INTERNATIONAL LUNG SOUNDS ASSOCIATION

Boston, MA October 10 and 11, 2008

2008

The 33rd

International Conference on Lung Sounds

Caritas St. Elizabeth's Medical Center October 10 and 11, 2008

The 33rd

INTERNATIONAL CONFERENCE

ON

LUNG SOUNDS

Presented by

The International Lung Sounds Association

October 10-11, 2008

Boston, Massachusetts

FINAL PROGRAM AND ABSTRACTS

ORGANIZATION

President:	Sadamu Ishikawa, M.D.
Chairman:	Raymond L.H. Murphy, Jr., M.D.
Scientific Committee:	Sadamu Ishikawa, M.D. Raymond L.H. Murphy, Jr., M.D. John Earis, M.D. Masato Takase, M.D. Jukka Rasanen Shoji Kudoh, M.D.

HISTORY OF THE INTERNATIONAL LUNG SOUNDS ASSOCIATION

In October 1976, the First International Conference on Lung Sounds was held in Boston, MA. The objectives of this conference were defined as follows:

"Studies of lung sounds have been reported with increasing frequency in recent years. This conference is convened to provide an opportunity for exchange of ideas and experience among those who have an active interest in the subject. Clinicians, physiologist, engineers and perceptual psychologists can each contribute towards a better understanding of what lung sounds mean. They will have a better chance of doing so after talking together."

"We hope that comparisons of methods of recording, analyzing and describing lung sounds will reduce ambiguity. We hope that discussions about work in progress may prevent unnecessary duplication of effort. We hope that investigators will save time and avoid some mistakes by learning what others have done."

Enthusiasm generated by this conference has continued, and annual meetings have been held since. These annual conferences have typically occurred over a period of two to three days being devoted to presentation of papers with discussion, and a half day being devoted to a workshop. Attendance at the conferences has averaged about 60. This is the 33rd annual meeting.

Co-founders – Robert G. Loudon, MD and Raymond L.H. Murphy, Jr., MD

LIST OF ILSA CONFERENCES

No.	Date	Place	Local Organizer(s)
1.	October, 1976	Boston, MA	Raymond L.H. Murphy, Jr.
2.	September, 1977	Cincinnati, OH	Robert Loudon
3.	September, 1978	New Orleans, LA	William Waring
4.	September, 1979	Chicago, IL	David Cugell
5.	September, 1980	London, England	Leslie Capel & Paul Forgacs
6.	October, 1981	Boston, MA	Raymond L.H. Murphy, Jr.
7.	October, 1982	Martinez, CA	Peter Krumpe
8.	September, 1983	Baltimore, MD	Wilmot Ball
9.	September, 1984	Cincinnati, OH	Robert Loudon
10.	September, 1985	Tokyo, Japan	Riichiro Mikami
11.	September, 1986	Lexington, KY	Steve S. Kraman
12.	September, 1987	Paris, France	Gerard Charbonneau
13.	September, 1988	Chicago, IL	David Cugell
14.	September, 1989	Winnipeg, Canada	Hans Pasterkamp
15.	October, 1990	New Orleans, LA	David Rice
16.	September, 1991	Veruno, Italy	Filiberto Dalmasso
17.	August, 1992	Helsinki, Finland	Anssi Sovijarvi
18.	August, 1993	Alberta, Canada	Raphael Beck
19.	September, 1994	Haifa, Israel	Noam Gavriely
20.	October, 1995	Long Beach, CA	Christopher Druzgalski
21.	September, 1996	Chester, England	John Earis
22.	October, 1997	Tokyo, Japan	Masahi Mori
23.	October, 1998	Boston, MA	Sadamu Ishikawa
24.	October, 1999	Marburg, Germany	Peter von Wichert
25.	September, 2000	Chicago, IL	David Cugell
26.	September, 2001	Berlin, Germany	Hans Pasterkamp
27.	September, 2002	Helsinki, Stockholm	Anssi Sovijarvi
28.	September, 2003	Cancun, Mexico	Sonia Charleston, Ramon Gonzales Camerena & Tomas Aljama Corrales
29.	September, 2004	Glasgow, Scotland	Ken Anderson & John Earis
30.	September, 2005	Boston/Cambridge, MA	Raymond L.H. Murphy, Jr.
31.	September, 2006	Halkidiki, Greece	Leontios Hadjileontiadis
32.	November, 2007	Tokyo, Japan	Shoji Kudoh
33.	October, 2008	Boston, MA	Sadamu Ishikawa & Raymond L.H. Murphy,Jr.

GENERAL INFORMATION

Conference venue	
Friday, October 10, 2008 -	Caritas St. Elizabeth's Medical Center Boston, MA
Saturday, October 11, 2008	Caritas St. Elizabeth's Medical Center Boston, MA
Local Organizing Committee:	Sadamu Ishikawa, M.D., President Raymond L.H. Murphy, Jr., M.D.
Address:	International Lung Sounds Association Raymond L.H. Murphy, Jr., M.D. 1153 Centre Street Boston, MA 02130
Telephone Number:	617 983-7000, x4436
Fax Number:	617 524-4419
E-Mail:	rlmurphy@partners.org
Registration:	Registration will be held at the Caritas St. Elizabeth's Medical Center on Friday morning at 8:30-9:00 a.m.
Registration fees	$125 for members/nonmembers $75 membership fee **NOTE**: Paid members will have a reduced Registration fee of $100 *Note that NO CREDIT CARDS will be accepted

ILSA members are required to pay the membership fee (if it hasn't already been paid) followed by the ILSA 2008 conference registration fee.

Certificate of attendance:	Participants, duly registered, will receive a certificate of attendance upon request.
Social Evening/Reception	Friday, October 10, 2008 at Dr. Murphy's house

FINAL

PROGRAM

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33rd INTERNATIONAL LUNG SOUNDS ASSOCIATION ANNUAL MEETING

Caritas St. Elizabeth's Medical Center
Boston, Massachusetts

October 10-11, 2008

Friday, October 10

8:30 Registration

9:00 Welcoming Address — Nicolaos E. Madias, M.D., Professor of Medicine, Tufts University School of Medicine, Chairman, Department of Medicine, Caritas Christi Health Care System

Scientific Session A

Chairpersons: John Earis, M.D. and Sadamu Ishikawa, M.D.

9:20–9:40 COUGH IN INTERSTITIAL PULMONARY DISEASE (IPF)
K Holt, A Key, C.J. Warburton, JA Smith, J.E. Earis

9:40-10:00 A HARD DAY IN THE LIFE OF A SOFT CELL
Jeffrey J. Fredberg

10:00-10:20 LUNG SOUND CHANGES FOLLOWING 'GLUE' (BRONCHOSCOPIC BIOLOGIC) LUNG VOLUME REDUCTION (LVR) IN ADVANCED COPD PATIENTS
S. Ishikawa, L. Kenney, M. Pritchett, K.F. MacDonnell and B. Celli

10:20-10:40 DISCONTINUOUS ADVENTITIOUS SOUNDS IMAGING
G Dorantes-Mendez, S. Charleston, R. Gonzalez-Camarena, G. Chi-Lem, T. Ajama-Corrales

10:40-11:00 RATIO OF LOW FREQUENCY ENERGY TO HIGH FREQUENCY ENERGY OF LUNG SOUNDS IN PATIENTS WITH CHRONIC OBSTRUCTIVE LUNG DISEASE
Andrey Vyshedskiy and Raymond Murphy

11:00-11:30 **Break**

11:30-11:50 MULTICHANNEL LUNG SOUND ANALYSIS BEFORE AND AFTER MECHANICALLY INDUCED LUNG INJURY
R. Murphy, A. Vyshedskiy, P. Quinn, D. Rayburn & A. Wong-Tse

11:50-12:10 MULTICHANNEL LUNG SOUND ANALYSIS
R. Murphy, A. Vyshedskiy, A Wong-Tse

12:10-12:30 **Photo**

12:30-1:30 **Lunch**

Scientific Session B

Chairpersons: Zahra Moussavi, Ph.D. and Masato Takase, M.D.

1:30-2:30 Special Lecture:

HUMAN LUNGS AND OFFSHORE GAS RIGS – THE ROLE OF VORTICES IN THE COMMON SOUND GENERATION MECHANISMS

Stewart A.T. Stoneman PhD, FIMechE, FIOA,
Managing Director "Stoneman Solutions"
Co-authors: R. Parker, PhD, DSc. K. Knaevelsrud (BEng) Statoil R. Herfjord (BEng) Statoil and Kerry Hourigan (BMath, PhD), Monash University, Melbourne, Australia

2:30-2:50 A ROBUST METHOD FOR CLASSIFICATION OF BREATH SOUNDS AND SNORE SOUNDS
Azadeh Yadollahi, Zahra Moussavi

2:50-3:10 ON ARITHMETIC MISCONCEPTIONS OF SPECTRAL ANALYSIS OF BIOLOGICAL SIGNALS, IN PARTICULAR RESPIRATORY SOUNDS
Azadeh Yadollahi, Zahra Moussavi

3:10-3:30 **Break**

3:30-3:50 A MODEL FOR NORMAL SWALLOWING SOUND GENERATION BASED ON WAVELET ANALYSIS
Azadeh Yadollahi, Zahra Moussavi

3:50-4:10 LONGITUDINAL SPEED OF SOUND IN BONES
Andrey Vyshedskiy, Rigo Ramirez, Leon Cogan, David Vyshedsky, Nathan Briginski and Raymond Murphy

4:10-4:30 STUDY OF SOUND TRANSMISSION MECHANISMS IN THE HUMAN RESPIRATORY SYSTEM BY MEANS OF COMPLEX ACOUSTIC SIGNALS
Vladmir I. Korenbaum, Anatoly V. Nuzhdenko, Alexander A. Tagiltsev, Anatoly Kostive

4:30-4:50 DATA DRIVEN APPROACH FOR ACOUSTIC DIAGNOSIS OF CARDIOPULMONARY DISEASE
Bryan Flietstra, Natasha Markuzon, Roy Welsch, Andrey Vyshedskiy, Raymond Murphy

4:50-5:10 LUNG SOUNDS AND THE STETHOSCOPE. A LUNG SOUNDS PRIMER
David Cugell, Noam Gavriely, Dan Zellner

5:10-5:30 ACOUSTIC EVALUATION OF COUGH SOUNDS DURING A HISTAMINE PROVOCATION TEST
M. Silva, A.Fremaul, V. Exadaktylos, J-M. Aerts, M. Decramer, D. Berkmans

5:30-5:50 Business Meeting

5:50 Bus transportation to the Murphy Residence

Social Evening/Reception

9:00 Bus leaves for the Best Western Hotel

Saturday, October 11

<u>Scientific Session C</u>

Chairpersons: Jukka Rasanen, M.D. and Noam Gavriely, M.D.

9:00-9:20 EFFECT OF PNEUMOTACHS ON TRACHEAL BREATH SOUNDS
Zahra Moussavi and Saif Huq

9:20-9:40 ACOUSTICAL ASSESSING OF OXYGEN DIVERS' LUNG FUNCTION DYNAMICS AFTER SHALLOW WATER IMMERSION
Irina A. Pochekutova, Vladimir Korenbaum

9:40-10:00 SPECTRAL ANALYSIS OF VESICULAR SOUNDS IN CHILDREN RECORDED WITH AN ELECTRONIC STETHOSCOPE (LITTMANN TM MODEL 4100)
Masato Takase, Takehide Imai, Junji Shirai, Kiwako Shimizu

10:00-10:00 AUSCULTATORY ABNORMALITIES IN SHIPYARD PIPECOVERERS – A LONGITUDINAL STUDY
J. Mansouri, M Testa

10:20-10:40 **Break**

10:40-11:00 EFFECT OF RESPIRATORY GAS PRESSURE AND DENSITY ON THE DURATION OF FORCED EXPIRATORY TRACHEAL NOISES
A.D. D'yachenko, V. Korenbaum, A. Osipova, Yu Popova, Yu Shulagin

11:00-11:20 EFFECTS OF PROCATEROL INHALATION ON LUNG SOUNDS AND PULMONARY FUNCTION IN WHEEZING ASTHMATIC PATIENTS
Yukio Nagasaka, Syohei Yasuda, Yasuhiro Ieda

11:20-11:40 INTER-CHANNEL INHOMOGENEITY OF THE TIMING OF LUNG SOUNDS IN PATIENTS WITH CHRONIC OBSTRUCTIVE LUNG DISEASE
Andrey Vyshedskiy and Raymond Murphy

11:40-12:00 VALIDATION OF AN AUTOMATIC WHEEZE DETECTOR
Eldad Vizel, Yulia Genis, Alon Avrahami, Isaac Kronin, Simon Godfrey, Noam Gavriely

12:00-1:00 **Lunch**

1;00-2:00 **Special Lecture: A Clinician's View of Lung Sound Investigations**

John J. Reilly, Jr., M.D., Vice Chair for Clinical Affairs of the Department of Medicine of the University of Pittsburg Medical School

Scientific Session D

Chairpersons: Shoji Kudoh, M.D. Jeffrey Fredberg, Ph.D.

2:00-2:20 RELATION OF CRACKLE SOUND TO AIRWAY GENERATION AND DIAMETER
Arnab Majumdar, Zoltán Hantos, József Tolnai, Harikrishnan Parameswaran, Robert Tepper, and Béla Suki

2:20-2:40 ARE CRACKLES IN IPF RELATED TO DISEASE ACTIVITY AS MEASURED BY PULMONARY FUNCTION?
A Key, D. Davies, J.E. Earis

2:40-3:00 PROBING THE EXISTENCE OF MEDIUM PULMONARY CRACKLES VS MODEL-BASED CLUSTERING
Mete Yeginer, Yasemin P. Kahya

3:00-3:20 **Break**

3:20-3:40 THE SPECIFICITY OF THE CRACKLES OF INTERSTITIAL PULMONARY FIBROSIS
Bryan Flietstra, Natasha Markuzon, Roy Welsch, Andrey Vyshedskiy and Raymond Murphy

3:40-4:00 MECHANISM OF INSPIRATORY AND EXPIRATORY CRACKLES
Andrey Vyshedskiy, Ruqayyah M. Alhashem, Rozanne Paciej, Margo Ebril, Inna Rudman, Jeffrery J. Fredberg and Raymond Murphy

4:00-5:00 **Panel Discussion:**

Mechanism of Production of Crackles – Current Thinking
Jeffrey Fredberg (Chairman), Bela Suki, Steven Holford and Andrey Vyshedskiy

5:00 **Closing Comments**
Raymond Murphy, M.D., D.Sc.

SCIENTIFIC SESSION A

CHAIRPERSONS:

John Earis M.D. and Sadamu Ishikawa, M.D.

Cough in Interstitial Pulmonary Fibrosis (IPF)

K. Holt BSc'·\ A. Key BS$_c$l.3, C. J. Warburton MOl, J. A. Smith Ph0[2],.T. E. Earis M0[13]

1University of Salford, Manchester, UK.

2 North West Lung Centre, Wythenshawe Hospital, Manchester, UK. 3Respiratory OepaJiment, University Hospital Aintree, Liverpool, UK.

Introduction:

Cough is a well-recognised and troublesome feature of IPF, whose cause is unknown. The main aims of this pilot study are to determine the absolute numbers of cough over 24 hours, to compare cough rates with physiological markers of disease severity and to compare subjective outcome of cough assessments with the objective cough counts.

Methods:

Eleven patients with ATS criteria of IPF were recruited with mean age 76 (50-80) yrs, FEVI % 77%, TLC 74% (±19.4), DLco 43% (±17). Cough was recorded on two occasions, at least one week apart, using a customised digital sound recorder and analysed by two fully trained cough counters using Cool Edit 2000. Patients completed a Leicester Cough Questionnaire (LCQ) and a 100mm Visual Analogue Scale (VAS). Statistical analysis used the Spearman Rank Co-efficient.

Results:

The reproducibility of the two recordings for each patient was good with mean difference of 1.2 coughs per hour daytime and 0.1 night-time.

Overall hourly cough rates varied from 54 to 4 coughs/hour with daily rates of 9.0. There were marked diurnal variations with a mean of 14.02 during the day and 1.31 at night (p<O.OO 1). A relationship was found between all domains of the LCQ and mean daytime cough rates (e.g. total LCQ 1=-0.94 p=0.005). The mean daytime counts also correlated with the V AS (r=0.745 p 0.008). No correlations were found between physiological measures of IPF severity and cough rates

Discussion:

This group of IPF patients, who were not chosen because they complained of cough, had a significant problem with daytime cough. Many of the rates are in the range seen in a chronic coughing population. The cough rates in these patients is closely related to quality of life measures. We found no correlation between measures of disease activity (e.g. spirometry, lung volumes or diffusing capacity) suggesting that the extent of the disease is not the prime determinant of the cough. As cough occurs during daytime activity may be a factor and this is in keeping with the anecdotal evidence that deep breathing precipitates cough in IPF patients. Strategies need to be developed to try and ameliorate this distressing symptom in IPF patients.

A Hard Day in the Life of a Soft Cell

Jeffrey, J. Fredberg, Ph.D.

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With every beat of the heart, inflation of the lung or peristalsis of the gut, cell types of diverse function are subjected to substantial stretch. Stretch is a potent stimulus for growth, differentiation, migration, remodeling and gene expression. Here, we report that in response to transient stretch, the cytoskeleton fluidizes in such a way as to define a universal response class. This finding implicates mechanisms mediated not only by specific signaling intermediates, as is usually assumed, but also by non-specific actions of a slowly evolving network of physical forces. These results support the idea that the cell interior is at once a crowded chemical space and a fragile material in which the effects of biochemistry, molecular crowding and physical forces are complex and inseparable, yet conspire nonetheless to yield remarkably simple phenomenological laws. These laws seem to be both universal and primitive, and thus comprise a striking intersection between the worlds of cell biology and soft matter physics.

Lung Sound Changes following 'Glue' (Bronchoscopic Biologic) Lung Volume Reduction (LVR) in Advanced COPD Patients

S.Ishikawa*, L.Kenney, M. Pritchett, K.F. MacDonnell, and B.Celli

Pulmonary & Critical Care, Caritas St Elizabeth's Medical Center,Dept. of Medicine,

Tufts University School of Medicine, Boston MA,U.S.A.

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We have studied lung sounds changes following 'Glue'(Bronchoscopic-Biological) Lung Volume Reduction (LVR) in Patients with Advanced COPD.

Our report is based on results of three patients. (all patients have had FEV1 below 30% of predicted value prior to the procedure), All 3 patients have had LVR done on the right lung, 1 of the patients had LVR done on the Left Lung 4 months after LVR on his right lung.

With Chest CT as a guide, selected several 5^{1h} generation Bronchi were cannulated via fiberoptic bronchoscope and 'Glue'(biologic scleroseing soluvent) were introduced to block distal airways, which led to markedly emphysematous lesions.

Lung sounds signals were recorded over the neck near the trachea and 14 sites over the chest surface with contact microphone with the patient in a sitting position using Murphy's STG 16 system. Sounds signals were digitized and time expanded waveforms displayed.

We found that lung sound intensity and distribution of post LVR lung was markedly improved and a better ventilation of that lung was achieved compared to prior LVR, although FEV1 and RV/TLC failed to show a significant improvement.

Discontinuous Adventitious Sounds Imaging

G. Dorantes-Mendez[1], S. Charleston[1], R. González-Camarena[2], G. Chi-Lem[3], T. Aljama-Corrales[1]. [1] Department of Electrical Engineering, Universidad Autónoma Metropolitana, Mexico City , Mexico. [2] Department of Health Science, Universidad Autónoma Metropolitana, Mexico City , Mexico. [3] National Institute of Respiratory Diseases, Mexico City, Mexico.

Abstract

In this work, multivariate signal processing is explored to extract and to count crackles sounds from acquired lung sounds (LS), and a *new concept is proposed, the discontinuous adventitious sounds imaging*. Crackles sounds are adventitious respiratory sounds relevant for the diagnosis of pulmonary pathologies and several attempts have been proposed to detect and to count them. For example, Murphy *et al.* proposed the time expanded waveform analysis (TEWA) to detect crackles, but TEWA requires certain criteria that are difficult to achieve in most of the acquired lung sounds (LS). Extracting and counting fine and coarse crackles represent a difficult task since it depends, among other factors, on the amplitude relation between crackles and the background LS, and of the temporal overlapping of two or more crackles. A previous important stage to evaluate the performance of a proposed methodology is to use simulated signals where the magnitude, number and position of crackles, temporally and spatially, need to be controlled.

Image formation is of great interest in different fields, anatomic or functional modalities, and for the study of LS the application is recent. In this work a new concept is introduced, the ***crackle sounds imaging*** since the image would indicate the location, distribution or the approximate number of crackles. In this work image formation is based on the results of two proposed methodologies that use an autoregressive (AR) model. In the first case, the AR coefficients feed an artificial neural network (ANN) to classify temporal acoustic information as healthy or sick and; in the second case, a time-variant AR (TVAR) model permits to detect changes in the TVAR coefficients to be associated with the number of crackles.

It is shown that fine and coarse crackles can be detected by both, AR-ANN and TVAR-RLS methods. The relation in magnitude of the crackle sounds to LS impacts the goodness of the approximation to the spatial pattern. The TVAR-RLS results show that the proposed index allows to obtain the crackle distribution image in a good fashion, with the advantage that no training phase is needed and the mapping is generated directly from the estimated crackle number.

Ratio Of low Frequency Energy To High Frequency Energy Of Lung Sounds In Patients With Chronic Obstructive lung Disease

R. Murphy, A. Vyshedskiy, Brigham and Women's Faulkner Hospitals, Boston, MA

Objective:

To determine if time based parameters of lung sounds differed in patients with chronic obstructive lung disease (COPD) as compared to normal subjects and patients with other disorders.

Methods:

A 16-channel lung sound analyzer (Stethographics Model STG1602) was used to collect 20s samples of sound from patients with COPD (n=103), normals (n=379), pneumonia (PN, n=118), congestive heart failure (CHF, n=92) , bronchial asthma (n=62), and interstitial pulmonary fibrosis (IPF, n=39) during deeper than normal breathing. The ratio of sound energy from 20Hz to 80Hz to that from 80Hz to 800Hz was calculated (R4) in each patient.

Results:

The mean R4 in the left and right lungs are presented in Table 1. Notice that R4 was significantly greater in COPD (p<O.O5).

	Normals	IPF	CHF	Asthma	PN	COPD
Mean R4 left	0.3+0.4	0.4+0.6	0.5+0.5	0.5+0.7	0.6+0.7	0.9+0.8
Mean R4 right	0.4±0.4	0.4±0.5	0.5±0.5	0.6+0.5	0.6±0.7	0.9±0.8

Conclusion:

The mechanism of the increased R4 in COPD is unknown. A possible explanation is that it may be due to the relatively increased size of the air spaces in the lung of COPD patients as we have noted a similar increase in low frequency peaks in patients with pneumothorax and pneumonectomy as well in a patient with a giant bulla.

Clinical Implications:

A long-term goal of studies with multichannel lung sound analyzers is to provide useful diagnostic information at the bedside. The increase in low frequency peaks together with other features of COPD, such as decreased amplitude of sound and relatively prolonged inspiratory phases can help provide evidence that COPD is present. This can be done using a simple test using that requires little patient cooperation.

Multichannel Lung Sound Analysis Before and After Mechanically Induce Lung Injury

R. Murphy, A. Vyshedskiy, P. Quinn*, D Rayburn*A. Wong-Tse Faulkner Hospital, Boston, MA and *Walter Reed Army Institute of Research

ABSTRACT

Introduction

For the purpose of testing different types of protective gear to shield personnel from injury due to explosions on the battlefield, sheep were subjected to mechanically induced injury. We studied lung sounds in these sheep before and after these injuries. Our hypothesis was that abnormal sounds, not present before the injury, would likely be detected in damaged lungs. Detection of these acoustic abnormalities could have the potential of providing a rapid, noninvasive means of detecting lung injury in sheep undergoing such studies. It also could have implications for the diagnosis and monitoring military personnel who experience chest trauma.

Materials and Methods

Sheep were examined with a 16-channel lung sound analyzer (Stethographics Model 1602) (STG System) before and after mechanically induced chest trauma. The system uses miniature electret microphones mounted in commercially available stethoscope chest pieces to amplify, filter, and multiplex lung sounds to an analog-to-digital converter and then stores the data on a PC. The STG System software was custom developed to collect data and automate data analysis including calculation of acoustic amplitude as well as automated identification of wheezes, rhonchi and fine and coarse crackles.

Results

The sounds detected in these 9 sheep after mechanically induced damage, were louder and contained more crackles, wheezes, and rhonchi than they did prior to the injury. There were also abnormal patterns seen in the waveforms not previously present. A squeak-like sound (we call a CUSS) was detected that to our knowledge has not been previously described. A score based on acoustic parameters was statistically significantly increased after as compared to before the injury (p<OOOOl).

Conclusion

Computerized lung sound analysis appears to have promise in detection of contused lung.

Multichannel Lung Sound Analysis

Murphy, R, Vyshedskiy, Wong-Tse, A

Goal

Our goal in this investigation was to assess the clinical utility of multichannel lung sound analysis (MCLSA).

Methods

Using a multichannel lung sound analyzer as previously described, we studied 837 inpatients and out patients of a community teaching hospital diagnosed by their clinicians as follows: congestive heart failure (96), bronchial asthma (65), pneumonia (123), chronic obstructive pulmonary disease (109) Interstitial Pulmonary Fibrosis (39) and no recognized cardiopulmonary disease (405). The rate of abnormal sounds in each of these diagnostic categories was assessed. Working with MIT and the Draper Lab algorithms were developed for the detection of these disorders. We then assessed the potential clinical value of this approach to diagnosis.

Results

As would be expected wheeze rates were high in bronchial asthma. Wheeze rates were also high in pneumonia and wheezing was not uncommon in congestive heart failure. The highest crackle rate was seen in interstitial pulmonary fibrosis. Algorithms were helpful in diagnosing pneumonia, as compared to age-matched controls with no recognized lung disease and in separating interstitial pulmonary fibrosis from congestive heart failure and pneumonia and also in separating asthma from COPD. MCLSA was also useful in separating vocal cord dysfunction from asthma.

Discussion

Multichannel lung sound analysis provides important clinical information in an objective way that circumvents the problem of observer variability inherent in auscultation with an acoustic stethoscope. It is efficient in that it provides data from multiple sites at one time. Collecting data at multiple sites simultaneously also allows abnormalities such as pneumonia to be localized. The data obtained can be archived and readily retrieved and also can be telemetered for a second opinion by experts. The technique is noninvasive and does not involve the use of radiation. This is of particular value for pregnant women and children.

Conclusion

Our assessment after multiple observations and studies using a MCLSA is that it improves medical care by providing clinicians with information that is useful in making diagnoses and in following the course of illnesses.

SCIENTIFIC SESSION B

CHAIRPERSONS:

Zahra Moussavi, Ph.D. and Masato Takase, M.D.

Human Lungs and Offshore Gas Rigs -

The role of vortices in the common sound generation mechanisms

Stewart A.T. Stoneman PhD, FIMechE, FIOA, Managing Director "Stoneman Solutions"
Co-authors: R. Parker, PhD, DSc. K. Knaevelsrud (BEng) Statoil R. Herfjord (BEng) Statoil and Kerry Hourigan (BMath, PhD), Monash University, Melbourne, Australia

In 2000 the largest semi-submersible gas rig in the world was commissioned in the Norwegian Sea. The rig was known as Asgard B and it was operated by the National oil and gas company of Norway - Statoil asa. When the gas export flow rate exceeded the relatively low level of 20% of design export flow rate. a major acoustic phenomenon was triggered, which induced mechanical vibration of certain piping components causing them to fail in fatigue.

A preliminary investigation of the cause of the phenomenon by Stoneman of Fluid & Acoustic Ltd revealed that the acoustic energy that was driving the resonances was created by vortex shedding on the inner corrugated surface of two 950 metre long flexible pipes that carried the gas to the export piping system on the sea bed.

A diagnosis of the root cause of the gas rig acoustic problem was able to be made because of the results of earlier research that had been conducted into, *infer alia,* the origins of lung sounds conducted by Stoneman and Parker. The application of fundamental analytical techniques (based on the physical geometry of the system and the properties of the gas), which had been developed from, and applied to, other flow induced problematic situations in industry, allowed the acoustic resonant characteristics of the gas rig to be predicted and modeled with very high precision.

The analytical model developed allowed various solutions to the problem to be proposed that would either eliminate or at least control the effects of the acoustic resonances. These were presented to the client Statoil as the rig operator.

At the end of this project Fluid & Acoustic Ltd were then re-engaged by Statoil on a second project to assist in the design of parts of a new gas rig (Kristin) to try and avoid it having any deleterious acoustic phenomena. The understanding derived from the work undertaken in the Asgard B project and in earlier projects allowed the design of an active acoustic absorption system, which was installed on the Kristin rig to ensure that it did not suffer from any damaging acoustic phenomena. Kristin has subsequently been successfully commissioned and has run for some time without any significant acoustic phenomena.

This paper will discuss the similarities (and differences) between the corrugated pipes of the human bronchial system and the corrugated pipes of an offshore gas rig. It will point out the lessons learned in these projects about the role of vortices in the sound generation mechanisms in corrugated pipe systems, which could be applied to lung sounds research.

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A Robust Method for Classification of Breath

and Snore Sounds

Azadeh Yadollahi, Student member, IEEE and Zahra Moussavi, Senior member, IEEE

Abstract

In this study a new method is proposed to segment and classify the respiratory sounds recorded over the neck of patients undergoing full-night PSG. Energy of the recorded sounds is calculated in the logarithmic scale and the median of the energy values is used to find the sound and silent segments automatically. Then, for every sound segment a two-dimensional feature set is calculated which is composed of the number of zero crossings and logarithm of the signal's energy. F'ischer Linear Discriminant is implemented for feature extraction and the Bayesian threshold is used to classify the sound segments into either snore or breath classes.

Three sets of experiments were implemented to investigate the method's performance for different training and test data sets considering different neck positions and sleep stages. Five male subjects (2 simple snorers and 3 patients with obstructive sleep apnea) were participated in this study. In the first experiment every subject with at least two sleep positions (3 subjects). was considered individually, and their data in supine and right positions were used to form training and test data sets. In Experiment II training data set was composed of data of the three subjects at one position (supine/right). Then, their data at the other position (right/supine) was used as the test data set. In the last experiment performance of the classifier was investigated under the conditions that the train and test data sets were subject and position independent. Leave-one-out was used to form test and train data sets and the results were averaged among all subjects. In addition to examining the method's performance with respect to subjects' physical parameters and neck positions, the effects of sleep stage was also considered.

In general, it was found that in all experiments the accuracy of the proposed method is more than 90% in detecting snore and breath sounds. This is similar or better than the results of previous studies in which sounds were recorded with a microphone in the vicinity of patient's head. Since the data in this study was recorded over the neck, it has more information about the breathing sounds in particular and snore sounds in general. The results of this study can also be used to detect apnea and hypopnea events which are currently under investigation. Furthermore, the slight dependency of the results on the neck position and sleep stage, simplifies data analysis and increases the robustness of the classification performance during the entire night recording.

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On Arithmetic Misconceptions of Spectral

Analysis of Biological Signals, in Particular

Respiratory Sounds

Azadeh Yadollahi, *Student member*, IEEE and Zahra Moussavi, *Senior member*, IEEE

Spectral analysis is one of the most common methods in sound signal analysis, which approximates the sound power at different frequencies. It is common to present the sound power in logarithmic scale in terms of dB. In this paper, the nonlinear effects of logarithm function are examined and the mathematical issues regarding the spectral analysis of sound signals are discussed. As a practical example, respiratory sound analysis is considered in detail.

The initial preprocessing step in most acoustical analysis of respiratory sounds is to use power subtraction to remove the ambient noise. During this step, two misconceptions may occur, the first happens if the noise power is subtracted in logarithmic scale instead of Watt scale, while the second error is due to mathematical implementation issues of the available softwares such as Matlab. On the other hand, one of the most frequently used features in the assessment of respiratory sounds' characteristics is the average power. To address the effects of averaging the power values in different scales, the flow-sound relationship at different flow rates is investigated in detail.

Investigating the previous studies, it was found that most of the errors happen during noise power reduction. If the noise power is subtracted from the sound power in the logarithmic scale, instead of noise reduction, sound detection possibility would be estimated. Furthermore, in very low frequency components, noise dominates sound signal and power of (signal – noise) would be negative. Hence, when displaying the results in logarithmic scale, MATLAB calculates the complex logarithm and shows power of (noise – signal) instead of power of (signal – noise); hence, does not represent the real characteristics of respiratory sounds.

In the last experiment the effects of averaging power values in the wrong scale was investigated by considering the flow-sound relationship at different flow rates. Power values were averaged in Watt and logarithmic scales and the regression coefficients between tracheal sounds average power and flow at different flow rates were estimated and compared. Considering the results, it was found that when power values are averaged in Watt values, the regression coefficients fit better to a line at different flow rates. These results arise from the underlying acoustical relationship between air flow and the generated sounds power values which will be manipulated if power values are calculated in the logarithmic scale.

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A Model for Normal Swallowing Sound

Generation Based on Wavelet Analysis

Azadeh Vadikkagum *Student member*, IEEE and Zahra Moussavi, *Senior member*, IEEE

In this paper a new model for swallowing sounds generation is proposed. The model is composed of a cascade of two systems. The first system simulates the muscles and bones movements in the pharynx and the interactions between the bolus and the pharynx structure. This part is assumed to have an output in the form of impulse trains, in which the impulse occurrences are related to the physiological and mechanical events happening in the pharyngeal phase. The second part of the model is a system representing the esophageal wall structure, tissue and skin beneath the microphone. Since the two systems of the model are convolved with each other cepstrum analysis was used to estimate the characteristics of the second part of the model from the actual recorded swallowing sounds. In order to estimate the impulse train input to the second part or the model (which is the output of the first part of the model), wavelet analysis using Symlet wavelet of order 8 was used.

To have a general understanding whether such a model can be a representative of swallowing sound generation. its performance in describing differences in swallowing sounds characteristics for two bolus textures with different viscosities was evaluated. Normal swallowing sounds were recorded from five adult males (26.4 ± 1.95 years old). For each swallow, the wavelet coefficients were thresholded automatically and the number or impulses were calculated and compared for the two bolus textures. The results showed the numbers of impulses were consistently higher during swallowing the juice texture than that of yogurt. This is in agreement with the experimental observations that thin liquid (i.e. juice) swallows are usually louder than thick liquid textures (i.e. yogurt). Also, it was shown that during initial discrete sounds (IDS). the numbers of clicks of yogurt swallows were more, and their amplitudes were higher than those of juice swallows. These results are congruent with the results of previous studies for EMG analysis of submental and laryngeal strap muscles of normal subjects during swallowing different bolus

Although the results show the model may predict the changes in the swallowing sounds characteristics and the outcomes of the model comply with the common knowledge of the swallowing mechanism, further investigations are required. Future studies on this topic need the simultaneous recording and analysis of swallowing sounds and high speed videofluorosopic images, which would be helpful to relate the impulse train sequence and their underlying physiological events more precisely.

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Longitudinal Speed of Sound In Bones

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Abstract

Objective: Sound injected into a chest travels through the lung with some energy transmitted through the bones. In an attempt to separate vibrations transmitted through the lungs from those transmitted by bone, we wanted to use the difference in speed of sound through the lung and the bone. Speed of sound in the healthy lung has been previously reported. It is approximately 30m/s - ten times smaller that the speed of sound in the air (340m/s) and 50 times smaller than the speed of sound in water (1500m/s). A review of the literature revealed that the speed of sound in bone is between 1500 to 5000m/s. However, all reports used ultrasound to measure the speed of sound. It was unclear to us if sounds in the audible frequency range are transmitted as fast as ultrasound. Accordingly, we investigated the speed of audible sound in bones.

Methods: Multiple bones were studied both in vitro and in vivo: human femur, human ribs, and bovine femur. Audible sounds were injected into the bones from a number of sound sources: a speaker, a tuning fork and by tapping on the bone. Sounds were detected by acoustic sensors positioned along the bone at equal distances. When recording from human bones in vivo, sensors were placed on top of soft tissue. When recording from bovine and sheep bones, soft tissue was cleaned and microphones were placed directly on the bone. In this case a the soft gel pad was used to establish a good contact between the sensor and the bone.

Results: The speed of sound in bones was between 90 and 140m/s. Therefore, this speed was similar to that measured in normal lungs.

Conclusion: The observed speed of sound in bones (90 to 140m/s) is significantly lower than that reported in literature (1500 to 5000m/s). One possible explanation for the discrepancy is frequency dependence of the speed of sound in bones. All reports used ultrasound to measure the speed of sound. Our report is the first one to our knowledge that uses low frequency sound (10 to 500Hz) to measure speed of sound in bones.

STUDY OF SOUND TRANSMISSION MECHANISMS IN THE HUMAN RESPIRATORY SYSTEM BY MEANS OF COMPLEX ACOUSTIC SIGNALS

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Background:

Complexity of respiratory path has already caused assumptions on existence of several ways of sound transmission to chest wall.

Purpose:

Pilot estimation of opportunities of lung sounding by complex acoustic signals to reveal **various transmission mechanisms.**

Methods:

Two kinds of signals were used: frequency sweep (FS. 80 - 1000 Hz. 20 s): phase manipulated (PhM. 511-symbol m-coded sequences. 200. 300. 750 Hz. 2.5 s). Potential resolution is about I ms. Sounding signals were entered from loudspeaker into the mouth in 3 volunteers. Responses were recorded by three acoustic sensors (accelerometers): above trachea. middle and basal areas of right lung. Convolutions of synchronous fragments of electric copy of sounding signal with the responses were calculated. Time delays between emission and receiving of the responses maxima were evaluated.

Results:

Delays are very similar for both signals in all attempts of the same subject but differ between subjects. In middle and basal areas two arrivals have been found. delays (ms) between which are shown in the table.

Signal	FS			PhM			
Attempts	#1	#2	#3	**#1**	#2	#3	#4
Subject #1	9.2	8.1	7.9	**9.3**	9.2	9	9.1
Subject #2	13.1	n/s	12.4	13.2	12.4	12.5	-
Subject #3	7.5	7.2		**8.3**	7.8	7.9	-

Delays of the first arrival in middle and basal areas re trachea are similar to delays obtained by Bergstresser et al. (2002), where narrowband frequency-manipulated sounding signal was entered into the mouth. While delays of the second arrival in middle and basal areas are similar to delays obtained by Paciej et al. (2003). where sounding signal was entered into supraclavicular area.

Conclusions:

Since responses of our sounding signals. entered into the mouth. contain t\\ o arrivals similar to above described, it is reasonable to state an opportunity of simultaneous existence of 2 mechanisms of transmission of sound oscillations in lung. The first one may be defined as air-structural, while the second one may be referred to excitation of sound waves by pulsating walls of trachea (standing wave) in upper part of thorax. .

Acknowledgement:

The study is supported by FEB RAS grant 06-1-P12-043.

Data Driven Approach for Acoustic Diagnosis of Cardiopulmonary Disease

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Variations in training and individual clinician's listening skills make diagnosing a patient via stethoscope-based auscultation a difficult task. Clinicians have now turned to more advanced devices such as x-rays and computed tomography (CT) scans to make diagnoses. However, the development of electronic stethoscopes allows for auscultation to be performed with an array of microphones, which send the lung sounds to a computer for processing. The computer automatically identifies adventitious sounds using time expanded waveform analysis and allows for a more precise auscultation. In our study we have used a multichannel lung sound analyzer developed by Stethographics (Stethographics- STGl6).

We have investigated the ability to automatically diagnose patients with cardiopulmonary disease based on features extracted from abnormal sounds detected by sound analyzer. We performed pair-wise comparisons and multi-way classification in application to interstitial pulmonary fibrosis (IPF), congestive heart failure (CHF), pneumonia (PN), asthma, and COPD. We also developed models that separate patients with the above mentioned conditions from "Normal" patients, those without diagnosed cardiopulmonary disease. We used a data mining approach and employed several techniques such as *k* nearest neighbors, neural networks, and support vector machines to make classifications in pair-wise comparisons and multi-class scenarios. We have investigated the importance of automatically extracted features horn different abnormal sounds in making a correct diagnosis, and the contribution of clinical information to improving the performance.

We have achieved a good recognition performance using a combination of features from several abnormal sounds such as crackles, wheezes, and rhonchi. Reporting on the test, we separated patients with IPF with over 80% accuracy, Asthma vs. CO PO with over 70% accuracy, "Normals" with over 85% accuracy. However it proved difficult to separate PN vs. CHF using sound data only, the addition of clinical information has significantly improved the performance and made it close to 70% . In a multi-way classification, good performance was achieved for "Normals" and IPF patients with more than 80% recognition accuracy on the test set.

Our results show that performing computerized lung auscultation offers a low-cost procedure that can improve noninvasive diagnosis.

LUNG SOUNDS AND THE STETHOSCOPE

A Lung Sounds Primer

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It is often overlooked that the interpretation of lung sounds in clinical settings is substantially dependent on visual clues the patient provides by his breathing pattern. Determining whether a breath sound is an inspiration or expiration can be quite difficult for the rank novice – especially so in the absence of an actual patient. Recorded instructional materials generally rely on some combination of a blinking or moving cursor, verbal comment or text to inform the student about the sounds to which he is listening. To overcome the missing visual clues, an animated thorax was created. The motion of the thorax, the acoustic waveform, and a moving cursor dictating the segment of breath sound that is currently audible are all displayed concurrently. This combined audio and visual presentation of breath sounds is a useful instruction tool for auscultation novices.

ACOUSTIC EVALUATION OF COUGH SOUNDS DURING A HISTAMINE PROVOCATION TEST

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To identify in what degree airway resistance influences cough sounds, 10 patients with respiratory symptoms were asked to cough after every inhalation of a histamine solution during an asthma-histamine provocation test. During the histamine provocation test, lung resistance was measured with acoustic impedance, 5 Hz together with the basic lung function variables FEV1 and FVC. The histamine concentration was doubled (starting from 0.03 mg/ml) until the FEV1 dropped by 20% compared to the initial FEV1 value. Before every histamine inhalation, a nebulized solution of NaCl (0.09%) was inhaled. Coughs were recorded and processed in Matlab and assessed following acoustic features: The energy content at frequency range (100-600 Hz) and (600-1200 Hz), length of the first and second cough sound (s), and relative energy content ratio between the first and second cough sound vs. the total cough sound and the RMS value of the second cough sound. A significant increase in duration of the second cough sound was observed ($p < 0.01$) comparing the reference coughs with the coughs at FEV1-20%. RMS value of the second cough sound decreased comparing the same classes of coughs. In both the first and second cough sounds, the power of both frequency ranges increased, although not significantly. The relative energy content ratio of the first cough sound over the total cough sound decreased while the ratio of the second cough sound increased towards the higher airway resistance. In conclusion, duration and RMS value of voluntary cough sounds are mostly affected by varying airway resistance. Although there are indications for certain dependencies between lung resistance and sound features, the biggest problem in cough sound analysis is the intra-subject variability.

SCIENTIFIC SESSION C

CHAIRPERSONS:

Jukka Rasanen, M.D. and Noam Gavriely, M.D.

Effect of Pneumotachs on Tracheal Breath Sounds

Zahra Moussavi and Saif Huq

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Acoustic respiratory flow estimation has been advanced significantly in recent years that it may be considered as a promising alternative for traditional flow measurements. However, since all flow estimations are being compared with the actual flow measured by a flow meter (i.e. pneuomotach), one may question whether the pneumotach change the breathing sounds. In another words, the question is whether the acoustic flow estimation would be different if the person breathe with or without a pneumotach at the same flow rate. Therefore, we investigated this issue by using tracheal respiratory sounds from 8 healthy subjects with no pulmonary diseases, who breathed at their normal (medium: 0.5-0.8L/s) flow rate in a seated position. The subjects were instructed to breathe at least 3-5 full breaths with a mouth-piece pneumatoch (Fleisch No3) and another 3-5 breaths thereafter without the pneumotach but with the same flow rate. The tracheal sound signals were recorded by placing a Sony microphone (ECM77B) over the suprasternal notch, and digitized by a 10240Hz sampling rate.

The sounds were band-pass filtered, and segmented into windows of 10ms with 50% overlap between successive windows. Recent studies have shown the best feature to estimate flow from tracheal sounds is the variance (in dB) of the band-pass filtered sound. Therefore, the so called Log-Variance of the sounds over the [300-600] Hz was calculated in each window. Then, from the calculated Log-Variance in each respiratory phases, the mean value of the top 20% segments in dB and the peak value were calculated, and investigated in the periods of with and without flow-meter breathing. In addition, the duration of respiratory phases (estimated from the Log-Variance) was compared in the two periods of with and without flow-meter breathing. The two-way statistical analysis of variance (ANOVA) was done using Matlab, and the results are presented below. The results show no significant change in any of the calculated parameters ($p > 0.4$). In fact, the calculated features during the periods of with and without flow meter were found very close to each other, implying no significant effect of the pneumotach on breathing, and hence on acoustic flow estimation.

	with flow-meter	without flow-meter
Top 20% [dB]	65.97±5.13	64.04±4.95
Peak [dB]	72.03±5.53	70.10±5.40
Duration [sec]	1.61±0.16	1.45±0.09

ACOUSTICAL ASSESSING OF OXYGEN DIVERS' LUNG FUNCTION DYNAMICS AFTER SHALLOW WATER IMMERSION

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Background:

Diving activity renders negative influence on human respiratory system especially when using oxygenous breathing apparatus. The spirometry indexes traditionally used for estimating the lung function have poor sensitivity to the toxic effect of oxygen.

Purpose:

To reveal minimum impairments of the lung function in oxygen divers by analysis of dynamics of the forced expiratory tracheal noises duration.

Methods:

47 male divers (18-29 years) were tested before and after single shallow water immersion (3 - 10m) in the oxygen closed-type breathing apparatus I DA-71 (Russia). A sensor (electret microphone with stethoscopic head) was placed on the sitting subject's right larynx area. The noise signal from sensor was entered in a portable personal computer through sound card (sampling frequency 8000 Hz. filtering 200 - 2000 Hz). One and the same experienced operator subjectively measured forced expiratory tracheal noises duration (FETND). The FETND and spirometry indexes of each diver were recorded before and after immersion. To estimate the significance of differences in the indexes Wilkson T-test for dependent samples was used. Individual dynamics of acoustic and spirometry indexes was computed too.

Results:

After immersion a significant drop of lung volumes over the group as a whole has been found although not overshooting normal limits, the significant increase of FETND exceeding the natural variability limit (17%, $p<O.05$), is detected in 14 persons (29.8%). analyzing individual dynamics. Three of them during dipping had respiratory symptoms characteristic for initial manifestations of pulmonary oxygen poisoning. Two of these divers presented essential decrease in FEV I. The asymptomatic increase of FETND in the rest 11 divers was interpreted as a sign of development of hidden phase of toxic oxygen influence on lungs manifesting by local bronchial obstruction or increase of lung mechanical heterogeneity owing to a change of elastic properties of pulmonary parenchyma.

Conclusions:

Obtained results are a testimony of the significance of lung function changes which oxygen divers have even after single immersion. Dynamics of FETND may be promising acoustic feature to monitor such changes.

Acknowledgement:

The study is supported by the RFBR grants 05-08-18171. 06-08-08069.

SPECTRAL ANALYSIS OF VESICULAR SOUNDS IN CHILDREN RECORDED WITH AN ELECTRONIC STETHOSCOPE (LITTMANN", MODEL 41 00)

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Introduction

In patients with mild airway narrowing, decrease in low frequency power and/or increase in high frequency power are usually observed in inspiratory breath sound spectrum. These changes could be normalized after bronchodilator inhalation. We have previously reported that certain spectral parameters, such as spectral edge frequency (F_{99}) obtained from inspiratory breath sounds in asthmatic children have good correlations with pulmonary function parameters such as FEF25-75%. Increased expiratory sound is another feature of airway narrowing preceding appearance of wheezes. We believe that careful auscultation of lung sounds together with objective measurement of lung sound parameters would be quite useful in the clinical management of childhood airway diseases. Use of currently marketed electronic stethoscope with recording function, as a tool for acquisition of lung sounds would be favorable in order to make the procedure more accessible to general physicians.

Aim and Methods

The first step was to develop software for easy calculation of spectral parameters using lung sound files recorded with the electronic stethoscope. We have collaborated with a group of engineers in Konica-Minolta Medical & Graphics, Inc. at this phase. This software enabled us to collect and analyze a large number of lung sound samples obtained during busy clinical work.

The next step of the study is to establish the feature of normal lung sounds in children and to characterize variances in lung sounds caused by different lung diseases.

Results and Discussion

We are now on the way of gathering lung sound samples. Preliminary analysis of the data revealed that within a frequency range of 150-1200Hz, the median frequency (F_{50}) is around 200-350Hz, and F_{99} is over 500Hz. Thus, we are now investigating another parameter, low frequency (below 400Hz) and high frequency (400Hz and above) power ratio (L/H400). As we decided to go without flow measurement, changes between tidal breathing and effort breathing should also be studied. The effects of contamination with wheezes and crackles should be evaluated. Minimal time-length of recording needed for good reproducibility should also be defined. This is still an ongoing study, and some results would be presented at the conference.

Auscultatory Abnormalities in Shipyard Pipecoverers-A Longitudinal Study

Jaleh Mansouri and Marcia Testa

Background

A study of 102 pipecoverers working in new ship construction was begun in 1965. Evidence of disease in these workers was assessed by respiratory questionnaires, physical examination, pulmonary function studies and chest x-rays. The results of the studies were compared to those in 95 shipyard workers who were not directly working with asbestos. Findings consistent with asbestosis were more common in the pipecoverers than in the controls as reported in 1972.

Goal

The goal of this study was to assess whether the mortality in these pipecoverers was greater than that of the controls and to determine the relative value of the auscultatory findings in predicting this mortality as compared to the other variables assessed.

Methods

Workers were examined in 1965 and 1972. Their charts were assessed in 2008 and a mortality study was also done in 2008.

Results

Preliminary survival analysis (Cox regression) of 132 individuals that were able to be traced showed that the exposed group, which was the group with the more abnormal auscultatory findings, had a 74% higher probability of dying compared to the controls (hazard ratio 1.74). This result was significant at a p value of 0.007.

Conclusion

The level of exposure to asbestos in the shipyard pipecoverers was associated not only with development of asbestosis, but also with an increased mortality as compared to the controls. Results of the specific parameters assessed will be presented.

Effect of Respiratory Gas Pressure and Density on the Duration of Forced Expiratory Tracheal Noises

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Recently we found that at the normal pressure an acoustical duration of a forced expiration T_a increased with gas mixture density.

The purpose of this work was to study forced expiratory tracheal noises at the elevated and normal pressures in different respiratory gas mixtures. The first reason to study tracheal noises at different gas pressures and mixtures is a consideration of T_a as a useful parameter for evaluation airway conductance during diving. The second reason of the study is to give insight into density-dependent mechanisms of tracheal sound generation.

Methods

We studied 6 normal male volunteers. They performed forced expirations in a laboratory at the normal pressure l atm breathing air, OrHe, 01-Kr and in a hyperbaric chamber at the elevated pressures 2.63 atm breathing air and O2-He. We registered gas flow with a screen or an ultrasound flow meters and forced expiratory tracheal noise with a microphone.

Results

At fixed pressures T_a increased with gas density. Flow and volume parameters did not differ in gas mixtures with the same density and viscosity. Table below presents parameters (means ± SD) and significance P of differences obtained in the hyperbaric chamber with an ultrasound flow meter.

	Air, I atm	V\ir,2.63 plm	O,-He, ~63 alm	P (air, 1 atm vs air, 2.63 atm)	P (air, ~63 atm vs OrHe, 2.63 atm)	P (air, I ~lm vs p,-He, .63 atm)
density, g/l	1.29	3.31	1.26			
T PEF, s	0.19±0.03	K1.22±006	*0.IS±0.08*	0.064	<0.001	.023
T_a, s	*1.3S±0.28*	t2.56±114	2.04± 1.22	0018	0076	0.085

Conclusions

T_a increases with gas mixture density induced by both gas molecular weight and pressure increase. This effect demonstrates a significant role of flow turbulence in lung sounds generation. Temporal parameters of forced expiration such as T PEl' and T_a depend upon both density and pressure of gas mixture. Probably this dependence is associated with different gas compressibility.

This work was supported by grants NSh - 1792.2008.1 and FEB RAS 06-1PI2-043.

Effects of procaterol inhalation on lung sounds and pulmonary function in wheezing asthmatic patients

Yukio Nagasaka, Syohei Yasuda, Yasuhiro Ieda

Effect of procaterol (SABA, beta-2 full agonist) inhalation was assessed in 15 wheezing asthmatic patients who have been treated with inhaled cortico-steroids, leukotrien receptor antagonists and other controller drugs. Pulmonary function tests and breath sound analysis was performed before and 20 minutes after inhaling procaterol. In patients who responded to procaterol inhalation, increase of FEV1 correlated with decrease of highest pitch of exhaling breath sound or decrease of wheezing. In a patient who showed good response to procaterol inhalation, there was a significant improvement of breath sound without significant change in pulmonary functions. We assume pulmonary functions and breath sounds focuses different aspect of airway obstruction in wheezing asthmatic patients.

Inter-channel Inhomogeneity of the Timing of Lung Sounds in Patients with Chronic Obstructive Lung Disease

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Objective:

To determine if time based parameters of lung sounds differed in patients with chronic obstructive lung disease (COPD) as compared to normal subjects and patients with other disorders.

Methods:

A 16-channel lung sound analyzer (Stethographics Model STG1602) was used to collect 20s samples of sound from patients with COPD (n=103), normals (n=379), pneumonia (PN, n=118), congestive heart failure (CHF, n=92) , bronchial asthma (n=62), and interstitial pulmonary fibrosis (IPF, n=39) during deeper than normal breathing. The difference in timing between the start of the inspiration at the trachea and the start at each chest wall site was calculated. The inhomogeneity of the start of the inspiration (Sl) was defined as the ratio of the mean of these starting time differences to the duration of the inspiration at the trachea. The negative sign indicates that chest microphones detected inspiration before the tracheal microphone. The end of inspiration inhomogeneity (EI) was defined similarly.

Results: The Sl and EI are presented in Table 1. Notice that inhomogeneity of the start and end of inspiration was significantly more common in COPD ($p<O.OS$).

	Normals	IPF	Asthma	CHF	PN	COPO
Start of inspiration	-1±9	0±6	-5±12	-6±18	-8±15	-16±21
End of inspiration	14±18	B±B	12±19	19±21	17±23	27±26

Conclusion:

The mechanism of the Inter-channel inhomogeneity is unknown, but a possible explanation is regional variations in elasticity and airway resistance. In other words in a normal subject as the chest wall moves outward on inspiration the airways dilate relatively uniformly and the lung is uniformly expanded. In COPD, airway dilatation is less likely to be uniform and dilatation more inhomogeneous secondary to regional variations in elasticity and resistance.

Clinical Implications:

A long-term goal of studies with multichannel lung sound analyzers is to provide useful diagnostic information at the bedside. The increase in the inter-channel Inhomogeneity together with other features of CO PD, such as decreased amplitude of sound and relatively prolonged inspiratory phases can help provide evidence that COPD is present. This can be done using a simple test that requires little patient cooperation.

Validation of an Automatic Wheeze Detector

Eldad Vizel BSc, Yulia Genis BSC, Alon Avrahami MSc, Isaac Kroin MBA, Simon Godfrey MD, PhD and Noam Gavriely MD DSc

Automatic Wheeze Detection is needed for acoustic non-invasive monitoring of the status of the airways in Asthma and other airway diseases. The duration of wheeze as percent of the elapsed time (Tw/Ttot) has previously been established as a measure of wheeze severity expressed as the Wheeze Rate (Wz%) and has been implemented as the Automatic Wheeze Detector Algorithm in a commercial device (PulmoTrack®, KarmelSonix Ltd. Haifa. Israel). Validation of the algorithm was necessary to ensure that the automated detection is as accurate as a trained physician's findings. This study describes a parameters optimization method (ROC) and two methods for validating the accuracy of the Algorithm: (a) Sensitivity and Specificity analysis and (b) regression analysis of the correlation between the Algorithm determination and the consensus of a panel of experts who reviewed the recordings using audio and visual inspection of the sonograms. The results of a mixed data sample from asthma patients (pediatric and adults) and normal volunteers in a variety of environments show Sensitivity of 93% and Specificity of 90% with a regression equation given by AlgWz% = 0.95 ExpWz% + ~ (p = 0.0_) where AlgWz% and ExpWz% are the Algorithm and Experts wheeze rate, respectively. These values were as accurate as or better than the determination of each individual panel member. We conclude that the Automatic Wheeze Detector accurately detects wheezing in realistic clinical environments, including those that are inherently noisy.

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SCIENTIFIC SESSION D

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Relation of Crackle Sound to Airway Generation and Diameter

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Airways that collapse during deflation generate a crackle sound when they reopen during subsequent reinflation. Since each crackle is associated with the reopening of a collapsed airway, the likelihood of an airway to be a crackle source is identical to its vulnerability to collapse. To investigate this vulnerability of airways to collapse, crackles were recorded during the first inflation of six excised rabbit lungs from the degassed state, and subsequent reinflations from 5, 2, 1 and 0 cmH_2O end-expiratory pressure (*EEP*) levels. We derived a relationship between the amplitude of a crackle sound at the trachea and the generation number (n) of the source airway where the crackle was generated. Using an asymmetrical tree model of the rabbit airways with elastic walls, airway vulnerability to collapse was also determined in terms of airway diameter D. During the reinflation from *EEP*=0 cmH_2O, the most vulnerable airways were estimated to be centered at n=12 with a peak. Vulnerability in terms of D ranged between 0.1 and 1.3 mm with a peak at 0.3 mm. During the inflation from the degassed state, however, vulnerability was much less localized to a particular n or D with maximum values of n=8 and D=0.75 mm. Numerical simulations using a tree model that incorporates airway opening and closing support these conclusions. Thus, our results indicate that there are airways of a given range of diameters which can become unstable during deflation and vulnerable to collapse and subsequent injury.

Are Crackles in IPF related to disease activity as measured by Pulmonary Function?

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Introduction:

Idiopathic pulmonary fibrosis (IPF) is a disease associated with progressive breathlessness, showers of inspiratory crackles, restrictive ventilation and characteristic CT shadowing. This study assesses this possible relationship between disease severity, as measured by pulmonary function, and the numbers and distribution of crackles.

Methods:

Fourteen IPF patients (mean age 68.5, 0=12) diagnosed using *ATS/ERS* criteria underwent pulmonary function testing (PFT's) and crackle recordings. Recordings were made with Stethographics Inc. STG software using a customized 8 microphone array (4 anterior and 4 posterior). Four breathing manoeuvres (normal breathing (NB), deeper breathing (DB), slow vital capacity (SVC) and slow inspiratory capacity (SIC) were performed. Three recordings were made for each breathing pattern. No statistical differences were found between recordings. Initially crackles were reported as crackles per breath and no statistical associations were found with the various physiological parameters. As this may reflect different size of breaths at different stages of the disease (i.e. reduced breath size as the disease progresses) subsequent analysis was undertaken using the number of crackles per second (CPS).

Results:

The number of inspiratory CPS either correlated or showed a trend nearing significance with PFT's. During SIC, normal breathing and deeper breathing there are trends with FEV 1, FVC and DLco. However the inspiratory crackles during deeper breathing and SIC correlated with TLC (p=-0.594, r=0.25, p=-0.701, r=0.005 respectively), a trend was observed during normal breathing. The number of expiratory crackles were significantly related to TLC during deeper breathing (p=-0.626, r=O.O 17). During the other manoeuvres there was a trend which did not reach statistical significance.

Discussion:

In this study, in order to overcome the problem of varying breath size due to the severity of interstitial fibrosis, the numbers of crackles per unit time of inspiration or expiration was used. Using CPS showed a trend towards increase numbers and physiological measurement of disease progression with significant changes related particularly to TLC. Further analysis of the data is required to look at regional changes and to evaluate other ways of measuring crackles (e.g. Crackles per unit volume). However, these initial results suggest that crackles may be useful in assessing disease severity in IPF.

Probing the Existence of Medium Pulmonary Crackles via Model-Based Clustering

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The objective of this study is to probe the existence of a third crackle type. medium. besides the traditionally accepted types, namely, fine and coarse crackles and, furthermore, to explore the representative parameter values for each crackle type. The lung sounds were acquired from 13 subjects with obstructive and/or restrictive respiratory disorders from 14 different locations on the posterior chest. From these records, 2711 crackles were visually detected from time expanded waveforms of lung sounds by two independent observers. The database of crackles consisted of a wide range of crackle samples from coarse to fine. A preprocessing algorithm is performed on each crackle to eliminate vesicular sound with an aim to avoid incorrect crackle parameterization.

Five different feature sets are extracted from the preprocessed crackle samples, two of which are conventional parameters that have been suggested by Murphy et al. and Hoevers and Loudon and that are derived from the zero-crossings of crackle waveforms. The third feature set corresponds to the modeling spectral components of the crackles whereas the remaining two sets are derived from a single- and double-node wavelet network.

A set of clustering experiments have been conducted on pulmonary crackles where a model-based clustering algorithm, the Expectation-Maximization algorithm, is used and the resulting cluster numbers are validated with Bayesian Inference Criterion. The results of the clustering experiments demonstrate strong evidence for the existence of a third crackle type. Moreover, the labels yielded by clustering experiments using different feature sets match for roughly 80% or more of the crackle samples, resulting in similar representative crackle parameter values of the three clusters for all feature sets.

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The Specificity of the Crackles of Interstitial Pulmonary Fibrosis

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The crackles in patients with interstitial pulmonary fibrosis (IPF) can be difficult to distinguish from those heard in patients with congestive heart failure (CHF) or pneumonia (PN). Misinterpretation of these crackles can lead to inappropriate therapy. The goal of this study was to determine if there were features of the crackles of IPF patients that could help distinguish them from the crackles in patients with CHF and PN.

We studied 39 patients with IPF, 95 with CHF and 123 with PN using a multichannel lung sound analyzer (Stethographics- STGI6). Recordings were made at 14 sites over the chest. Crackle parameters were extracted from the time amplitude plots of these recordings and were analyzed using the statistical technique of support vector machines. Models were created using two-thirds of the data, and tested on the remaining third. Ten random selections of training and test data were generated. The reported results are the average over ten test sets performances.

Modeling has shown that the IPF crackles had distinctive features that allowed them to be separated from those in patients with PN with a sensitivity of 0.76 and a specificity of 0.83 and an accuracy of 0.82. IPF crackles were separated from those of CHF with a sensitivity of 0.80 and a specificity of 0.85 and an accuracy of 0.84.

The achieved results indicate that the nature of lPF crackles is different from that of the other diseases we studied and that the difference can be electronically detected at the bedside. Adding information about crackle distribution over the chest marginally improved the performance, while adding features from other abnormal sounds such as wheezes and rhonchi. did not improve the recognition performance. The proposed approach has the potential of aiding clinicians in diagnosis of IPF, thus helping to avoid medication errors.

Mechanism of Inspiratory and Expiratory Crackles

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Objective:

Although crackles are frequently heard on auscultation of the chest of patients with common cardiopulmonary disorders, the mechanism of production of these sounds is inadequately understood. The goal of this research was to gain insights into the mechanism of crackle generation by systematic examination of the relationship between inspiratory and expiratory crackle characteristics.

Methods:

Patients with a significant number of both inspiratory and expiratory crackles were examined using a multichannel lung sound analyzer. These patients included 37 with pneumonia, 5 with heart failure and 13 with interstitial fibrosis. Multiple crackle characteristics were calculated for each crackle, including frequency, amplitude, crackle transmission coefficient, and crackle polarity.

Results:

Spectral, temporal, and spatial characteristics of expiratory and inspiratory crackles in these patients were found to be similar, but two characteristics were strikingly different: namely crackle numbers and crackle polarities. Inspiratory crackles were almost twice as numerous as expiratory crackles (3308 versus 1841) and had predominately negative polarity (76% of inspiratory crackles versus 31% of expiratory crackles).

Conclusion:

These observations are quantitatively consistent with the so-called stress-relaxation quadrupole hypothesis of crackle generation. This hypothesis holds that expiratory crackles are caused by sudden airway closure events that are similar in mechanism but opposite in sign and far less energetic than the explosive opening events that generate inspiratory crackles. We conclude that the most likely mechanism of crackle generation is sudden airway closing during expiration and sudden airway re-opening during inspiration.

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