rat Lungs - N. Gavriely, Y. Shabtal-Musih
3:15 - 3:45	Conference Summary - Hans Pasterkamp
3:45	Closing Remarks
4:15	Steering Committee Meeting

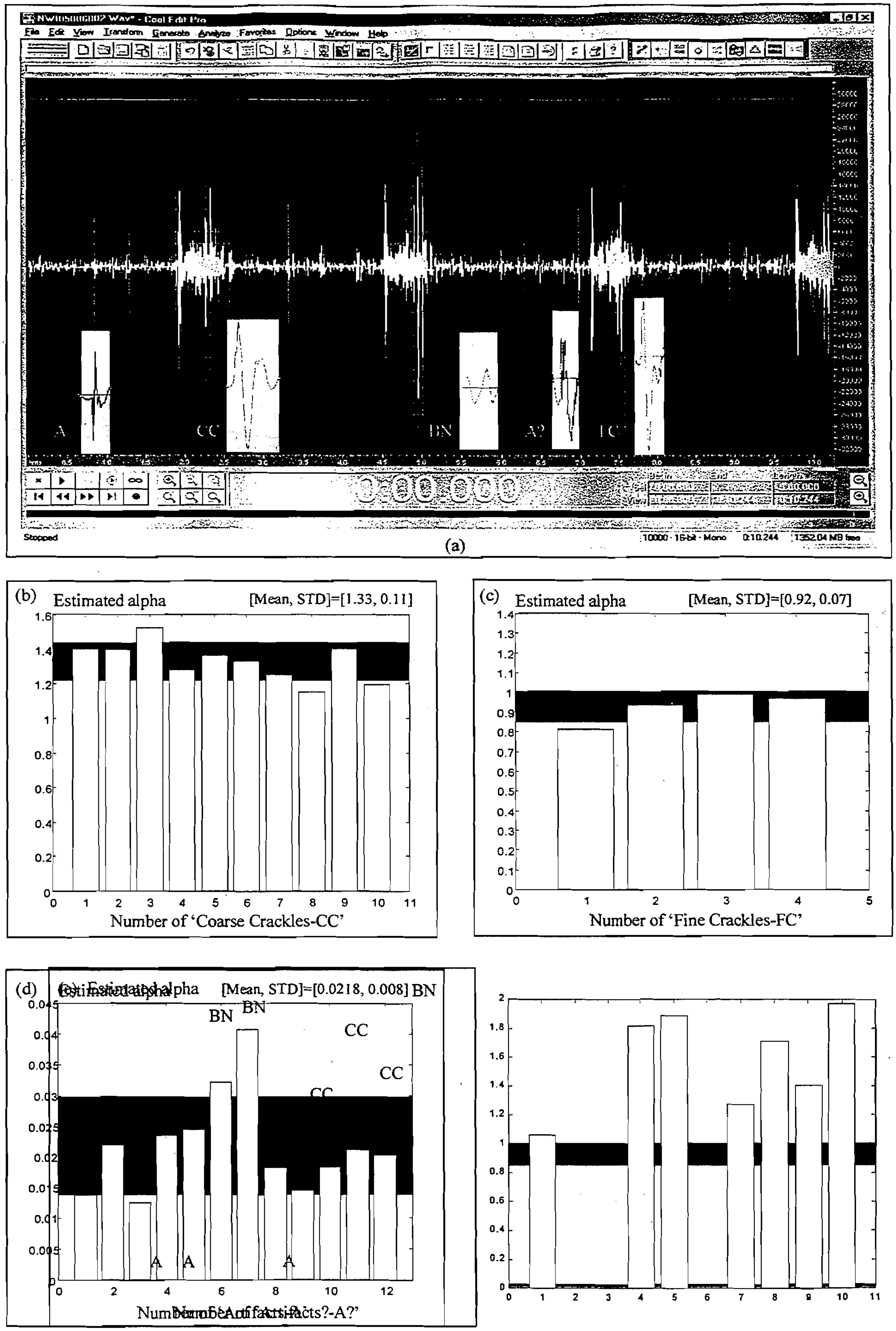


Fig. 1. (a) Analyzed signal. (b)-(d) Estimated a, for crackles and artifacts. (e) Classification results using S□S modeling (BN: background noise).

Auditory detection of simulated crackles in breath sound

Hiroshi Kiyokawa MD, Matthew Greenberg,
Kazuhiko Shirota MD, Hans Pasterkamp MD

Respiratory Acoustics Laboratory John Buhler Research Centre
715 McDermot Avenue Winnipeg Manitoba R3C 3J7, Canada

Background: Computerized analysis of lung sounds has relied on human auditory perception as the reference standard for identifying crackles. In this study, we tested the audibility of crackles by using artificial clicks in recorded lung sounds.
Objectives: a) To establish the audibility of simulated crackles introduced in lung sounds of different intensity, b) to study the effects of crackle characteristics on their audibility, and c) to investigate crackle detection within and between observers.
Methods: Fine, medium and coarse crackles with large and small amplitude were synthesized by computer software. Waveform parameters were based on published characteristics of lung sound crackles. The amplitude for small crackles was defined as just above the threshold of audibility for simulated crackles inserted in sound recorded during breath hold. Simulated crackles were then superimposed on lung sounds recorded at 0 L/s (breath hold), 1 and 2 L/s airflow. Five physicians listened during playback and detected crackles on two separate occasions.
Results: Failed detection of crackles was significantly more common in the following conditions: a) background lung sounds had higher intensity (2 L/s airflow) compared to lower intensity (1 L/s), b) crackle type was coarse or medium compared to fine, c) crackle amplitude was small compared to large. Both intra- and inter-observer agreements was high (kappa > 0.6).
Relevance: The validation of automated techniques for crackle detection in lung sound analysis should not rely on auscultation as the only reference. Auscultating detection of crackles will be easiest when patients take slow, large breathes that generate little breath sounds.

Inspiratory Crackle Rate During Normal, Deeper than Normal, and Deepest Breathing

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

Purpose: To investigate the influence of breathing effort on crackle rate in patients with crackles and in normal subjects.
Methods: A 16 channel STG Monitor (Stethographics Inc.) was used to automatically identify and count crackles while subjects were instructed to breath normally, deeper than normal, and as deep as possible.
Results: The inspiratory crackle rate in all the patients with crackles was comparable to or higher in the deeper than normal breathing than it was during either normal or deepest breathing maneuvers. In the normal subjects very few crackles were observed in all three maneuvers.

Lung Sound Analysis Before and After Hemodialysis

M. Murphy, K. Bergstrom, V-A Power, C. Aronstein, D. Cahan & R. Murphy

Patients undergoing hemodialysis commonly have a lower body weight at the end as compared to the beginning of the treatment. We hypothesized that the lung might contain more fluid prior as opposed to after the procedure. As the number of crackles are believed to be related to the degree of lung edema we studied crackle counts in patients undergoing the procedure.

Methods: The lung sounds of six dialysis patients were studied using a Multi-Channel Lung Sound Analyzer. The examinations were done within thirty minutes of the beginning of dialysis and again within thirty minutes of dialysis completion on two separate occasions. The studies were made with the patients in a reclining position at a thirty-degree angle. Weight change as measured immediately before and immediately after each dialysis session was recorded.

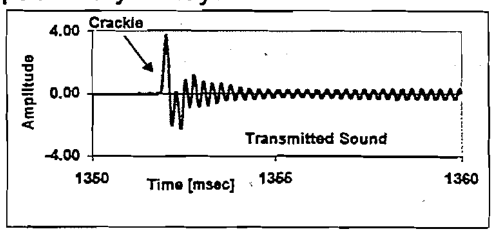
Results: Data from each of the two dialysis sessions were calculated separately. During the first session the average patient lost 2.42 kg on dialysis (range 0.1 to 3.2). Five of the six patients had an increase in crackle counts post dialysis. The mean change in the crackles per second was -.47. This result was due to a large decrease in crackle counts in one of the patients. This overall change in crackle counts was not statistically significant. In the second event the average patient lost 1.65 kg on dialysis (range .6 to 2.9). Four of the six patients had no change or an increase in crackle counts. The mean change in crackles per second was +.88. This increase was also not statistically significant. The over all crackle counts in these patients were low averaging 1.86 (range .1 - 10.4) crackles per second pre-dialysis and 2.09 (range .4 -5.8) crackles per second post-dialysis.

Conclusion: The reason our data show no statistically significant relationship between crackle counts and weight changes is unclear. Possible interpretations are: 1) the crackles are a relatively insensitive index of change in lung fluid 2) the fluid lost post dialysis reflects changes in the whole body and that the amount of fluid change in the lungs was relatively small or 3) the patients were immobile for three hours and this induced atelectasis producing crackles that masked a decrease due to fluid loss.

Acoustic monitoring of crackles and airway reopening in excised rat Lungs

N. Gavriely and Y. Shabtai-Musih. Rappaport Faculty of Medicine, Technion, Haifa, Israel 31096

The hypothesis that sudden reopening of closed airways generates respiratory crackles was evaluated in the present study by using an acoustic probe method. Excised rat lungs were deflated and then slowly re-inflated at constant flow rate while measuring airway-opening pressure. An acoustic sine source (4000 Hz) was applied at the airway opening. The sound was picked up over the pleura with a contact sensor. At a critical opening pressure crackles appeared in the sound signal. Some of the crackles were associated with a sudden small drop in airway opening pressure, indicating opening of an airway that was previously blocked. The crackles were also associated with a sudden increase in amplitude of sound at the lung surface (picture). These data show that sudden reopening of blocked airways generates respiratory crackles and that acoustic probing can monitor the patency status of pulmonary airways.



Supported by a grant from the US-Israel Binational Science Foundation.