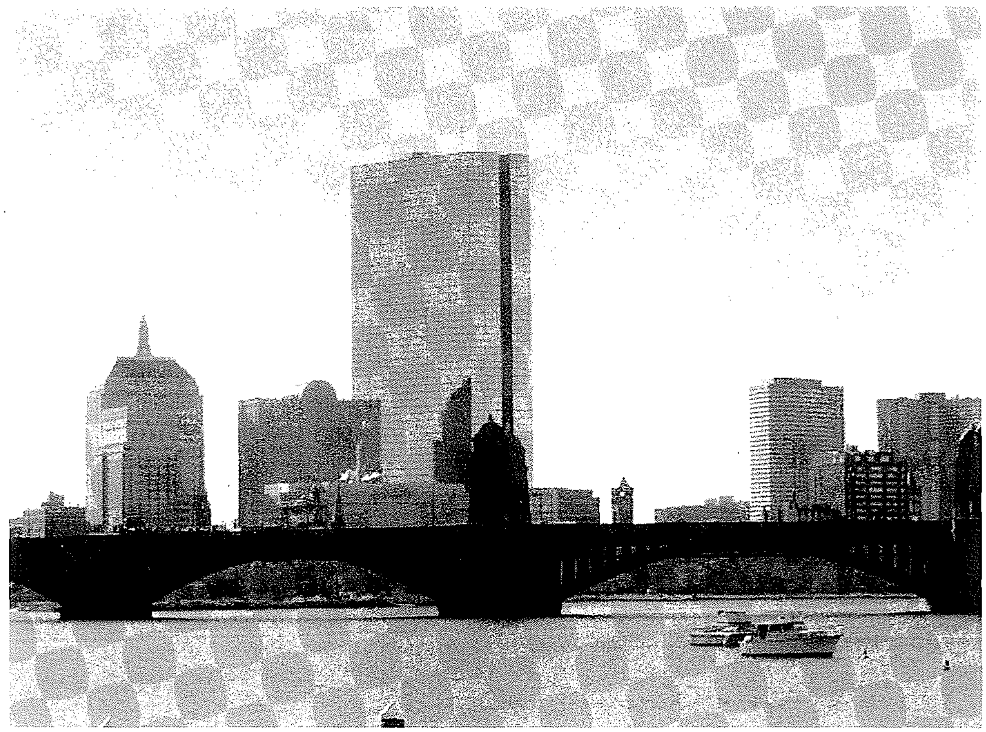
International
Lung
Sounds
Association

Boston and Cambridge, MA   October 6 and 7, 2005



2005

The 30th
International Conference
on Lung Sounds

Brigham & Women's / Faulkner Hospital
Massachusetts Institute of Technology
October 6, 7, 2005

The 30th

INTERNATIONAL CONFERENCE

ON

LUNG SOUNDS

Presented by

The International Lung Sounds Association

October 6-7, 2005

Boston/Cambridge, Massachusetts

FINAL PROGRAM AND ABSTRACTS

General Information

Conference Venue

Thursday, October 6, 2005- Brigham & Women's/Faulkner Hospital, Boston MA

Friday, October 7, 2005 – Massachusetts Institute of Technology, Cambridge MA

Registration

Registration will be held at the Brigham & Women's/ Faulkner Hospital on Thursday morning between 8:30-9:00am

Certificate of Attendance

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

Posters & Presentations

Posters will be on display on October 6th in the Atrium II Conference Room after 8:45am. The poster discussion will begin at 3:30 pm.

Social Evening/Reception:

At approximately, 5:00pm, a bus will depart from the Faulkner Hospital For a reception for ILSA members and their guests at the home of Dr. Raymond Murphy.

The 30th International Conference on Lung Sounds
Cambridge/Boston, Massachusetts
October 6-7, 2005

AUTHORS INDEX

A. Adams
R. Balk
J.W. Day
D.G. Frazer
B. Gross
N. Ilkka
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S. Annsi
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M. Ebril
J. Gnitecki
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A. Jukka
U. Koehler
H. Mansy
D. Michalak
R. Paciej
H. Pasterkamp
G. Pressler
T. Royston
S. Taplidou
K. Tuomisto
W. Warren
A. Yadollahi

FINAL

PROGRAM

1:00 **Panel Discussion on Crackles**
Discussion Leaders: J. Fredberg, S. Holford, B. Suki, A.Vyshedskiy

SESSION II Poster Session
Session Chairs: Steve Kraman and John Earis

2:30 p.m. **Poster Viewing**

Poster Discussions

3:30 p.m. *Automatic Detection of Crackles: Validation of SuperHelsaII Lung Sound Analyzer*
T. Karolina, P. Piirila, J. Airaksinen, and A. Sovijarvi, Helsinki University Hospital and Finnish Institute of Occupational Health, Finland

3:35 p.m. *Short-time Spectrogram as a Technique for Visualisation and Detection of Crackles*
I. Nissila, K. Tuomisto, J. Airaksinen, T. Ojala, P. Helisto, P. Piirila, and A. Sovijarvi, Helsinki University, Finland

3:40 p.m. *Wheeze Episode Representation in the Hilbert-Huang Transform Domain*
S.A. Taplidou and L.J. Hadjileontiadis, Aristotle University of Thessaloniki, Greece

3:45 p.m. *Gravity Independence of Wheezing*
S. Ishikawa, M. Zulik, M. Khamees, K.F. MacDonnell, and B. Celli, Tufts University, USA

3:50 p.m. *Geometrical and Dynamical State Space Parameters of Lung Sounds*
J. Gnitecki, Z. Moussavi, and H. Pasterkamp, University of Manitoba, Canada

3:55 p.m. *Smaller Contact Lung-Sound Sensor Based on an Electret Condenser Microphone Cartridge*
F. Sakao, Kinki University, Hiroshima, Japan

4:00 p.m. **Business Meeting**

5:00 p.m. **Bus leaves for Social Gathering at the Murphy House**

8:30 p.m. **Bus leaves Murphy House for Kendall Hotel**

3:15 p.m.	*Relationship of Respiratory Flow Rate to Breath Sounds Measured at the External Ear* G. Pressler, H. Pasterkamp, S. Kraman, and G. Wodicka, Purdue University, USA, University of Manitoba, Canada, and University of Kentucky, USA
3:30 p.m.	*Auscultation Through a Shirt: Sinful or Saintly?* S. Kraman, University of Kentucky, USA
3:45 p.m.	*Prolongation of the Expiratory Phase in Chronic Obstructive Lung Disease* R. Murphy, A. Vyshedskiy, R. Paciej, A. Wong-Tse, and D. Bana, Brigham and Women's/Faulkner Hospitals, USA
4:00 p.m.	*Robust Flow Estimation Using Tracheal Sounds Entropy* A. Yadollahi and Z. Moussavi, University of Manitoba, Canada
4:15pm	*Before There Was Auscultation* J. Thierman, A. Vyshedskiy, R. Murphy, Faulkner Hospital, USA
4:30 p.m.	**Closing Comments** Steve Kraman, ILSA President

SESSION I – CRACKLE SYMPOSIUM

Session Chair – Jeff Fredberg

ILSA 2005 Program Schedule
October 6-7, 2005

Thursday, October 6 (Brigham & Women's/Faulkner Hospital)

SESSION I **Crackle Symposium**
Session Chair: Jeff Fredberg

9:00 a.m. *Airway Physiology*
J. Fredberg, Harvard School of Public Health, USA

9:15 a.m. *Stress Relaxation Quadrupoles*
S. Holford, Onset Computer Corporation, Mansfield, MA. USA

9:30 a.m. *Mechanism of Expiratory Crackles*
A.Vyshedskiy, R.M. Alhashem, R. Paciej, M. Ebril, and R. Murphy, Brigham and Women's/Faulkner Hospitals, USA

9:45 a.m. *A Model of Crackle Sound Generation: The Rupture of a Stressed Liquid Bridge*
A.M. Alencar and S. Buldyrev, Harvard School of Public Health and Yeshiva University, USA

10:00 a.m. *On Enhancing Explosive Lung Sounds Using Empirical Model Decomposition and Fractal Dimension Analysis*
L.J. Hadjileontiadis, Aristotle University of Thessaloniki, Greece

10:15 a.m. *Modeling and Clustering of Pulmonary Crackles Using Wavelet Networks*
M. Yeginer and Y.P. Kahya, Bogazici University, Turkey

10: 30 a.m. *Statistical Analysis of Crackles*
B. Suki, Boston University, USA

10: 45 am Break

11:00 a.m. **Grand Rounds**
A 67-year-old Female with Acute Onset of Wheezing
R. Murphy, Brigham and Women's/Faulkner Hospitals, USA

Noon **Lunch**

1:00 **Panel Discussion on Crackles**

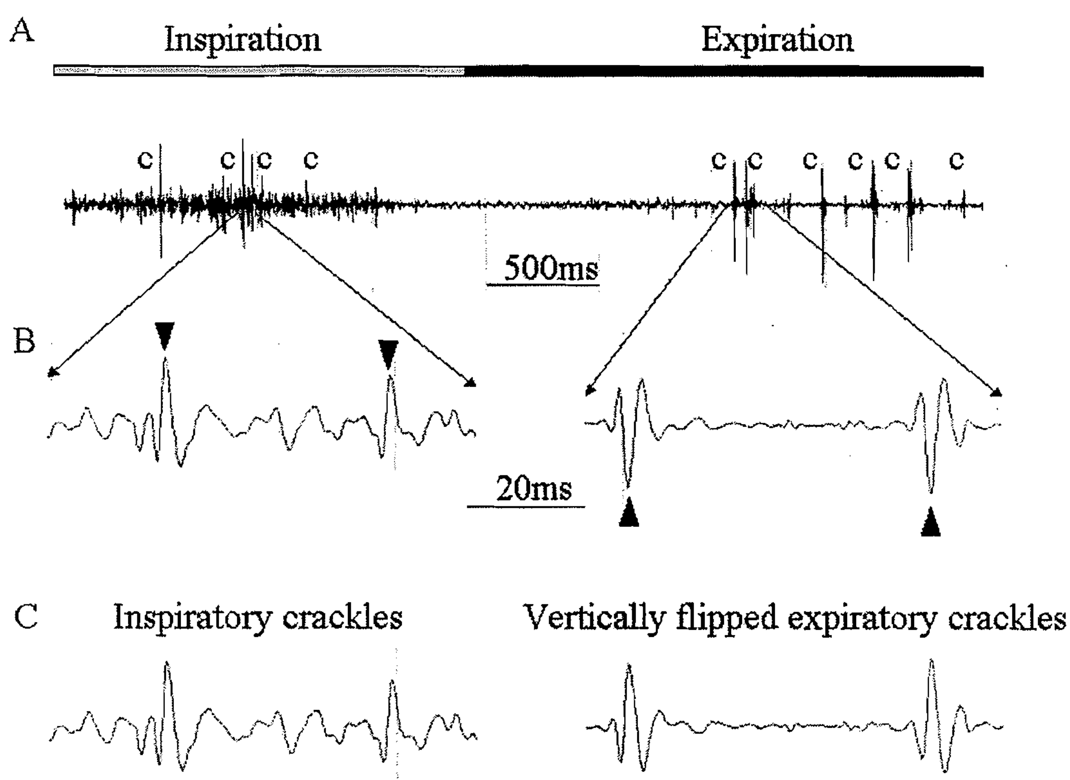
Discussion Leaders: J. Fredberg, S. Holford, B. Suki, A.Vyshedskiy

SESSION I - ABSTRACTS

Mechanism of Expiratory Crackles

Andrey Vyshedskiy, Ruqayyah M. Alhashem, Rozanne Paciej, Margo Ebril, and Raymond Murphy
Brigham and Women's / Faulkner Hospitals, Boston, MA

Purpose: (1) to gain insights into the crackle generation mechanism and (2) to test the predictions of stress-relaxation quadrupole crackle generation theory.
Methods: Patients with pneumonia, CHF, and interstitial fibrosis (n=55) were examined using a multichannel lung sound analyzer. Multiple crackle characteristics were calculated for each crackle family.
Results: Inspiratory crackles characteristics were found to be very similar to those of expiratory crackles. The one parameter that was clearly different between inspiratory and expiratory crackles was polarity. The majority of patients had predominantly positive polarity of inspiratory crackles (98%) and predominantly negative polarity of expiratory crackles (81%). We have then studied crackle polarity within each crackle family. We have found that in majority of crackle families polarity of daughter crackles was identical to that of the mother crackle. However we were able to find multiple examples in which daughter crackles polarity was reversed from that of a mother.
Conclusion: The reported findings are consistent with the hypothesis that expiratory crackles are caused by events that are identical in mechanism and opposite in direction to that of inspiratory crackles. Thus we conclude that the most likely mechanism of expiratory crackles is that of airway closing. The existence of daughter crackles with polarity reversed from that of a mother is consistent with stress-relaxation quadrupole crackle generation theory.



A model of crackle sound generation: the rupture of a stressed liquid bridge

Adriano M. Alencar[1] and Sergey Buldyrev[2]

[1] Harvard School of Public Health, Harvard University, Boston, MA, 02115 USA
[2] Department of Physics, Yeshiva University, 500 W 185th Street, New York, NY, 10033 USA

We determine the surface, free energy, and the critical stability conditions in a system composed of a liquid bridge formed between two parallel planes, separated by a distance h, with a contact angle ϕ using both Monte Carlo simulation and variational calculus. We numerically model the system with respect to the volume of liquid, distance between the two planes, and the contact angle in a three phase system composed of airway wall, liquid, and vapor. The system can only be in two equilibrium states: liquid bridge (closed state) and droplets (open state). We find the state of the system as function of h, and ϕ at a given temperature. The numerical results are in agreement with analytical solution based on variational calculus of minimization of surface with volume and contact angle constrains. During the stretching of the liquid bridge the free energy monotonically increase. Since the surface of one or two droplets formed from the liquid bridge after its rupture is smaller than the surface area of the stretched liquid bridge, the stored energy is abruptly released to the system. We suggest that most of this energy accumulated and released is acoustic, and for the specific case of liquid bridge rupture in the lung airway, this acoustic energy is the crackle sound. This suggestion supports what has been hypothesized about crackle generation, a result of a relaxation of a stress concentration near the airway relative to the stress near the airway in the open state.

ON ENHANCING EXPLOSIVE LUNG SOUNDS USING EMPIRICAL MODE DECOMPOSITION AND FRACTAL DIMENSION ANALYSIS

Leontios J. Hadjileontiadis

Dept. of Electrical & Computer Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece (leontios@auth.gr)

The accurate detection of lung sounds in the sound recordings attracts special attention in the diagnostic evaluation of lung sounds, especially when explosive lung sounds (ELS), such as fine/coarse crackles and squawks, are involved. This is due to the nonstationary nature of ELS given that they behave as transient signals of a short time duration superimposed on the background sound noise (vesicular sound). A novel technique for denoising ELS from the background noise is presented here. The proposed technique is based on a combination of empirical mode decomposition (EMD) and fractal dimension (FD) analysis. Using these, a denoising tool, namely EMD-FD filter, is constructed. The latter, initially applies EMD to decompose lung sound recordings into a number of intrinsic mode functions (IMFs). Then, it uses FD analysis to efficiently categorize portions of automatically selected IMFs to significant (high values of FD) and non significant (low values of FD) ones. By adding the portions at each category, the denoised ELS signal and the background noise are estimated, respectively. The EMD-FD filter is realized either in a non-iterative or an iterative way, providing refinement alternatives to its performance, maximizing its performance accuracy in the ELS enhancement. Experimental results (see Fig. 1), when applying the EMD-FD filter on real data, prove its efficiency (mean detectability 98.4%; sensitivity 98.1%; specificity 97.7%) to successfully extract ELS from background noise, without altering both their time location and structural characteristics.

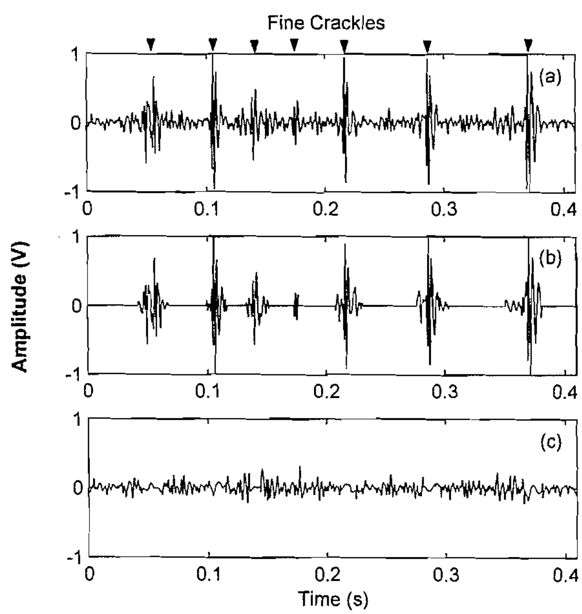


Fig. 1 Experimental results of the EMD-FD filter applied to a section of breathing sound including a series of 7 fine crackles (FC), recorded from a patient with pulmonary fibrosis. (a) The lung sound recording (f_s=2500 Hz), (b) the denoised FC, and (c) the estimated background noise (vesicular sound).

Modeling and Clustering of Pulmonary Crackles Using Wavelet Networks

Mete Yeginer[1], Yasemin P. Kahya[2]
Institute of Biomedical Engineering[1], Department of Electrical and Electronic Engineering[2], Bogazici University, Istanbul, Turkey

In this study, wavelet networks are used to model pulmonary crackles with a view to obtain features for the clustering analysis of crackles obtained from subjects with a wide spectrum of pulmonary disorders. Crackles are very common adventitious sounds which are transient in character and whose characteristics, such as type, number of occurrence and pitch, convey information regarding the type and severity of the pulmonary disease. Crackles generally start with a sharp deflection and continue with a damped and progressively wider sinusoidal wave. To diagnose the disorder, crackles detected from the acquired respiratory signal belonging to a subject with the disorder should be analyzed and parameterized. In this study, visually detected crackles are used such that the signal window including the crackle is filtered to eliminate background noise according to the second quartile of its cumulative frequency. In order to be able to represent the preprocessed crackles in time and frequency domains, a wavelet network (WN) is employed. Complex Morlet function is used as transfer function of WN since the function is continuous and differentiable to optimize iteratively the estimated signal. One hidden layer node is adequate to represent the complexity of crackles. The five parameters of the WN node, i.e. scaling, time-shifting, frequency and two weight factors of sinus and cosines components are used as features in the clustering analysis of crackles. The resulting clusters correspond to the two most common clinical classes of crackles, i.e. fine and coarse with an additional class of medium crackles. Each pulmonary disease in the study is further characterized according to the percentage of the crackles belonging to each class.

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SESSION II – POSTER SESSION

Session Chairs – Steve Kraman and John Earis

SESSION II **Poster Session**

Session Chairs: Steve Kraman and John Earis

2:30 p.m. **Poster Viewing**

Poster Discussions

3:30 p.m. *Automatic Detection of Crackles: Validation of SuperHelsaII Lung Sound Analyzer*
T. Karolina, P. Piirila, J. Airaksinen, and A. Sovijarvi, Helsinki University Hospital and Finnish Institute of Occupational Health, Finland

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I. Nissila, K. Tuomisto, J. Airaksinen, T. Ojala, P. Helisto, P. Piirila, and A. Sovijarvi, Helsinki University, Finland

3:40 p.m. *Wheeze Episode Representation in the Hilbert-Huang Transform Domain*
S.A. Taplidou and L.J. Hadjileontiadis, Aristotle University of Thessaloniki, Greece

3:45 p.m. *Gravity Independence of Wheezing*
S. Ishikawa, M. Zulik, M. Khamees, K.F. MacDonnell, and B. Celli, Tufts University, USA

3:50 p.m. *Geometrical and Dynamical State Space Parameters of Lung Sounds*
J. Gnitecki, Z. Moussavi, and H. Pasterkamp, University of Manitoba, Canada

3:55 p.m. *Smaller Contact Lung-Sound Sensor Based on an Electret Condenser Microphone Cartridge*
F. Sakao, Kinki University, Hiroshima, Japan

4:00 p.m. **Business Meeting**

5:00 p.m. **Bus leaves for Social Gathering at the Murphy House**

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SESSION II - ABSTRACTS

Automatic Detection of Crackles: Validation of SuperHelsaII Lung Sound Analyzer

Karolina Tuomisto, Piirilä Päivi, Airaksinen Jukka, Sovijärvi Anssi
Laboratory of clinical physiology, Helsinki University Hospital, Helsinki, Finland
Finnish Institute of Occupational Health, Helsinki, Finland

Objectives. Crackles are heard in several pulmonary disorders reflecting the quality and severity of the disease. The aim of this study was to validate the automatic crackle detectors in SuperHelsaII lung sound analyzer, i.e. the Kaisla method based on spectral stationarity and the Vannuccini method based on the crackle waveform.

Methods. Lung sounds on the back basal part of the lungs of 20 asbestos exposed workers were recorded. The number of crackles obtained from the automatic crackle detector in SuperHelsaII using only the Kaisla method (Kaisla et al 1991) with threshold levels 500, 750, 1000, 1500 and 2000 dBHz was compared with crackle counts by the combined Kaisla and Vannuccini (Vannuccini et al 1998) method as well as with the count of crackles found by two observers in time-expanded waveform display according to Murphy's criteria.

Results. The total amount of crackles validated was 1140 for observer A. Pearson's rank correlation coefficient between the count of crackles obtained by 1) the automatic method, 2) the automatic method combined with the Vannuccini method and 3) the assisted automatic method, and the counts by observer A are shown in the chart. P-values for the correlations were as follows: Automatic method $p<0,001$ and for the assisted automatic method $p<0,00001$. For the combined Kaisla and Vannuccini method the correlations were not statistically significant.

Figure 1: The Pearson's correlation coefficients between the counts obtained by 1) the Kaisla method, 2) the Kaisla method combined with the Vannuccini method and 3) the edited automatic method, and observer A's visual detection from time-expanded waveform.

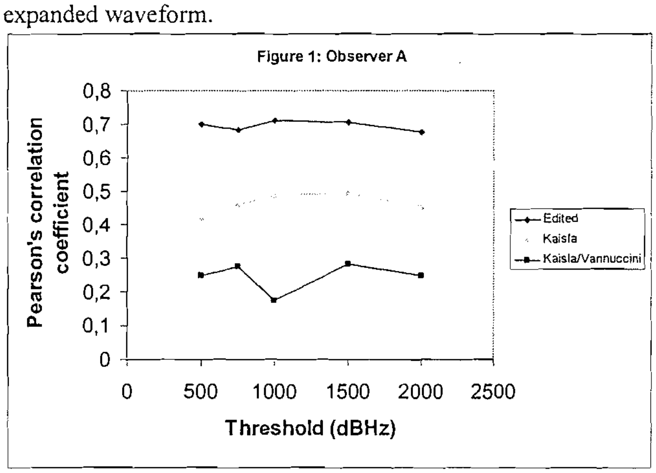

Table 1: Total counts for each method with each threshold.

	Kaisla	Kaisla/Vann.	Edited
500 dBHz	2715	1212	1167
750 dBHz	1767	806	796
1000 dBHz	1262	641	532
1500 dBHz	696	308	369
2000 dBHz	416	203	284

Conclusions. Crackle counts obtained with Kaisla's method at all used threshold levels (500-2000 dBHz) correlated significantly with the visual counts obtained according to Murphy's criteria. The combination of Vannuccini and Kaisla methods did not improve the results in the present patient material. The highest correlation coefficients were obtained by the edited Kaisla method. The level of detecting threshold of the automatic method did not influence the correlation figures.

Short-time spectrogram as a technique for visualisation and detection of crackles

Nissilä Ilkka[1], Tuomisto Karolina[2], Airaksinen Jukka[2], Ojala Terhi[2], Helistö Panu[1], Piirilä Päivi[2], Sovijärvi Anssi[2]

[1] Laboratory of Biomedical Engineering, Helsinki University of Technology, Espoo, Finland
[2] Laboratory of Clinical Physiology, Department of Clinical Physiology and Nuclear Medicine, Helsinki University Central Hospital, Helsinki, Finland

In this study, techniques based on the short-time Fourier spectrogram were developed in order to identify crackles. Lung sounds in the back basal part of both lungs of 20 asbestos exposed workers were recorded. In order to test the spectrogram as a visual aid to detection of crackles, two doctors counted the crackles in our data set based on the waveform and the spectrogram, separately. Due to the acoustic properties of the body, the lower frequencies (< 500 Hz) of the crackle sounds are phase-delayed relative to the higher frequencies, which gives crackles a characteristic shape in the spectrogram.

Observers A and B counted 1140 and 890 crackles, respectively, using the waveform. From the spectrogram, the observers counted 938 and 801 crackles. Pearson's rank correlation coefficient between the numbers of crackles counted by observer A using the two representations was 0.96 ($p<0.0001$), and the coefficient for observer B was 0.94 ($p<0.0001$).

Table 1: Correlations between counts obtained with the different analysis methods

	Observer A, TEWA	Observer B, TEWA	Observer A, SA
Observer A, SA	0.958	0.833	1
Observer B, SA	0.714	0.940	0.758
Observer A, TEWA	1	0.807	0.958

TEWA = Time expanded waveform analysis
SA = Spectral analysis

WHEEZE EPISODE REPRESENTATION IN THE HILBERT-HUANG TRANSFORM DOMAIN

Styliani A. Taplidou and Leontios J. Hadjileontiadis

Dept. of Electrical & Computer Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece (stellata@auth.gr; leontios@auth.gr)

Wheezes, by directly being connected to severe pulmonary dysfunctions, such as asthma and chronic obstructive pulmonary disease, are important in the diagnosis of lung pathology. Research efforts reported in the literature have been focused on the automated detection of wheezes in the breathing cycle involving time or frequency domain analysis of the recorded lung sounds. In this paper, a newly introduced time-frequency representation technique, namely Hilbert-Huang Transform (HHT) is applied for the detection of wheezes. The HHT takes into account both the time and frequency representation of the lung sound signal, thus revealing its characteristics that can be used in the wheeze identification. The HHT is realized in two steps. Initially, a 'peeling' procedure, i.e., empirical mode decomposition (EMD), is applied to the data, decomposing them into a number of intrinsic mode components. Then, the Hilbert transform is applied to the decomposed intrinsic mode functions (IMFs) and the time-frequency spectrum is constructed. Using the information of the HHT, a HHT-wheezing episode detector (HHT-WED) is formed. In this way, the distinct frequency peaks that characterize the wheeze frequency representation are revealed as they evolve over time. Figure 1 shows an example of the wheeze analysis with the HHT-WED. As it is clear from Fig. 1, the wheeze episode (Fig. 1(a)) produces a distinct harmonic peak in the time-frequency representation of the short-time Fourier transform (STFT), shown in Fig. 1(b). However, a more clear representation of the wheeze is seen in the time-frequency domain (Fig. 1(c)), where the output of the HHT-WED is depicted. As it is apparent from Fig. 1(c), simple thresholding could automatically isolate the area of importance and the localization of the wheeze in the time domain can be achieved. On going analysis of wheezes drawn from the Marburg Respiratory Sound (MaRS) Database (www.lung-sound.de) can lead to the justification of the efficiency of the proposed HHT-WED scheme.

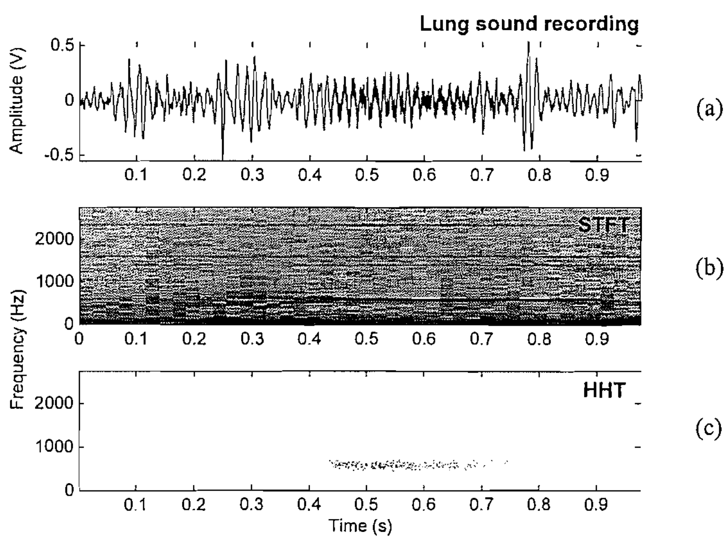

Fig. 1 Experimental results of the HHT-WED applied to a section of breathing sound including a wheezing episode. (a) The lung sound recording (f_s=5512 Hz), (b) the corresponding STFT, and (c) the output of the HHT-WED.

GRAVITY INDEPENDENCE OF WHEEZING

S.Ishikawa,*,M.Zulik,M.Khamees,K.F.MacDonnell,andB.Celli
Pulmonary & Critical Care,Caritas St Elizabeth's Medical Center
Dept. of Medicine, Tufts University School of Medicine Boston MA, U.S.A.

Wheezes are musical sounds produced by the rapid passage of air through a bronchus that is narrowed to the point of closure. The walls of the bronchus oscillates between closed and barely open positions, and generate audible sounds. We are interested whether the generated wheezes is influenced by gravity. Five asthmatic subjects who were in an exacerbation and had audible wheezing were selected. Lung sounds were recorded on sitting and supine positions. Sounds signals were recorded at the neck and 14 sites on the posterior chest surface with contact microphones, using Murphy's STG16 system. Wheezes were identified from sound recordings based on a technique similar to the one described by Fenton & Pasterkamp et al (IEEE Trans Biomed Eng. 1985 Jan;32(1):50-5) Briefly, each 100ms segment is defined as normal or abnormal on the basis of spectral peaks (wheezes and rhonchi have characteristically strong spectral peaks) Furthermore, the abnormal segments are classified as wheeze or rhonchi on the basis of their spectral peaks frequency. Wheeze detection was carried out on all channel recordings. Topographical map of wheezes on the posterior chest surface was constructed.

We have found that wheezes were relatively independent of the gravity.

Geometrical and Dynamical State Space Parameters of Lung Sounds

J. Gnitecki[1], Z. Moussavi[1], and H. Pasterkamp[2]
[1]Department of Electrical Engineering, University of Manitoba
[2]Department of Pediatrics, University of Manitoba, and Manitoba Institute of Child Health
Winnipeg, Manitoba, Canada

State space parameters calculated from time series data, in particular embedding dimension (m), time delay (τ) and Lyapunov exponents (λ), characterize the system from which the data emerge and may aid modeling the system. These features were therefore determined for lung sounds, acquired at flows of 7.5, 15, and 22.5 ml/s/kg from six healthy subjects, ages 10-26 y, over the right upper lobe (RUL) anteriorly and lower lobe (RLL) posteriorly. Additionally, lung sounds from a 15 y/o boy recorded at 15 ml/s/kg over the RLL pre- and post-bronchial narrowing induced by methacholine were analyzed. Sounds within 85-100% of maximum inspiratory flow were used. Lung sounds from healthy subjects were also digitally filtered within 150-450 Hz to examine the effect of reducing signal bandwidth. For healthy subjects, means of m were similar between sensor locations and filtered *vs.* original signals. With increasing flow for both RUL and RLL original data, means of τ decreased and percent of breaths with positive λ increased. These parameters were relatively lower for filtered sounds. The highest flow RUL original data exhibited the highest percentage of positive λ, at 96.1±5.0%. For the patient pre-bronchial narrowing, all parameters were within the range of values for healthy lung sounds at comparable flows. Values of τ increased and number of positive λ decreased post-bronchial narrowing, and m values did not change appreciably. Thus, both τ and presence of positive λ may prove valuable in developing a model that will predict changes in respiratory status using lung sounds.

SMALLER CONTACT LUNG-SOUND SENSOR BASED ON AN ELECTRET CONDENSER MICROPHONE CARTRIDGE

Fujihiko SAKAO *
Ajina 3-6-20, Hatsuka-ichi, Hiroshima-Ken, Japan 738-0054

A type of contact accelerometer type stethoscopic sensor has been developed by the author, for about ten years. It is based on an electret condenser microphone cartridge as the sensing element. It is simple and low cost, yet has fairly good sensitivity over wide range of frequency (1 - 3).

So far, the sensing element used was a 10 mm diam. cartridge. A smaller one, of 6 mm diam, often caused noise trouble due to incomplete electric connection, while the smaller size would be convenient for various applications. Now finally, a type of 6 mm diam. cartridge with reliable electric shield is found available for the author. Hence it is used as the sensing element.

Due to smaller size, there are minor changes in set up procedure, though essential structure remains the same as previous lager ones. Rather to the author's surprise, the sensitivity of the smaller one is essentially the same as a larger one. Details of the frequency characteristics or other performances are now being examined using a calibration facility.

References

1) Fujihiko SAKAO et al : 18th ILSA Conf.
2) Fujihiko SAKAO et al : 23rd ILSA Conf.
3) Fujihiko SAKAO et al : 24th ILSA Conf.

*) No affiliation : e-mail = sakao-f@lime.ocn.ne.jp

SESSION III – PHYSIOLOGIC MEASUREMENT AND TECHNIQUES

Session Chairs – Hans Pasterkamp and Masato Takase

Friday, October 7 (MIT Building E25)

Session III	**Physiologic Measurement and Techniques** Session Chairs: Hans Pasterkamp and Masato Takase
9:00 a.m.	*Breath Sound Changes Associated with Pneumothorax* H. Mansy, S. Hoxie, W.H. Warren, R.A. Balk, D. Michalak, N. Gierut, T. Royston, and R.H. Sandler, Rush University Medical Center, USA
9:15 a.m.	*Acoustic Changes in Pneumothorax and Hemothorax* R. Murphy, A. Vyshedskiy, A. Wong-Tse, A. Adams, and J. Marini, Brigham and Women's/Faulkner Hospitals, and Regions Hospital, USA
9:30 a.m.	*Assessment of Swallowing Sounds' Stages with Hidden Markov Model* Z. Moussavi, University of Texas at El Paso, USA and University of Manitoba, Canada
9:45 a.m.	*Acoustic Nocturnal Long-Term Recording as a Diagnostic Option of Initial Unclear Cough in Sleep – A Case Report* C. Reinke, V. Gross, T. Penzel, U. Koehler, and C. Vogelmeier, Philipps University, Germany
10:00 a.m.	*Computerized Lung Sound Analysis in a Thoracic Surgical Intensive Care Unit* N. Patil, Brigham and Woman's Hospital, USA
10:15 a.m.	*Measuring Minimum Critical Flow for Normal Breath Sounds* A. Yadollahi and Z. Moussavi, University of Manitoba, Canada
10:30 a.m.	**Break**
11:00 a.m.	**Plenary Lecture** "*Respiration and Speaking: Similarities and Differences*" K.N. Stevens, Massachusetts Institute of Technology, USA
Noon	**Group Photo**
12:15 p.m.	**Picnic Lunch**
1:30 p.m.	**Tour of MIT**

SESSION III - ABSTRACTS

Breath Sound Changes associated with Pneumothorax

Hansen A. Mansy, PhD, Silas J. Hoxie, MS, William H. Warren, MD, Robert A. Balk, Debra Michalak, RN, MD, Nick Gierut, Thomas Royston, PhD, and Richard H. Sandler, MD

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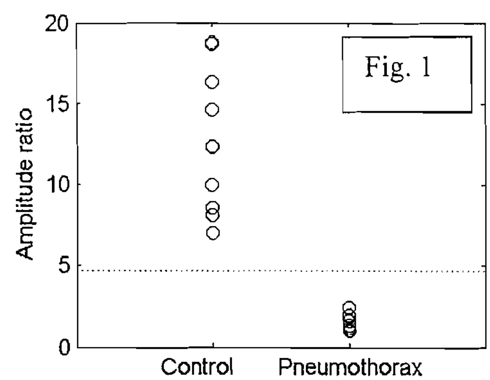
PURPOSE: Pneumothorax (PTX) is a potentially life-threatening condition, especially in critically ill patients. Although usually diagnosed clinically, physical signs may be equivocal, thus leading to delayed diagnosis and possible adverse clinical outcomes. Chest radiography may not always establish the diagnosis, and CT scanning may be impractical given cost, availability and scheduling considerations. We hypothesized that PTX can be detected by computerized analysis of breath sounds.

METHODS: After IRB approval and informed consent, Breath sounds were recorded in 20 subjects (10 controls and 10 with PTX) during 3 deep breaths using electronic stethoscopes. Sound signals were digitized and processed using a personal computer where the breath sound amplitude variability during the cycle was calculated.

Results: The inspiratory breath sound variability (in the 400-600Hz, Fig 1) was smaller in the PTX group, which is consistent with ventilation reduction due to PTX. The variability was significantly different ($p < 0.0001$, rank sum test) between the control and PTX groups. In addition, the two groups can be separated with a 100% accuracy using a threshold value in the 3-6 range.



Conclusion: Pneumothorax may cause detectible breath sound changes. Further research investigating the clinical utility of automated analysis of breath sounds for PTX diagnosis is warranted.

Acoustic Changes in Pneumothorax and Hemothorax

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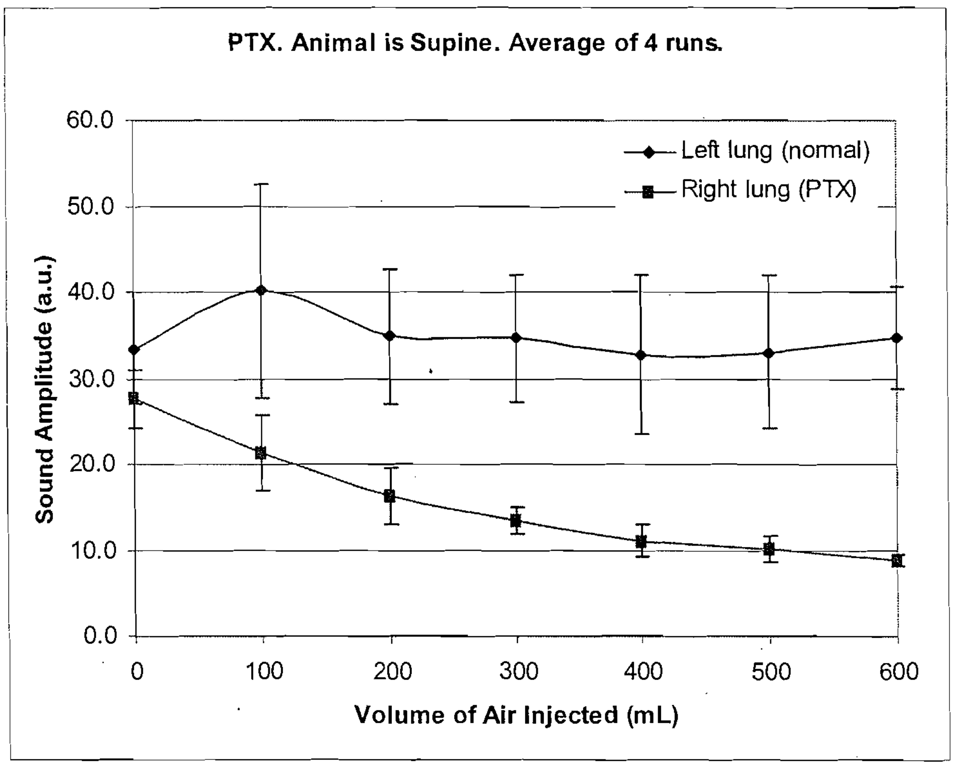
Purpose: The goal of this study was to quantify the acoustic changes in pneumothorax (PTX) and hemothorax (HTX).
Methods: Sequential boluses of air were injected into 2 sedated, ventilated pigs to induce unilateral PTX. Similarly saline was used to simulate HTX. Lung sounds were recorded using a multichannel lung sound analyzer.
Results: When no adventitious sounds were present lung sound amplitude was greater in the normal as compared to either PTX or HTX sides. This amplitude difference was proportional to the amount of air or saline injected. It was observed in both supine and prone positions. Statistically significant differences in sound amplitude were observed in PTXs as small as 100mL.
Conclusion: A quantifiable relationship between the amount of air and/ or saline injected was observed. To see this relationship, however, analysis of segments of the respiratory cycle free of adventitious sounds was required.



Assessment of Swallowing Sounds' Stages with Hidden Markov Model

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Abstract- Swallowing sounds analysis has received much attention recently due to its diagnostic potentials. The process of swallowing is one of the most complicated mechanisms of the body, in which a few different events are occurred in a few milliseconds. The timing and coordination of these events within a breath cycle is crucial for a safe swallow to occur. In order to improve our ability to treat swallowing disorder and to create non-invasive acoustical diagnostic methods, we must develop a detailed understanding of how the swallowing sounds are produced and what the contribution of each swallowing event is to the sounds that are heard and recorded as swallowing sounds. This paper presents a Hidden Markov Model (HMM) of the swallowing sounds, in which it is shown for the first time that the swallowing sounds have three stages. The number of stages was found to be very consistent between the subjects and the bolus textures implying the robustness and fitness of the model.

Acoustic nocturnal long-term recording as a diagnostic option of initial unclear cough in sleep – a case report

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The benefit from acoustic nocturnal long-term recording in a 58-year-old man with initial unclear, chronic persistent dry cough in sleep is reported. Physical examination, lung auscultation and lung function in the daytime showed no pathological findings. The technique of acoustic nocturnal long-term recording proved the existence of significant nocturnal bronchial obstruction in addition to cough. The parallel polysomnography revealed a disturbed sleep structure with frequent transitions to wake. In addition with the findings of a computed tomography of the paranasal sinuses and an ENT (ear, nose and throat department) consultation we could find a sinubronchial syndrome with chronic sinusitis and postnasal drip syndrome as the cause of nocturnal cough and distinct bronchial obstruction. With appropriate treatment the clinical course improved significantly within a few days, as could be seen in the additional acoustic nocturnal long-term recording.

OBSERVATIONS ON THE UTILITY OF COMPUTERIZED LUNG SOUND ANALYSIS IN A THORACIC SURGICAL INTENSIVE CARE UNIT

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Thoracic surgery patients need very close monitoring in the immediate post-operative period. Atelectasis, pneumothorax, exacerbation of chronic obstructive lung disease, congestive heart failure and pneumonia are of particular concern. Each of these conditions is associated with changes in lung sounds, however the assessment of these sounds is subject to observer variability. We used a multichannel lung sound analyzer (Stethographics, Inc. Model 1605) to examine some of these patients. The objective information obtained on the patterns of lung sounds provided some very interesting findings. We would like to present our preliminary data in some post-operative thoracic patients. Comparing a simple pneumonectomy with an extrapleural pneumonectomy lung sounds suggested that the presence of pleura dampens the sounds in the empty lung cavity. An exacerbation of obstructive airways disease was detected promptly and distinguished from congestive failure. These findings suggest that computerized lung sound analysis has the promise of providing a non-invasive method to aid in the management postoperative surgical patients.

MEASURING MINIMUM CRITICAL FLOW FOR NORMAL BREATH SOUNDS

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Abstract- Relationship between respiratory sounds and flow has always been of interest for researchers and physicians. However, the flow-sound relationship at very low flow rate has been questionable because breath sounds must exceed a minimum flow in order to be audible and different from the background noise. This study aimed to find the minimum critical flow rates for respiratory sounds to be audible and different from background noise. Tracheal and lung sound signals of healthy subjects in two groups of adults (12 subjects) and children (9 subjects) were studied. The values of minimum critical flow were determined comparing the spectrogram of the respiratory sounds at very low flow with that of during breath hold. The values of minimum critical flow for tracheal sounds were found to be 2.8 ± 1.5 ml/s/kg and 1.6 ± 1.4 ml/s/kg for adults and children, respectively. The minimum critical flow for lung sounds were found as 4.2 ± 1.9 ml/s/kg and 3.0 ± 2.5 ml/s/kg for adults and children, respectively.

SESSION IV – PHYSIOLOGIC MEASUREMENT AND TECHNIQUES

Session Chairs – Sonia Charleston and Leontios Hadjileontiadis

Session IV **Physiologic Measurement and Techniques**

Session Chairs: Sonia Charleston and Leontios Hadjileontiadis

3:00 p.m. *Changes in Cough Sound Characteristics of Guinea Pigs Associated with Changes in Airway Resistance*
J.W. Day, J.S. Reynolds, J.B. Day, and D.G. Frazer, National Institute for Occupational Safety and Health, USA

3:15 p.m. *Relationship of Respiratory Flow Rate to Breath Sounds Measured at the External Ear*
G. Pressler, H. Pasterkamp, S. Kraman, and G. Wodicka, Purdue University, USA, University of Manitoba, Canada, and University of Kentucky, USA

3:30 p.m. *Auscultation Through a Shirt: Sinful or Saintly?*
S. Kraman, University of Kentucky, USA

3:45 p.m. *Prolongation of the Expiratory Phase in Chronic Obstructive Lung Disease*
R. Murphy, A. Vyshedskiy, R. Paciej, A. Wong-Tse, and D. Bana, Brigham and Women's/Faulkner Hospitals, USA

4:00 p.m. *Robust Flow Estimation Using Tracheal Sounds Entropy*
A. Yadollahi and Z. Moussavi, University of Manitoba, Canada

4:15pm *Before There Was Auscultation*
J. Thierman, A. Vyshedskiy, R. Murphy, Faulkner Hospital, USA

4:30 p.m. **Closing Comments**
Steve Kraman, ILSA President

SESSION IV - ABSTRACTS

Changes in Cough Sound Characteristics of Guinea Pigs Associated with Changes in Airway Resistance

J. W. Day, J. S. Reynolds, J. B. Day and D. G. Frazer

It has been shown that citric acid exposure is responsible for time dependent, chemically induced, alterations in airway resistance. A system was developed which was capable of exposing guinea pigs to aerosols of citric acid (0.39 M, count median diameter = 3.2µm) while simultaneously measuring cough sound characteristics and specific airway resistance ($R_{aw}C_g$ / $P_{ambient}$, where R_{aw} = airway resistance, C_g = compliance of thoracic gas, and $P_{ambient}$ = ambient pressure). Following exposure to citric acid, both cough sounds and specific airway resistance were recorded over a 10 minute recovery period for each guinea pig (N = 6) . Coughs were separated into 3 groups based on measured values of $R_{aw}C_g$ immediately before each cough. Several parameters were used to describe the coughs based on time dependent, octave, and power spectral analyses. A principal component analysis was performed to reduce the redundancy within the data set. The principal components representative of alternate coughs for each guinea pig were used to train a neural network classifier employing back propagation. Results of an ROC analysis demonstrated it was possible to discriminate between coughs with high and low specific airway resistance with an accuracy of 0.90. When the sensitivity and specificity of correctly identifying coughs in the two groups were equal they had a value of 0.81.

Relationship of Respiratory Flow Rate to Breath Sounds Measured at the External Ear

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Respiratory monitoring during athletic activity and other clinical and occupational settings would benefit from a method that does not obstruct the airway. The ear canal provides a novel, unobtrusive location for breath sound measurement. Eleven adults were studied to determine the relationship between volumetric flow rate and breath sounds measured at the ear. Six different test configurations were used: mouth, nose, and mouth-and-nose breathing, each with and without a pneumotachograph. Without a pneumotachograph, flow rate was measured by inductive plethysmography. The power spectral density for a given subject and configuration generally maintained a characteristic spectral shape, but varied in amplitude with changes in flow rate. The relationship between flow rate (F) and sound power between 300 and 600 Hz (P) followed the general form $P=AF^B$. The mean value of B for a given respiratory phase and breathing route ranged from 3.6 to 5.1 across all of the subjects, with a coefficient of determination (R^2) above 0.8 when a pneumotachograph was used to measure flow rate. These findings support the potential monitoring of respiratory flow rate from breath sounds measured at the external ear.

AUSCULTATION THROUGH A SHIRT: SINFUL OR SAINTLY?

Steve S. Kraman, M.D.

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Doctors are exhorted to always place the stethoscope directly on the skin and never to auscultate through clothing. Nevertheless, casual observation both as a doctor and patient reveals that doctors and even pulmonologists often violate this principle. What do they hear? Are they going through the motions or can they effectively auscultate through a shirt? I could find no studies that address this question. The present study was designed to evaluate the sensitivity of two common stethoscopes (Littmann Classic and Littmann Master Cardiology) under conditions of light (60 to 100 gm), medium (240 gm) and heavy (555 gm) pressure when placed on a lung sound test platform with one or two layers of cloth (T shirt material or flannel) interposed between the stethoscope and the test surface (the Bioacoustic Transducer Tester [BATT] driven by amplified white noise). The amplitude spectra were compared over a range of 0 to 2000 Hz. RESULTS: Compared to the sensitivity on a bare BATT surface, either fabric in single or double layers attenuated the sounds by 5 to 30 dB under light pressure. This attenuation was nearly abolished at all examined frequencies by the addition of heavy pressure on the stethoscope head. CONCLUSION: The deleterious effect of one or two layers of indoor clothing on lung sounds heard through a stethoscope can be negated by pressure on the stethoscope head making effective auscultation possible.

Prolongation of the Expiratory Phase in Chronic Obstructive Lung Disease

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Purpose: The expiratory phase of respiration is commonly described as prolonged in patients with Chronic Obstructive Pulmonary Disease (COPD). The goal of this study was to quantify the degree of this expiratory sound prolongation in patients with COPD as compared to normals.
Methods: We studied 38 patients with COPD and 43 normals using a multichannel lung sound analyzer (Stethographics, STG1602) as previously reported. The ratio of the duration of inspiration to expiration (R1) was measured on time-amplitude plots from the microphone placed over the trachea.
Results: R1 averaged 0.67±0.16 in the COPD patients and 0.83±0.16 in the normals ($p<0.0001$). The frequency distribution of R1 is shown in Figure 1. R1 equal to or less than 0.6 was observed in 39% of COPD patients, but only in 9% of normals. R1 equal to or less than 0.5 was observed in 18% of COPD patients, but only in 2% of normals. The sensitivity of R1 equal to or less than 0.6 was 0.39, the specificity was 0.91, and the positive predictive value was 0.79.
Conclusion: As expected a relatively prolonged expiratory phase was more common in COPD than normals. Values of R1 less than 0.6 were particularly more common in COPD than normals. However, low R1 values were seen in some normals and relatively high values were seen in some COPD patients.
Clinical Implications: A simple test using a lung sound analyzer that requires little patient cooperation can identify the presence of prolonged expiration consistent with COPD. Although the test has relatively low sensitivity, the relatively high specificity can help guide the selection of patients for further evaluation.

ROBUST FLOW ESTIMATION USING TRACHEAL SOUNDS ENTROPY

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Abstract-The relationship between respiratory sounds and flow is of great interest for researchers and physicians. Due to difficulties and inaccuracy of the flow measurement techniques, several researchers have attempted to estimate flow from respiratory sounds. However, all of the proposed methods heavily depend on the availability of different rates of flow for calibration of the model, which makes their use limited by a large degree. In this paper, a robust and novel method for estimating flow using entropy of the band pass filtered tracheal sounds is proposed. The proposed method is independent of the flow rate chosen for calibration; it requires only one breath for calibration and can estimate any flow rate even out of the range of calibration flow. The method was tested on data of 10 healthy subjects at three different flow rates. The estimation error was found to be 7.3 ± 2.0% and 7.4 ± 3.2% for inspiration and expiration phases, respectively.

Before there was Auscultation: A Review of the History of Percussion from Auenbrugger (1761) to a New Medical Percussion Device

Jonathan S. Thierman, Andrey Vyshedskiy, PhD, Raymond Murphy, MD

Laennec is famous as the inventor of auscultation since his discovery in 1815 that the heart could be heard through a cylinder of paper applied to the patient's chest and held to the physician's ear. However, 54 years earlier in 1761, a German physician, Auenbrugger wrote a treatise on medical percussion, opening a new era in the scientific rationale of the practice of medicine. In this talk, we review the history of percussion from the origins with Auenbrugger, to its popularization under the fame of Napoleon Bonaparte's physician Corvisart who embraced the practice of percussion. We review the results of experiments performed by Cammann and Clark in 1840 in which a method of auscultatory percussion was used to accurately locate the borders of organs. We will also discuss more recent experimental results by Guarino from the 1990's. Finally, we present some of our own results obtained with a novel percussion-stethoscope device we designed and are testing as a means to increase the sensitivity and reliability of the percussion exam.