A MULTICHANNEL AUTOREGRESSIVE MODEL APPLIED TO ACOUSTIC INFORMATION IN DIFFUSE INTERSTITIAL PNEUMONIA

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A group of respiratory diseases called diffuse interstitial pneumonia (DIN) cts a significant number of people and shares clinical, radiological and functional ings making difficult their diagnosis at early stages. The former situation produces ibly the progress of the pneumopathology making it irreversible in a short period. erent imaging and laboratory techniques such as planar X-ray radiography, X-ray outed tomography and biopsy permit to evaluate DIN severity; however, they can ly be applied in a routine basis to evaluate pneumonia progress. In consequence, the lopment of non-invasive tools for diagnosis of DIN appears suitable.

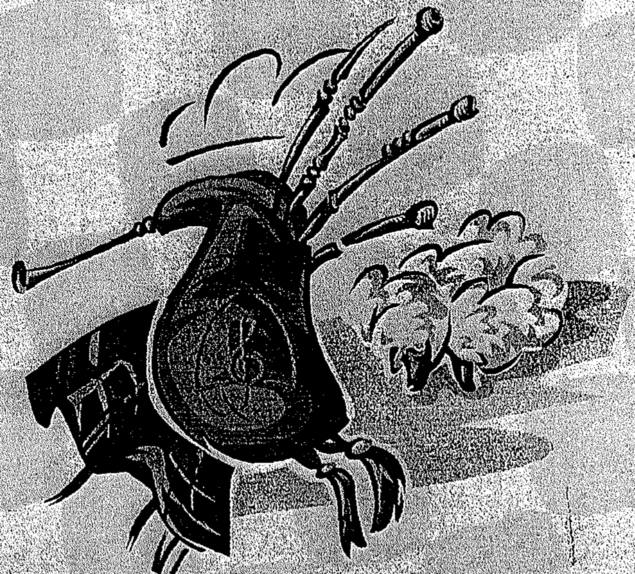
erent efforts have been focused on classify normal and abnormal respiratory sounds verse pneumopathologies using two to five microphones on the thoracic surface. The tic signal processing is made on a channel per channel basis, i.e., in a univariate ach, using feature extraction techniques such as spectral frequency parameters and nodel coefficients. Regarding the classification task, K-NN classifiers or supervised l networks have been employed. This work proposes the use of multichannel gressive model applied to the inspiratory phases obtained from healthy subjects and ts with DIN. Multichannel AR model combined spatial acoustic information, which sent during DIN.

coustic signals were acquired with a sampling frequency of 7000 Hz at airflows of timately 1.0 L/sec. The inspiratory phases were segmented in automatic fashion and phase was divided in thirty windows with an overlapping of 25%. From each w, a fourth order multichannel AR model was computed. Afterward the sionality of the feature vector was reduced by applying singular value position. A supervised feedforward neural network, with backpropagation and on Levenberg-Marquardt adaptation rule, was implemented for classification e. After the network was trained with 874 feature vectors the results validated with ure vectors showed a sensitivity of 85% and specificity of 88%. According to this stic capacity, also a positive predictive value of 88% and a negative predictive f 84% were found.

oposed methodology provided a moderate performance, but it seems promising to acoustic information in patients with DIN.

29th ANNUAL CONFERENCE OF

THE INTERNATIONAL LUNG SOUNDS ASSOCIATION



GLASGOW, SCOTLAND
9th-10th SEPTEMBER 2004

PROGRAM AND ABSTRACTS

29th ANNUAL CONFERENCE OF THE INTERNATIONAL LUNG SOUNDS ASSOCIATION

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Venue: **Royal College of Physicians and Surgeons of Glasgow 232-242 Vincent Street, Glasgow G2 5RJ**

September 9–10th 2004

We thank Allen and Hanbury, Boehringer Ingelheim and Astra Zenica for their kind support.

CLASSIFICATION OF LUNG SOUNDS DURING BRONCHIAL PROVOCA USING WAVEFORM FRACTAL DIMENSIONS

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Lung sounds (LS) of children after bronchoconstriction should differ baseline LS in terms of amplitude and pattern characteristics. To test these hypot time-domain and fractal based analyses have been applied to LS acquired from children ages 9-15 y pre- and post-methacholine challenge (MCh). Change in f expiratory volume in 1 s after MCh ranged from -4% to -37%, with change proportio severity of bronchoconstriction. Sounds were recorded over the posterior right lower lobe while subjects breathed normally for 60 s with flow measurement, and during 1 breath hold (BH). From root-mean-square (RMS) of LS and BH signals, signal-to- ratio (SNR) was determined. Two fractal dimension (FD) algorithms were applied, on signal variance and morphology. Feature vectors for 1-nearest-neighbor classific contained FD and RMS values within flow plateau ranges. Results for LS within 75 Hz indicate that the combination of RMS-SNR and morphology-based FD values c better classification of bronchoconstriction with LS, relative to using RMS-SNR variance-based FDs and RMS-SNR alone. True positive classification was 90.3%, 6 and 58.3% respectively, and false positive classification was 23.4%, 24.9% and 2 respectively. Both RMS-SNR and FD values provide useful insight into LS changes bronchoconstriction.

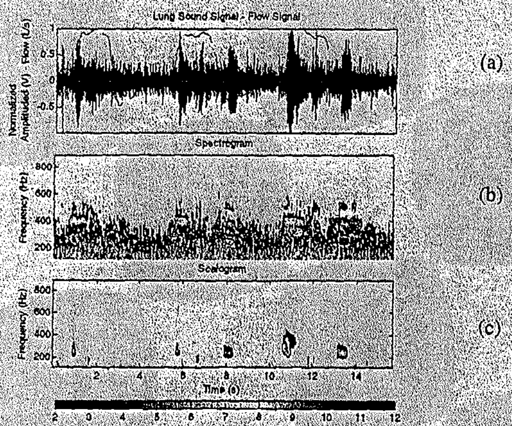


Fig. 1 Experimental results of the CWT-WED on severely contaminated wheezing episodes.

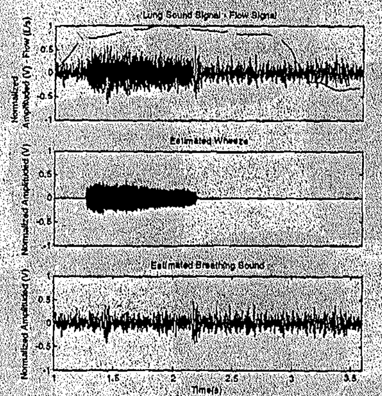


Fig. 2. The denoising performance of the CWT-WED using ICWT.

It is with great pleasure that we welcome you to the 29th International Lung Sounds Conference in Glasgow. The Society was started by Robin Loudon and Ray Murphy who are both hoping to be with us at this year's conference. Glasgow is a particularly appropriate place to hold the conference as Robin Loudon was brought up in Scotland. Ray Murphy also has very strong Celtic connections as his family comes from Ireland.

Unfortunately Robin has not been able to attend recent conferences and the Symposium on Cough on Thursday morning has been designed as a tribute to him. His original work involved analysing cough in patients suffering from tuberculosis and it was this interest in cough that later developed into his long association with lung sounds research.

The venue for this year conference is the Royal College of Physicians and Surgeons of Glasgow. The College was founded in 1599 and in 1862 the college acquired No 242 St Vincent Street to which it has since added the adjacent properties giving it now the magnificent frontage of 232 - 242 St Vincent Street. In addition to its impressive buildings the College has a library collection that includes many valuable manuscripts and early printed works, historical medical and surgical texts, as well as modern books and journals.

INTERNATIONAL LUNG SOUNDS ASSOCIATION ANNUAL CONFERENCE 2004

Sessions

Session I ~ Cough symposium

Session II ~ Poster session

Session III ~ Signal processing

Session IV ~ Lung sounds and disease

Session V ~ Teaching and testing

Session VI ~ Lung sounds and disease

Programme

Thursday, 9th September

08:45-09:15 *Registration*

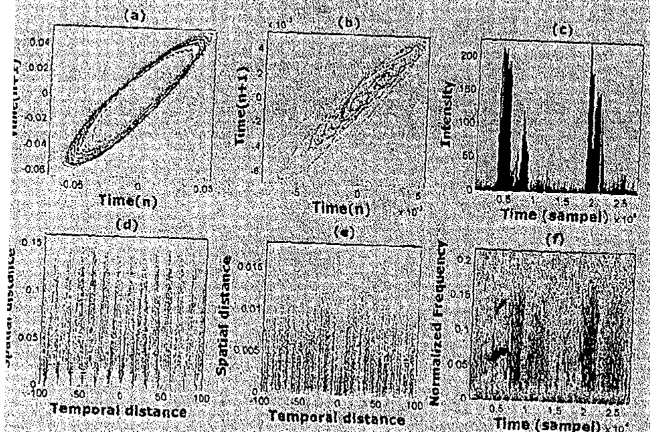
09:15-09:25 *Welcome & Opening Remarks Ken Anderson*

WHEEZE EPISODE REPRESENTATION IN THE CONTINUOUS WAVEI TRANSFORM DOMAIN

Stella A. Taplidou[1], Leontios J. Hadjileontiadis[1], Volker Gross[2], Thomas Penz Stavros M. Panas[1]

[1]Dept. of Electrical & Computer Engineering, Aristotle University of Thessalor Thessaloniki, Greece (leontios@auth.gr) [2]Dept. of Medicine, Div. Pulmonary anc Care Med, Philipps-University Marburg, Germany (www.lung-sound.de)

Wheezes are important in the diagnosis of lung pathology, since they are connected to severe pulmonary dysfunctions, such as asthma and chronic obst pulmonary disease. So far, many research efforts have been focused on the aut detection of wheezes in the breathing cycle involving time or frequency domain a of the recorded lung sounds. In this paper, a new approach in the wheeze detec proposed, based on the continuous wavelet transform (CWT). The CWT take account both the time and frequency representation of the lung sound signal revealing its characteristics that can be used in the wheeze identification. In partic CWT-wheezing episode detector (CWT-WED) is formed by taking the CWT usi Morlet wavelet, as an analysis basis. In this way, the distinct frequency peak characterize the wheeze frequency representation (mainly in the area of 100-1000 H revealed as they evolve over time. Figure 1 shows an example of the w representation in the CWT domain. As it is clear from Fig. 1, the wheeze episodes 1(a)) produce distinct harmonic peaks in the time-frequency representation of the time Fourier transform (STFT), shown in Fig. 1(b). However, a more clear represen of the wheeze is seen in the time-scale domain (Fig. 1(c)), where the output of the WED is depicted. As it is apparent from Fig. 1(c), simple thresholding automatically isolate the area of importance and through the inverse CWT (ICWT) noised version of the wheeze in the time domain can be achieved. This is depicted i 2, from where the localization accuracy of the CWT-WED in identifying both in the (though the ICWT) and frequency (through CWT) domains the existence of a wheez be deduced. On going analysis of wheezes drawn from the Marburg Respiratory S (MaRS) Database (www.lung-sound.de) can lead to the justification of the efficien the proposed CWT-WED scheme.



. Time-delay trajectories (a, b) and space-time separation plots (d, e) from a
g (a, d) and a non-wheezing (b, e) segment. Wheezing detections for the whole
re indicated in (c) as the intensity exceeds a threshold. For comparison, the
g segments are illustrated at time $0.5 \cdot 10^4$ and $2 \cdot 10^4$ in a spectrogram (f).

SESSION I – COUGH SYMPOSIUM

09:25-09:30	Steve Kraman	Introduction *Lexington, Kentucky USA*
09:30-10:00	John Widdicombe	Historical Perspective *London UK*
10:00-10:30	Jacky Smith	Measurement of Cough *Manchester UK*
10:30-11:00	Shoji Kudoh	Rheological properties of Mucus and Cough *Tokyo Japan*
10:30-10:50	***Coffee Break***	
10:50-11:20	Jean Marie Aerts	Cough Research using an Animal Model *Leuven Belgium*
11:20-11:50	David Frazer	Voluntary Cough *Morgantown, West Verginia USA*
11:50-12:20	Michal Javorka	The Sound of Cough in Health and Disease *Martin, Slovakia*
12:20-12:45	Steve Kraman	The future for Cough Research *Lexington, Kentucky USA*
12:45-13:00	***Group Photograph***	
13:00-14:00	***Lunch***	

SESSION II ~ POSTER SESSION

Chaired by George Wodicka

Posters on Display	*1.00pm onward*
Posters Attended by Authors	*2.00pm onward*
Poster Discussion	*2.30 - 3.30*
Victor Grinchenko et al	About one mechanism of generation of tonal sound in bronchi with a stenosis. *Institute of Hydromechanics NAS of Ukraine, KIEV*
Ray Murphy et al	Automated analysis of squawks *Respiratory, Brigham and Women / Faulkner Hospital, BOSTON, USA*
January Gnitecki et al	The fractality of lung sounds: A comparison of three waveform fractal dimension algorithms. *Department of Electrical Engineering, University of Manitoba, WIINNIPEG, Canada*
Y. Qiu et al	A preliminary study of contact effects of air coupled stethoscopes. *Dept Mechanical Engineering University of Glasgow and Crosshouse Hospital GLASGOW Scotland*
Volker Gross et al	Frequency analysis of lung sounds during bronchial provocation test. *Dept of Respiratory and Critical Care Medicine Philipps University of MARBURG Germany*

WHEEZE ANALYSIS AND DETECTION WITH NONLINEAR STATE-SPACE EMBEDDING

C. Ahlstrom[1], P. Hult[1], B. Schmekel[2], P. Ask[1]
[1]Dept. of Biomedical Engineering, Linköping University, Sweden
[2]Dept. of Medicine and Care, Linköping University, Sweden

Wheezes are abnormal lung sounds indicating airways obstructions, relevant to dise such as chronic obstructive pulmonary disease (COPD) and asthma. The sounds are characterized by their musical nature, in contrast to the chaotic behavior of normal l sounds.
Our new wheeze detection method is based on concepts originally developed for no time series analysis. A segment of the lung sound signal is transformed into a traject m-dimensional state space using Takens' delay embedding theorem. The distance be pairs of points on the trajectory is calculated and their state-time separations are computed. A normalized periodicity histogram of the state-time separation is characterized by distinct peaks for wheezing regions, or by the absence of such peak non-wheezing regions. The method is most successful for wheeze localization and sl promise as a viable technique. Applying this method to signals from five patients demonstrates adequate results where all wheeze periods were correctly detected.

OBSERVATIONS MADE WITH A MULTI-CHANNEL LUNG SOUND ANALYZER

ymond Murphy, MD [1]*, Andrey Vyshedskiy, PhD [1], Anna Wong-Tse, RN [1], zanne Paciej, BS [1] and Fran Power-Charnitsky, BS [1], [1] Respiratory, Brigham and Women / Faulkner Hospital, Boston, MA, UNITED STATES OF AMERICA

d on the belief that lung sounds reflect underlying pulmonary physiology pathophysiology we have been studying these sounds with a multichannel sound analyzer (STG16). We have calculated lung sound amplitude and tified adventitious lung sounds in over 700 patients. Clinically important rvations based on these findings include the following:

A wheeze rate of greater than 4% is not found in normals. A crackle rate of greater than 3 per breath is not found in normals. Crackles can be found in patients with asthma, but they are usually few in number, i.e. 3±3 per breath. When wheezing and crackles are present in the same afebrile patient, particularly if the crackles are more than 5 per breath, congestive heart failure should be considered as it is more likely to be associated with the presence of both crackles and wheezes.
Patients with COPD often have crackles but these are usually few in number i.e. 5±5 per breath. They are characteristically basilar in location and early inspiratory in timing.
Patients with pneumonia and heart failure tend to have greater numbers of inspiratory crackles than patients with COPD, i.e.6±5 in CHF; 7±5 in PN.
Pneumonia and heart failure are difficult to separate by their pulmonary acoustic findings. One difference is that expiratory crackles are more common in pneumonia than in heart failure. We believe that these observations support the hypothesis that quantification of lung sounds has the promise of providing clinically useful noninvasive diagnostic information.

Yoshitsugu Seo	Decreased fine crackles in supine position in patients with interstitial fibrosis. Analysis with a 16 channel analyzer. *Fourth Dept of Internal Medicine, Nippon Medical School. TOKYO Japan*
Ruqayyah M.	Crackle polarity is influenced by respiratory cycle *Boston Univ and Brigham and Women;s Faulkner Hospitals BOSTON USA*
Stella A. Taplidou	Crackle categorization using wavelet-based energy criteria *Dept Electrical & Computer Engineering Aritotle Univiversity THESSALONICA Greec, Dept of Medicine Philipps University MARBURG Germany*
Norihisa Motohashi	Influence of rheological properties of airway mucus on cough sound generation. *Department of Internal Medicine, Nippon Medical School, Tokyo, JAPAN, Department of Respiratory Medicine. Tokyo Metropolitan Hiro-o General Hospital, TOKYO Japan*
3.30 – 3.45	*Tea*
3.45 – 5.15	*ANNUAL BUSINESS MEETING*
5.30	*Evening Reception in the Royal College of Physicians followed by a guided tour of the Library and College. Buildings led by Mr Beaton.*
7.30	*Evening Dinner at University of Glasgow College Club*

Friday 10th September

SESSION III ~ SIGNAL PROCESSING
Chaired by Ken Anderson and Leontios Hadjileontiadis

09:00-09:20	Berger et al	Velocity and attenuation of sound in the isolated foetal lung as it is expanded with air *Monash Institute of Reproduction and Development, Monash University.* *Newborn Services, Monash Medical Centre CLAYTON, Australia*
09:20-09:40	Davidson et al	The effect of continuous positive airway pressure on lung sounds amplitude. *Brigham and Women's/ Faulkner Hospitals BOSTON, USA*
09:40-10:00	Gnitecki et al	Reproducibility of flow-specific lung sound intensity in healthy children *Dept of Electrical Engineering, University of Manitoba,* *Biology of Breathing Group, Manitoba Institute of Child Health, WINNIPEG, Canada*
10:00-10:20	Takase et al	Effect of background noise subtraction on determination of sound spectral parameters *Dept. of Pediatrics, Nippon Medical School, TOKYO, Japan*
10:20-10:40	Sakao	Body surface friction noise into a stethoscope accelerometer on neck or chest *School of Engineering Kinki University, HIROSHIMA Japan*

10:40-11:00 *Coffee Break*

THE USE OF VISUAL FEEDBACK (SOUNDWAVE PLUS RESPIRATORY DISPLAY) FOR THE TEACHING OF PULMONARY AUSCULTATION

Salvatorie Mangione MD Gregg Lipschik MD

PROBLEM STATEMENT AND BACKGROUND: Chest auscultation is suffering from waning proficiency and declining education. To identify better teaching modalities, we assessed the impact on short -term learning of displaying the soundwave plus respiratory tracing.

METHODS: 123 sophomores from one Philadelphia schools were assigned to a 1-hour teaching session on lung auscultation. Students were divided into a group with visual feedback and one without. Sound recognition and disease identification were measured immediately after the teaching session. Except for the presence or absence of visual feedback, the content and format of the session was identical for both groups.

RESULTS: Of the 123 participating students, 105 (85.4%) completed both pre- and post-teaching assessment, which consisted in the analysis of six sounds, and were thus included in the final evaluation. Of these, 52 (49.5%) had access to soundwave display. There were no significant differences at post-test in *sound identification, disease identification,* and *cumulative sound scores* between the two groups. There were also no significant differences when comparing recognition of the individual sounds.

CONCLUSIONS: Teaching supplemented with visual display does not appear to improve short-term learning. Whether longer teaching sessions might benefit from this modality will need to be evaluated.

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Conclusions: 1) The type of coupler head of a lung sound transducer or stethoscope affects the character of the recorded sound in important, sometimes surprising ways. 2) Pressure or weight on the sensor device may or may not significantly affect the recorded sound. 3) The BATT is a convenient and effective device for testing and comparing lung sound transducers.

SESSION IV ~ LUNG SOUNDS AND DISEASE
Chaired by Hans Pasterkamp and Steve Kraman

11:00-11:20	Murphy et al.	Upper lung bronchial breathing in pulmonary tuberculosis *Respiratory, Brigham and Women / Faulkner Hospital, BOSTON, USA*
11:20-11:40	Ishikawa et al	Sound transmission in the lung of patients with bronchial asthma *Tufts Lung Station, Caritas St Elizabeth's Med. Ctr., Tufts Univ. School of Medicine, BOSTON, MA., U.S.A.*
11:40-12:00	Kiyokawa et al	The expiratory volume without generating rale was correlated airflow obstruction in bronchial asthma *Department of Internal Medicine, Social Insurance Kamata General Hospital, TOKYO, Japan* *Department of Respiratory Medicine, Higashisaitama National Hospital, SAITAMA, Japan*
12:00-13:30	***Lunch***	

SESSION V ~ TEACHING AND TESTING
Chaired by John Earis and Kudoh Shoji

13:30-13:50	Kraman et al	A bioacoustic transducer testing (BATT) system *University of Kentucky, LEXINGTON Kentucky, U.S.A.* *Purdue University, WEST LAFAYETTE, U.S.A.* *University of Manitoba, WINNIPEG, Canada*
13.50- 14.10	Kraman et al	Transducer and stethoscope testing using the bioacoustic transducer testing (BATT) system *University of Kentucky, LEXINGTON, Kentucky, U.S.A.* *Purdue University, WEST LAFAYETTE, U.S.A.* *University of Manitoba, WINNIPEG, Canada*
14.10-14.30	Mangione et al	The use of visual feedback (soundwave plus respiratory display) for the teaching of pulmonary auscultation *Jefferson Medical College, Thomas Jefferson UniversityE PHILADELPHIA, USA*
14.30-14:50	Murphy et al	Observations made with multi-channel lung sound recordings *Respiratory, Brigham and Women / Faulkner Hospital, BOSTON, USA.*

14.50-15.10 Coffee

TRANSDUCER AND STETHOSCOPE TESTING USING THE BIOACOUSTIC TRANSDUCER TESTING (BATT) SYSTEM

Steve S. Kraman[1], Hans Pasterkamp[2], George R. Wodicka[3] and Gary Pressler[3]
[1]University of Kentucky, Lexington, Kentucky, U.S.A., [2]University of Manitoba, Winnipeg, Manitoba,
CA and [3]Purdue University, West Lafayette Indiana, U.S.A.

<u>Methods and Protocol:</u>
We used the BATT system to evaluate a variety of lung sound transducers and stethoscopes. The electrical input was white noise. All stethoscope evaluations were performed using a Radio Shack electret microphone as the transducer. When tubing was left connected to the stethoscope head, the unused earpiece was occluded with putty or with another identical microphone. Test transducers and stethoscopes were:

- 3 different electret microphones in the same plastic coupler (chamber 10 mm width and 2 mm depth. One was evaluated with and without extra mass loading (1 oz).
- Standard Littman stethoscope, diaphragm and bell with and without tubing connected
- Tycos, 3-head stethoscope
- Littman Master Cardiology stethoscope including effect of mass loading to 48 oz.
- Two electronic stethoscopes: Andries Tek™ and Welch-Allen Meditron™

<u>Findings:</u>
- There was little difference observed between the 3 electret microphones.
- The addition of a one once weight on the Radio Shack microphone within the plastic chest piece extended the upper and lower frequency response of the device.
- The standard Littman head alone (diaphragm) captured a superior bandwidth as compared with both the plastic coupler and the Littman head with tubing.
- There was little difference between the two diaphragms of the Tycos stethoscope and the bell was superior to both diaphragms in smoothness of frequency response.
- The addition of extra weight on the Master Cardiology barely affected the frequency response.
- The Welch-Allen Meditron has an excellent frequency response for lung sounds. The Andries Tec does not and is adequate <u>only</u> for heart sounds.

A BIOACOUSTIC TRANSDUCER TESTING (BATT) SYSTEM

Steve S. Kraman[1], George R. Wodicka[2], Gary Pressler[2] and Hans Pasterkamp[3]

[1]University of Kentucky, Lexington, Kentucky, U.S.A., [2]Purdue University, West Lafayette Indiana, U.S.A. and [3]University of Manitoba, Winnipeg, Manitoba, CA

Since lung sounds were first recorded and analyzed in the 1960s, a wide variety of transducers have been used ranging from consumer grade microphones to manufactured single purpose devices including microphones in a variety of couplers, and accelerometers. However, there is no "standard" lung sound transducer or coupler nor has there been a device to evaluate and compare transducers so that differences in lung sound spectra or waveforms measured in different laboratories can be determined to be of physiologic origin rather than artefacts of the equipment used. To address this problem, we have designed and constructed a test device, the Bioacoustic Transducer Tester (BATT) that provides a stable and reproducible sound source and a test surface that is mechanically and acoustically similar to human skin and subcutaneous tissue. We designed the device to be equally suitable for microphones enclosed in couplers and for contact accelerometers. The device consists of a rigid chamber containing a loudspeaker and an opening to a mechanically stable antechamber that is in turn covered by a 7 mm thick commercially available viscoelastic material (Akton™). We found the acoustic amplitude at the surface to be relatively uniform from 100 to 1200 Hz. when driven by a white noise source We compared the viscoelastic layer to similar thicknesses of fresh meat and fat and found them to be acoustically equivalent. When driven by a recorded normal lung sound signal, the surface output spectrum as measured by the microphone in coupler was virtually identical to the spectrum of the electrical input. We conclude that the BATT system allows both air-coupled transducers and accelerometers used in respiratory sounds measurements to be compared under conditions similar to their intended use.

SESSION VI ~ LUNG SOUNDS AND DISEASE
Chaired by Anssi Sovijarvi and Ray Murphy

15.10-15:30	Ahlstrom et al	Wheeze analysis and detection with nonlinear state-space embedding *Dept. of Biomedical Engineering, Linköping University, Sweden and Dept. of Medicine and Care, LINKÖPING University, Swedenas*
15.30-15.50	Taplidou et al	Wheeze episode representation in the continuous wavelet transform domain *Dept. of Electrical & Computer Engineering, Aristotle University of Thessaloniki, THESSALONICA, Greece* *Dept. of Medicine, Div. Pulmonary and Crit. Care Med, Philipps-University MARBURG, Germany*
15.50-16.10	Gnitecki et al	Classification of lung sounds during bronchial provocation using waveform fractal dimensions *Dept of Electrical Engineering, University of Manitoba,* *Biology of Breathing Group, Manitoba Institute of Child Health, WINNIPEG, Canada*
16.10-16.30	Charleston et al	A multichannel autoregressive model applied to acoustic information in diffuse interstitial pneumonia *Universidad Autónoma Metropolitana-Iztapalapa, MEXICO CITYy, Mexico* *Instituto Nacional de Enfermedades Respiratorias, MEXICO CITY, Mexico*
16.30-16.45	Hans Pasterkamp	Closing remarks

SESSION II

POSTERS

SESSION V

TEACHING AND TESTING

THE EXPIRATORY VOLUME WITHOUT GENERATING RALE WAS CORRELATED AIRFLOW OBSTRUCTION IN BRONCHIAL ASTHMA

Hiroshi Kiyokawa[1], Makoto Yonemaru[2], Takeo Kawashiro[2]

1) Department of Internal Medicine, Social Insurance Kamata General Hospital, Tokyo, Japan
2) Department of Respiratory Medicine, Higashisaitama National Hospital, Saitama, Japan

Hypothesis: We considered the expiratory volume without generating rale (VtoR) under slow vital capacity (SVC) manoeuvre can be a quantitative indicator of obstructive ventilatory impairment.
Subjects: Adult non-smoker patients of bronchial asthma without recent history of respiratory infection.
Methods: The breath sounds were recorded through a pneumotachometer-equipped-microphone during the subjects performed a SVC manoeuvre for spirometry. The VtoR was determined with the breath sound analysis and the time-volume curve.
Results: Three asthmatic patients underwent 16 measurements. We found that the VtoR was significantly correlated with FEV1.0, PEF as well as FEV1.0%.
Conclusion: Since PEF is utilized for daily management of asthma, the VtoR may serve as a less effort-required parameter for monitoring obstructive impairment in patients with asthma.

Keywords: obstructive ventilatory impairment, lung sounds analysis, spirometry, bronchial asthma

ABOUT ONE MECHANISM OF GENERATION OF TONAL SOUND SIGNALS IN BRONCHI WITH A STENOSIS

Victor T. Grinchenko, Igor V. Vovk.
Institute of Hydromechanics NAS of Ukraine, Kiev vin-igm @gu.kiev.ua

A hypothesis about of possible mechanisms of occurrence of Wheezes (tonal sound signal) in human bronchial tree at its pathologies is put forward. It is supposed that viscous sputum allocated in affected airways, can form aerodynamic structures of the nozzle-jet-obstruction type. At the act of breathing a stenosis forming a high-speed jet plays the role of a nozzle. The other stenosis, bifurcation of the airways or the sputum formations can play the role of an obstruction. The check the mentioned hypothesis the experimental installation was used. This last included the physical model of an airway along with the equipment for registration and processing of the sound signal and estimation of the airflow velocity. As a result of experiments it was shown that presence of specified aerodynamic structures provides an efficient transformation of energy of stream in airways to the sound fluctuations, which spectra are similar to the spectra of the wheezes. The threshold values of the flow velocities at which the tonal sound fluctuations start to arise are estimated. It is shown that with increasing the relative distance a stenosis forming a jet and an obstruction, the threshold Reynolds numbers and the threshold frequencies of the tonal signal tend to decrease, and threshold Strouhal numbers tend to increase.

AUTOMATED ANALYSIS OF SQUAWKS

Raymond Murphy, MD [1*], Andrey Vyshedskiy, PhD [1] and Rozanne Paciej, BS [1]. [1]
Respiratory, Brigham and Women / Faulkner Hospital, Boston, MA, UNITED STATES OF AMERICA .

Abstract:
Squawks are short, isolated, end-inspiratory wheeze-like sounds, which are associated with pneumonia as well as hypersensitivity pneumonitis and other fibrotic disorders. We have previously demonstrated that squawks can provide relatively specific—although not very sensitive—evidence of pneumonia (1). We now report that we have developed a squawk detection algorithm. The algorithm was tested in 759 subjects. The computerized analysis was done using a multi-channel lung sound analyzer (Stethographics STG 16). Squawks were detected by the algorithm in 31 patients and by auscultation in 24 patients. The auscultatory findings were confirmed by inspection of the time-amplitude plots of the sound showing the characteristic waveform patterns of squawks as previously described (1). The sensitivity of the algorithm for detection of squawks heard by auscultation was 0.75; the specificity was 0.98; the positive predictive power was 0.58; and the negative predictive power was 0.99. As squawks are indicative of significant illness we believe that automated analysis by providing objective documentation of their presence has the promise of aiding clinicians in the diagnosis of theses conditions.

Ref. 1. R Paciej, A Vyshedskiy, D Bana, R Murphy, Squawks in pneumonia, Thorax 2004;59:177-179.

29th Annual Conference of ILSA

SOUND TRANSMISSION IN THE LUNG IN PATIENT WITH BRONCHIAL ASTHMA

S.Ishikawa, N.Aoun, E.Yalez, K.F.Macdonell and B.Celli
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Tufts Univ. School of Medicine, BOSTON, MA.,U.S.A.

To study Sound transmission (transit time) through the lungs ,we introduced monophonic 150 Hz sound at the mouth of 17 Normal subjects and 17 patients with Bronchial asthma at Total lung capacity with glottis open. In order to ensure the glottis is fully open, each subject were instructed to hold the speaker chamber next to the mouth to take a full inspiration then close the lips around the mouthpiece and expire very slowly through a plastic straw which is attached to the mouthpiece . Lung sound signals were recorded over the neck near the trachea (reference)and 14 sites on the chest surface with contact micro-phones using Murphy's STG 16 system , at sitting position.
Sound signals were digitized and time expanded wave form displayed. Transit time was measured by using a cross correlation technique.
We found transit time were as follows:

	Normal	B. Asthma
Rt Upper zone	1.316 ± 0.565	2.771 ± 1.342
Middle	1.404 ± 0.626	4.095 ± 1.873
Lower zone	1.356 ± 0.808	4.117 ± 1.063
Lt Upper zone	1.246 ± 0.135	2.652 ± 1.414
Middle	1.319 ± 0.015	3.486 ± 1.844
Lower zone	1.459 ± 0.135	4.094 ± 1.955
MEAN ± SD	1.372 ± 0.076	3.577 ± 1.751

In patients with Bronchial asthma,transit times were much higher than normal subjects and veried significantly within different region of the lung..

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UPPER LUNG BRONCHIAL BREATHING IN PULMONARY TUBERCULOSIS

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Pulmonary tuberculosis is associated with abnormal sounds recognized by clinicians since the elegant descriptions of these sounds by Laennec nearly 200 years ago. Since the advent of the chest x-ray less attention has been paid to auscultatory findings as the x-rays have been considered to be more reliable. Observer variability and lack of objective documentation likely contributed to the lack of interest in auscultation. We used a multichannel lung sound analyzer (STG16) to study the sounds of patients with pulmonary tuberculosis. We observed bronchial breathing to be present in the upper chest in 4 of the 10 subjects studied. Bronchial breath sounds were not seen in the upper chest in 50 normal subjects studied in a similar fashion. They were seen in only 2% of 161 patients with a variety of common illnesses (0 of 57 with COPD, 1 of 50 with CHF, 1 of 54 with pneumonia and in 3 of 16 with interstitial pulmonary fibrosis (IPF)). IPF is easily distinguishable from tuberculosis by the presence of numerous crackles. These data suggest that the presence of bronchial breathing in the upper chest can be a useful sign of tuberculosis in situations where chest x-rays are not readily available.

THE FRACTALITY OF LUNG SOUNDS: A COMPARISON OF THREE WAVEFORM FRACTAL DIMENSION ALGORITHMS

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Three waveform fractal dimension (FD) analyses of flow-specific lung sounds (LS) have been compared to examine the fractal nature of these signals. LS were recorded from five females, ages 24-40 y, breathing at flows between 0.353 ± 0.063 and 2.723 ± 0.331 L/s (mean ± SD) within a single recording, with simultaneous flow measurement (flow sensor with mouthpiece and noseclip). FDs of time-domain LS were calculated within three running windows: 200, 100, and 50 ms. Three techniques for waveform FD calculation were applied, based on: 1) signal variance; 2) non-normalized signal morphology; 3) signal morphology normalized along both axes within the windows. Sensitivity to y- and x-axis scalings was evaluated by comparing min and max FD values within flow-plateau portions of LS with flow and LS intensity (RMS). Min and max values of both the normalized morphology-based FDs and variance FDs increased with window length, the variance FDs more dramatically. Max values of the non-normalized morphology-based FDs decreased overall (no trend for min values). With LS amplitude, all FDs increased, though the FD method incorporating normalization exhibited the least increase (Table I). Hence, this method may prove useful in the measurement of true changes in LS fractality and deciphering differences between LS in health and disease.

TABLE I
MEAN ± SD FOR MIN AND MAX FD VALUES

FD method	50 ms (512 samples)		100 ms (1024 samples)		200 ms (2048 samples)	
	min	max	min	max	min	max
1)	0.7050 ± 0.0028	1.1816 ± 0.0639	0.8828 ± 0.0038	1.2526 ± 0.1209	0.9815 ± 0.0122	1.4758 ± 0.0711
2)	1.00000021 ± 0.00000002	1.00002613 ± 0.00002098	1.00000022 ± 0.00000003	1.00002026 ± 0.00001602	1.00000022 ± 0.00000003	1.00001651 ± 0.00001262
3)	1.0700 ± 0.0142	1.3204 ± 0.0097	1.1306 ± 0.0328	1.3415 ± 0.0202	1.1661 ± 0.0108	1.3627 ± 0.0169

A PRELIMINARY STUDY OF CONTACT EFFECTS OF AIR COUPLED STETHOSCOPES

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As computer techniques to help analyse breath sounds become more widespread, it is becoming more important to have an accurate way of calibrating the measurement transducers. Commonly used breath sound sensors are usually either those measuring vibration acceleration or velocity (surface vibration type), or those based on a microphone and an air coupler (stethoscopes). Existing calibration techniques do not adequately deal with the problem of contact effects between the transducer and the measurement surface. To our knowledge, no study of the frequency response of a diaphragm type air-coupler in contact use has been reported previously. In this paper a method using a laser Doppler vibrometer (LDV) to study a diaphragm type air-coupler in contact use is proposed.

The experimental results show that there are mutual effects of contact. One effect is on the measured signal, that is, the mass loading of the sensor distorts the true signal. The other effect is on the chest-piece acoustic properties. These mutual effects have been isolated, and thus the frequency response for contact use has been obtained for certain types of membrane. The calibrated spectrum of a normal subject's tracheal sounds using an estimated contact frequency response compares well with the LDV measurement.

SESSION IV:

LUNG SOUNDS AND DISEASE

BODY-SURFACE FRICTION NOISE INTO A STETHOSCOPIC ACCELEROMETER ON NECK OR CHEST

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An accelerometer-type stethoscopic sensor is sensitive to noise caused by accidental touching or rubbing the cable or body surface with cloth etc., while it has high sensitivity over wider frequency range than air-coupled microphones. The author reported that cable-touching noise can be prevented by putting a mass (pre-amplifier) near the sensor. This time, investigation was made on noise caused by body-surface friction, about under what conditions rubbing the skin can make significant noise in the sensor output. The sensor was set on places of actual use, that is, on neck or chest, and nearby skin was rubbed by a finger in different directions. Though the force etc can not be exactly reproduced, the followings were found: Significant noise is made only when the rubbing occurred fairly near the sensor, typically within 10 cm. Though not yet fully established, it is quite likely that rubbing away from the sensor makes larger noise than towards the sensor. Tapping the body surface makes less noise except at low frequencies. In all the cases, noise caused by rubbing the skin is much smaller than that by rubbing/touching the cable neighboring to the sensor (i.e., between the sensor and preamplifier).

FREQUENCY ANALYSIS OF LUNG SOUNDS DURING BRONCHIAL PROVOCATION TEST

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Electronic auscultation and analysis of lung sounds has a great potential for an automatic detection of lung diseases, especially for patients with bronchial obstructions (Soviajärvi, a et al. Eur Respir Rev 2000, 10:77).

We recorded lung sounds from 20 patients with asthma at five different positions with our lung sound analyzer (Gross, v. et al. Am J Respir Crit Care Med 2000; 162: 905-909) during standard bronchial provocation tests. In addition to the wheezing rate (WR) we calculated the median frequencies (f50) for the frequency band between 60-2100hz continuously and computed the mean value of F50 for in- and expiration separately. The results will be compared with the results of lung function test (Rtot).

Based on our results we propose that in addition to the continuous monitoring of the wheezing rate, the determination of the in- and expiratory median frequency in lung sounds is a useful parameter. The final analysis of the data is still in progress and will be presented at the ILSA-meeting.

DECREASED FINE CRACKLES IN SUPINE POSITION IN PATIENTS WITH INTERSTITIAL PULMONARY FIBROSIS: ANALYSIS WITH A 16-CHANNEL LUNG SOUND ANALYZER

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Fine crackles are a diagnostic feature of interstitial pulmonary fibrosis (IPF). Although these sounds have been shown to be gravity-dependent and that their distribution can vary with change in position, none of the studies offer detailed documentation of the change of position. In this study, we investigated how positions affect fine crackles in IPF patients with a 16-channel lung sound analyzer (Stethographics model 1602). In a phonopneumographic study of 10 patients with IPF and 10 normal subjects, fine crackles were audible at lung bases in their upright position, while the number and average lung sound amplitude (RMS) of fine crackles decreased in 9 IPF patients out of ten in an supine position. In lateral position, more crackles were observed in a lung above than the one below. These results may indicate that positions may affect snap opening of small airways or the vibration in the walls and interstitium of peripheral airways.

EFFECTS OF BACKGROUND NOISE SUBTRACTION ON DETERMINATION OF LUNG SOUND SPECTRAL PARAMETERS

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BACKGROUND: Spectral edge frequency (SEF) of inspiratory vesicular sound recorded at the chest surface is closely related with the degree of small airway obstruction measured as FEF25-75% in lung function test. When we determine the SEF in a flow targeted breath sound recording, we subtract a breathhold spectrum from an inspiratory spectrum to get a net breath sound spectrum. However, it is often difficult to obtain a breathhold spectrum in younger children.

OBJECTIVE: To evaluate magnitude of the effects of background noise subtraction on the determination of SEF in asthmatic children.

METHODS: Lung sounds were recorded simultaneously over right upper lobe (RUL) and right lower lobe (RLL) in 30 known asthmatic children (6-15 years old), before and after salbutamol inhalation. Two kinds of SEF (defined as the frequency below which contains 95% or 99% of the total spectral power between 150 1200Hz) were determined with and without background noise subtraction procedure. FEF25-75% (percent predicted) was measured by lung function test immediately after each recording. The SEFs were compared in relation to FEF.

RESULTS: Correlation with FEF25-75% was highest in "SEF99 with background subtraction" (r=-0.658) and followed by "SEF95 with background subtraction" (r=-0.647). "SEF99 without background subtraction" had much weaker correlation with FEF (r=-0.409). In terms of correlation with FEF, SEF95 with and without background subtraction did not vary significantly(r=-0.647 vs r=-0.525).

CONCLUSION: Subtraction of breathhold spectrum is a desirable procedure in determination of lung sound spectral parameters. However, the effect of background subtraction seems to be less significant in SEF95.

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CRACKLE POLARITY IS INFLUENCED BY RESPIRATORY CYCLE

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Purpose: Although crackles are heard over the chests of patients with a number of common cardiopulmonary disorders, the mechanism of production of these sounds is poorly understood. Fredberg and Holford postulated that crackles were due to a stress relaxation quadrupole associated with sudden airway opening and closing. Their model predicted that the polarity of expiratory crackles would be the reverse of inspiratory crackles. The goal of this research was to examine systematically the relationship between crackle polarity and respiratory cycle.
Methods: Patients with pneumonia (Pn), congestive heart failure (CHF) and interstitial fibrosis (IPF), with over 2 inspiratory crackles per breath (n=158), or over 2 expiratory crackles per breath (n=89) were examined using a 16-channel lung sound analyzer (Stethographics, Inc, Model STG1602). This device automatically analyzes crackles. Crackle polarity was defined as positive if the largest deflection of the crackle waveform was upward. Crackle polarity was defined as negative if the largest deflection was downward.
Results: The majority of patients had predominantly positive polarity of inspiratory crackles (88% of patients) and predominantly negative polarity of expiratory crackles (83% of patients). Seventy one percent of the 8,250 inspiratory crackles studied had positive polarity. Seventy five percent of the 3,485 expiratory crackles studied had negative polarity. Inspiratory crackle polarity was significantly different between CHF and IPF ($p<0.0008$). It was slightly different between Pn and IPF ($p<0.02$), but not statistically different between Pn and CHF. There were no significant differences in expiratory crackle polarity among the groups.
Conclusion: The reported findings are consistent with the hypothesis that sudden airway opening is responsible for inspiratory crackles and airway closing is responsible for expiratory crackles.
Clinical Implications: While there are no immediate clinical benefits to knowing the polarity of a patient's crackles, a clearer understanding of the mechanism of production of lung sounds offers the promise of improving noninvasive diagnosis of lung disorders.

CRACKLE CATEGORIZATION USING WAVELET-BASED ENERGY CRITERIA

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Characterization of the pulmonary acoustical changes seen during auscultation due to the underlying pathology can be achieved through the efficient categorization of discontinuous breath sounds (DBS), such as fine crackles (FC) and coarse crackles (CC). To this end, this study proposes an efficient discrimination scheme between FC and CC categories of lung sound recordings using Continuous Wavelet Transform (CWT)-based analysis. The proposed discrimination analysis, namely CWT-DA, captures the differences seen in the energy pattern of FC and CC in the CWT domain (realized using the Morlet wavelet) and forms a wavelet-based energy criterion to separate FC from CC. The CWT-DA was realized in Matlab 6.5 (Mathworks Inc. MA) and applied to 114 DBS corresponding to 73 FC and 41 CC cases, drawn from three international lung sound databases. Results show that the CWT-DA separates FC from CC efficiently, categorizing them into two energy classes, using an energy-amplitude threshold of E_{FC}=0.25E_{CC} and scale ranges of a_{FC}=[16-28] and a_{CC}=[29-53], respectively. Due to its low computational complexity, the CWT-DA could potentially be implemented in a real-time context simultaneously providing high discrimination accuracy. As a result, it can be used in clinical medicine as a module of an integrated intelligent patient evaluation system assisting the clinician in respiratory acoustics analysis.

REPRODUCIBILITY OF FLOW-SPECIFIC LUNG SOUND INTENSITY IN HEALTHY CHILDREN

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Acoustical assessment of changes in the airways requires knowledge of the natural variability of the airflow and lung sound relation. Few studies have examined this in adults [1-3] and none in children. To measure immediate (IMV) and short-term variability (STV) of flow-specific lung sounds (LS) and the effect of instrumentation, LS were recorded from posterior lower lung sites of four healthy children, ages 12-13 y (one female). Flow was recorded (Fleisch #3 pneumotachograph) simultaneously with LS using a mouthpiece and noseclip, and subsequently through a facemask. Subjects sat in an anechoic chamber and were coached to cover a range of flows during 1 min terminated by a 5 s breath hold. Two recordings were made for each instrumentation. After a 20-minute break (with sensors removed) the recordings were repeated. Signal-to-noise ratios (SNRs) within 150-300 and 300-600 Hz were averaged per 100 mL/s of flow at plateau (85-100% of max flow per breath). IMV and STV values of SNR at matching flows per subject were averaged. Median values of these averaged differences combined between two trials were calculated (see Tables). Use of the facemask tended to present higher LS variability than the mouthpiece recordings.

Table 1: Reproducibility, right lower lung lobe, mouthpiece

(n=4x2)	IMV	STV
150-300 Hz	0.62 (0.41 – 1.73) dB	0.84 (0.30 – 1.93) dB
300-600 Hz	0.61 (0.39 – 1.13) dB	0.53 (0.19 – 0.72) dB

Table 2: Effect of instrumentation, right lower lung lobe

(n=4x2x2)	mouthpiece	facemask
150-300 Hz	0.78 (0.30 – 1.93) dB	0.93 (0.30 – 4.32) dB
300-600 Hz	0.53 (0.19 – 1.13) dB	0.78 (0.27 – 2.08) dB

We will expand the sample size to provide normative data on IMV and STV of flow-specific LS in healthy children. These reference values will be important to determine significant changes in the flow-sound relation during induced or spontaneous airway changes.

THE EFFECT OF CONTINUOUS POSITIVE AIRWAY PRESSURE ON LUNG SOUND AMPLITUDE

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Background: Continuous Positive Airway Pressure (CPAP) is often used to assist the ventilation of patients. Presumably it improves ventilation to areas of the lung that are poorly ventilated.

Purpose: We were interested in whether CPAP affected the pattern of lung sounds over the chest.

Methods: Healthy volunteers breathed at 0 and 10 cm of CPAP. Lung sounds were measured with a multichannel lung sound analyzer as previously reported. Tidal volumes and flow were recorded.

Results: Tidal volumes and flow were generally lower on 10 cm of CPAP than they were on 0 cm CPAP. Lung sound amplitudes were also were generally lower on 10 cm of CPAP than they were on 0 CPAP. When flows were similar on both levels of CPAP the lung sound amplitudes were similar. The alteration in breathing pattern associated with the change in CPAP appears to be the reason for the change in lung sound amplitude.

INFLUENCE OF RHEOLOGICAL PROPERTIES OF AIRWAY MUCUS ON COUGH SOUND GENERATION

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Objectives: There have been several reports regarding the role of airway mucus in cough sound generation, but the properties of the mucus that influence cough sound generation remain unclear. The aim of this study was to elucidate the influence of the rheological properties of airway mucus on cough sound generation.

Methodology: The acoustic properties of voluntary cough sounds from 15 patients with chronic productive cough and nine controls with dry cough were analyzed by dividing the energy envelope of the sounds into three phases and computing the root mean square values and the duration of each phase as a proportion of the total cough duration. The rheological properties of the airway mucus (yield value, ciliary transportability and spinability) were also measured. Differences between productive and dry cough sounds, and correlations between the acoustic properties of cough sounds and the rheological properties of the airway mucus, were analyzed.

Results: The acoustic properties of productive and dry cough sounds differed significantly ($P < 0.05$). The acoustic properties of second phase cough sounds correlated significantly with the yield value and ciliary transportability of the airway mucus ($P < 0.05$).

Conclusions: The rheological properties of the airway mucus influenced cough sound generation.

SESSION III

LUNG SOUNDS: GENERAL ISSUES

VELOCITY AND ATTENUATION OF SOUND IN THE ISOLATED FETAL LUNG AS IT IS EXPANDED WITH AIR

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We tested the hypothesis that velocity and attenuation of audible sound in the isolated fetal sheep lung provide a measure of the volume of gas it contains. We introduced pseudo-random noise (70 Hz – 7 kHz) to one side of the lung and recorded noise on the surface immediately opposite, starting with the lung containing only liquid and making measurements after stepwise inflation with air. Velocity of sound in the lung fell from 187 $\pm$ 28.2 to 87 $\pm$ 3.7 $m.s^{-1}$ as lung density fell from 0.93 $\pm$ 0.01 to 0.75 $\pm$ 0.01 $g.ml^{-1}$; for technical reasons no estimate of velocity could be made before the first air injection. Thereafter, as lung density fell to 0.35 $\pm$ 0.01 $g.ml^{-1}$ velocity declined to 69.6 $\pm$ 4.6 $m.s^{-1}$. High frequency sound was attenuated as lung density decreased from 1.0 to 0.5 $g.ml^{-1}$, with little change thereafter down to a density of 0.35 $\pm$ 0.01 $g.ml^{-1}$. We conclude that velocity and attenuation of sound in the lung reflect the degree of lung inflation, particularly at high lung densities. Observation of the acoustic properties of the lung may therefore provide a means by which lung aeration can be monitored during mechanical ventilation of newborn infants.