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

Martinez G.1, Aljama T.1, Gonzalez R.1, Chi-Leh G.2, Charleston S.
1Universidad Autonoma Metropolitana-Iztapalapa, Mexico City, 09340, Mexico
2Instituto Nacional de Enfermedades Respiratorias, Mexico City, 04100, Mexico

A group of respiratory diseases called diffuse interstitial pneumonitis (DIN) affects a significant number of people and shares clinical, radiological and functional findings making difficult their diagnosis at early stages. The former situation produces an early regression of the pre-existent pathology making it irreversible in a short period. New imaging and laboratory techniques such as planar X-ray radiography, X-ray computed tomography, and bronchoalveolar lavage permit to evaluate DIN severity; however, they can only be applied in a routine basis to evaluate pneumonia progress. In consequence, the development of non-invasive tools for diagnosis of DIN appears suitable.

Recent efforts have been focused on classify normal and abnormal inspiratory sounds from both healthy and patients with DIN using feature extraction techniques such as spectral frequency parameters and model coefficients. Regarding the classification task, K-NN classifier or supervised neural networks have been employed. This work proposes the use of multichannel AR model applied to the inspiratory phases obtained from healthy subjects and patients with DIN. A multichannel AR model combined spatial acoustic information, which was measured during DIN.

Acoustic signals were acquired with a sampling frequency of 7000 Hz at airflow of approximately 1.0 L/sec. The inspiratory phases were segmented in automatic fashion and each phase was divided into thirty windows with an overlapping of 25%. From each window, a fourth order multichannel AR model was computed. This way, the vectoriality of the feature vector was reduced by applying singular value decomposition. A supervised feedforward neural network with backpropagation and the Levenberg-Marquardt algorithm was implemented for classification. After the network was trained with 874 feature vectors, the results validated with the test vectors showed a sensitivity of 85% and specificity of 88%. According to this, the network provided a positive predictive value of 88% and a negative predictive value of 84% were found.

The proposed methodology provided a moderate performance, but it seems promising to acoustic information in patients with DIN.
29th Annual Conference of the
ASSOCIATION OF THE
Canadian Lung Foundation

September 9-10, 2004

Royal College of Physicians

Venue:

John Barts
Ken Anderson
Steve Kramm
Katherine Pryda
George Wodicka
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Local Committee:

Scientific Committee:

Treasurer:

President:

Lung Foundation of Canada

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President:
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.
Programme

Thursday, 9th September

Session I - Lung Sounds and Disease
Session II - Teaching and Ethics
Session III - Signal Processing
Session IV - Poster Session
Session V - Computer Symposium

29th Annual Conference of ILSA
### SESSION I - COUGH SYMPOSIUM

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Title/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:25</td>
<td>Steve Kramer</td>
<td>Introduction</td>
</tr>
<tr>
<td>09:30</td>
<td>John Wilderмесe</td>
<td>Historical perspective</td>
</tr>
<tr>
<td>10:00</td>
<td>Isabey South</td>
<td>Measurements of Cough</td>
</tr>
<tr>
<td>10:30</td>
<td>Soji Kudo</td>
<td>Rheological properties of Mucus and Cough</td>
</tr>
<tr>
<td>10:50</td>
<td>Coffee Break</td>
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</tr>
<tr>
<td>10:50</td>
<td>Jean Marie Ahon</td>
<td>Cough Research using an Animal Model</td>
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<tr>
<td>11:20</td>
<td>David Frase</td>
<td>Voluntary Cough</td>
</tr>
<tr>
<td>11:50</td>
<td>Michal Javorka</td>
<td>The Sound of Cough in Health and Disease</td>
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<tr>
<td>12:20</td>
<td>Steve Kramer</td>
<td>The future for Cough Research</td>
</tr>
</tbody>
</table>

**Group Photograph**

**Lunch**
OBSERVATIONS MADE WITH A MULTI-CHANNEL LUNG SOUND ANALYZER.

Yoshitaka Seo

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

Rojas M.

Crackle polarity is influenced by respiratory cycle.
Boston Univ. and Brigham and Women's Faulkner Hospital, BOSTON USA

Stella A. Taglimou

Crackle categorization using wavelet-based energy criteria.
Dept. of Computer Engineering, Aristotle University, THESSALONICA, Greece.

Nontasa Morathias

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 Hiroo General Hospital, TOKYO Japan

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+ per breath. When wheezing and crackles are present in the same asthmatic 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+ per breath. They are characterized by 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+ in CHF, 7+ 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.

ANNUAL BUSINESS MEETING

3:30 - 3:45

3:45 - 4:15

4:30

7:30
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
Salvatore 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 school 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.

Sal Mangione, MD, Associate Professor of Medicine
Clinical Skills Center
Jefferson Medical College of Thomas Jefferson University
1025 Walnut Street -- Suite 121
Philadelphia, PA 19107
Salvatore.Mangione@jefferson.edu
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 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 University, 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
A BIOACOUSTIC TRANSDUCER TESTING (BATT) SYSTEM

Steve S. Kraman¹, George R. Wodicka², Gary Pressler² and Hans Pasterkamp³

¹University of Kentucky, Lexington, Kentucky, U.S.A., ²Purdue University, West Lafayette Indiana, U.S.A. and ³University 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, Sweden

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  Guitecki 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 CITY, Mexico
Instituto Nacional de Enfermedades Respiratorias, MEXICO CITY, Mexico

16.30-16.45  Hans Pasterkamp  Closing remarks

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SESSION V
TEACHING AND TESTING

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

Hiroshi Kiyokawa¹, Makoto Yonemaru², Takeo Kawashiro³
1) Department of Internal Medicine, Social Insurance Kamata General Hospital, Tokyo, Japan
2) Department of Respiratory Medicine, Higashi-Saitama 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

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 \(^2\) and Rozanne Paciej, BS \(^3\), \(^4\)
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 these conditions.


SOUND TRANSMISSION IN THE LUNG IN PATIENT WITH BRONCHIAL ASTHMA

S. Ishikawa, N. Aoun, E. Yalet, R. F. Macdonell and B. Celli
Tufts Lung Station, Caritas St Elizabeth’s Med. Ctr.
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 microphone using Murphy’s STG 16 system, at sitting position.

Sound signals were digitized and time expanded waveform displayed. Transit time was measured by using a cross correlation technique. We found transit time were as follows:

<table>
<thead>
<tr>
<th>Region</th>
<th>Normal Mean ± SD</th>
<th>Asthma Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Upper</td>
<td>1.316 ± 0.565</td>
<td>2.771 ± 1.342</td>
</tr>
<tr>
<td>Middle</td>
<td>1.404 ± 0.626</td>
<td>4.095 ± 1.873</td>
</tr>
<tr>
<td>Lower</td>
<td>1.356 ± 0.808</td>
<td>4.117 ± 1.063</td>
</tr>
<tr>
<td>Left Upper</td>
<td>1.246 ± 0.135</td>
<td>2.652 ± 1.414</td>
</tr>
<tr>
<td>Middle</td>
<td>1.319 ± 0.015</td>
<td>3.486 ± 1.844</td>
</tr>
<tr>
<td>Lower</td>
<td>1.459 ± 0.135</td>
<td>4.094 ± 1.955</td>
</tr>
<tr>
<td>MEAN ± SD</td>
<td>1.372 ± 0.076</td>
<td>3.577 ± 1.751</td>
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</tbody>
</table>

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

Sadamu Ishikawa, M.D. 736 Cambridge St., Boston, MA 02135
617-789-2563, fax 617-562-7756, sadamu@massmed.org
Upper Lung Bronchial Breathing in Pulmonary Tuberculosis

Raymond Murphy, MD 1,*, Anna Wong-Tse, RN 1 and Marie Turner, MD 1, 1 Respiratory, Brigham and Women's Faulkner Hospital, Boston, MA, UNITED STATES OF AMERICA.

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

January Gnietski 1, 2, Zahra Moussavi 1

1 Department of Electrical Engineering, University of Manitoba, Winnipeg, CANADA
2 Biology of Breathing Group, Manitoba Institute of Child Health, Winnipeg, CANADA

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>
<thead>
<tr>
<th>FD method</th>
<th>50 ms (512 samples)</th>
<th>100 ms (1024 samples)</th>
<th>200 ms (2048 samples)</th>
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</thead>
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<tr>
<td></td>
<td>min</td>
<td>max</td>
<td>min</td>
</tr>
<tr>
<td>1)</td>
<td>0.7050 ± 0.0028</td>
<td>1.1816 ± 0.0639</td>
<td>0.8828 ± 0.0038</td>
</tr>
<tr>
<td>2)</td>
<td>1.00000000</td>
<td>1.00000000</td>
<td>1.00000000</td>
</tr>
<tr>
<td>3)</td>
<td>1.0700 ± 0.0142</td>
<td>1.3304 ± 0.0097</td>
<td>1.1306 ± 0.0328</td>
</tr>
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</table>
A PRELIMINARY STUDY OF CONTACT EFFECTS OF AIR COUPLED STETHOSCOPES

Y. Qiu, A.R. Whittaker, M. Lucas
Department of Mechanical Engineering
University of Glasgow, Glasgow G12 8QQ
Scotland

K. Anderson
Crosshouse Hospital, Kilmarnock
Scotland

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
Fujihiko Sakao (Home*)

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

Seo Y, Abe S', Wada Y', Murata A', and Kudoh S
The Fourth Department of Internal Medicine, Nippon Medical School, Tokyo
KONICA MINOLTA MEDICAL & GRAPHIC, INC.

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

Masato Takase, Takehide Imai
Dept. of Pediatrics, Nippon Medical School, Tokyo, Japan

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.
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 quadropole 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

Stella A. Taplidou1, Leoniotis J. Hadjileontiadis1, Volker Gross2, Thomas Penzel2, and Stavros M. Panas1

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

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 $\alpha_{FC}=[16-28]$ and $\alpha_{CC}=[29-53]$, 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

J. Gnitecki1,2, H. Pasterkamp2

1Department of Electrical Engineering, University of Manitoba, 2Biology of Breathing Group, Manitoba Institute of Child Health, Winnipeg, MB, CANADA

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 mUs 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

Davidson, F, Wong-Tse, A, Murphy, R
Brigham and Women's/ Faulkner Hospitals Boston, MA, USA

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 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

Norihisa Motohashi, Yasushi Hashimoto, Akira Murata, Masashi Mikami, Seiichi Nakamura, Eiichi Yamanaka and Shoji Kudoh

Department of Internal Medicine, Nippon Medical School, Tokyo, Japan
Department of Respiratory Medicine, Tokyo Metropolitan Hie-o General Hospital

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

P. J. Berger, E. M. Skuza, C. A. Ramsden and M. H. Wilkinson
Ritchie Centre for Baby Health Research, Monash Institute of Reproduction and Development, Monash University, and Newborn Services, Monash Medical Centre, Clayton, 3168, Australia

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 ± 28.2 to 87 ± 3.7 m.s⁻¹ as lung density fell from 0.93 ± 0.01 to 0.75 ± 0.01 g.m⁻³; for technical reasons no estimate of velocity could be made before the first air injection. Thereafter, as lung density fell to 0.35 ± 0.01 g.m⁻³ velocity declined to 69.6 ± 4.6 m.s⁻¹. High frequency sound was attenuated as lung density decreased from 1.0 to 0.5 g.m⁻³, with little change thereafter down to a density of 0.35 ± 0.01 g.m⁻³. 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.