28th ANNUAL CONFERENCE OF THE INTERNATIONAL LUNG SOUNDS ASSOCIATION

CANCUN, MEXICO

SEPTEMBER 15-16, 2003

PROGRAM AND ABSTRACTS

Dept. of Electrical Engineering
Universidad Autonoma Metropolitana
Iztapalapa, Mexico.

Dept. of Health Science
Universidad Autonoma Metropolitana
Iztapalapa, Mexico.

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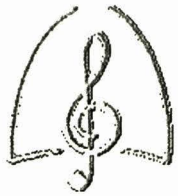
Editors: H. Pasterkamp, S. Charleston, R. González, T. Aljama



28th ANNUAL CONFERENCE OF THE INTERNATIONAL LUNG SOUNDS ASSOCIATION

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CANCUN, MEXICO
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INTERNATIONAL LUNG SOUNDS ASSOCIATION
ANNUAL CONFERENCE 2003

Program

Monday, September 15, 2003

08:30-09:00 ***Registration***

09:00-09:10 ***Welcome & Opening Remarks Sonia Charleston***

SESSION I ***COUGH SOUNDS***
Chairing: *Ramón González & Ray Murphy*

09:10-09:30	Goldsmith et al.	E&CTB, NIOSH Morgantown WV, USA Relationship between peak flow and total sound energy produced during voluntary coughs
09:30-09:50	Day et al.	E&CTB, NIOSH Morgantown WV, USA Voluntary cough analysis as a predictor of obstructive lung disease in men and women
09:50-10:10	Dalmasso et al.	Dept. of Pneumology, Mauriziano "Umberto I" Hospital, Turin, Italy Bioacoustic features of cough in patients with paralysis of a single vocal chord due to lung carcinoma
10:10-10:30	Ishikawa et al.	St. Elizabeth's Medical Center, Tufts Univ. School of Medicine, Boston MA, USA Cough sounds transmission to the chest surface in normals and asthmatics

10:30-10:50 ***Coffee Break***

SESSION II ***CRACKLES AND WHEEZES***
Chairing: *Sonia Charleston & Ray Murphy*

10:50-11:10	Kraman et al.	University of Kentucky, Lexington KY, USA Unfiltered crackle waveforms in 18 patients with a variety of lung disease
11:10-11:30	Fiz et al.	Hospital Universitario Germans, Badalona, Spain Wheeze detection during spontaneous breathing in asthma

11:30-11:50	Gross et al.	Philipps Univ, Marburg, Germany Is there a dependence between nocturnal wheezing and sleep position?
11:50-12:00	***Group Photo***	
12:00-13:00	***Lunch***	

SESSION III AIRFLOW-SOUND RELATION
***Chairing**: Steve Kraman & Leontios Hadjileontiadis*

13:00-13:20	Chi-Lem et al.	Instituto Nacional de Enfermedades Respiratorias/ Universidad Autónoma Metropolitana-Iztapalapa, Mexico City, Mexico Changes on tracheal sound intensity (TSI) using breathing resistive loads in children with and without severe obstructive sleep apnea (OSA)
13:20-13:40	Davidson et al.	Brigham / Women's / Faulkner Hospitals, Boston MA, USA Relationship of acoustic waveforms to mode of ventilation
13:40-14:00	Mentzer et al.	Brigham / Women's /Faulkner Hospitals, Boston, MA, USA Lung sound amplitude after single lung transplantation in patients with COPD
14:00-14:20	Ciftci et al.	Bogazici University, Istanbul, Turkey Estimation of airflow from respiratory sounds
14:20-14:40	Pasterkamp et al.	University of Manitoba, Winnipeg, Canada Characteristics of respiratory sounds standardized to flow from pneumotachograph vs. Respitrace®
14:40-15:00	Airaksinen et al.	Meilahti Hospital, Helsinki, Finland Association of lung sound frequency and intensity with anthropometric characteristics
15:00-15:20	***Coffee Break***	

SESSION IV TRANSMISSION AND LOCALIZATION
***Chairing**: Steve Kraman & Leontios Hadjileontiadis*

15:20-15:40	Gnitecki et al.	University of Manitoba, Winnipeg, Canada Recursive least squares adaptive noise cancellation filtering for heart sound reduction in lung sounds recordings

15:40:16:00	Charleston et al.	Universidad Autónoma Metropolitana-Iztapalapa, Mexico City, Mexico Influence of microphones number and volume discretization on algorithms for simulated breathing sound sources estimation
16:00-16:20	Charleston et al.	Universidad Autónoma Metropolitana-Iztapalapa, Mexico City, Mexico Respiratory acoustic thoracic imaging (RATHI): performance evaluation of interpolating functions for surface imaging
16:20-16:40	Murphy R et al.	Faulkner Hospital, Boston MA, USA Sound transmission in patients with pneumonia
19:00-	***Dinner/Social Evening***	

Tuesday, September 16, 2003

SESSION V ***SIGNAL PROCESSING***
Chairing*: George Wodicka & Hans Pasterkamp*

09:00-09:20	Hadjileontiadis et al.	Aristotle Univ of Thessaloniki, Greece De-noising of discontinuous lung sounds using kurtosis-based filtering
09:20-09:40	Ojala et al.	Finnish Inst Occ Hlth, Helsinki, Finland Validation of automatic lung sound crackle detectors in SuperHelsaII lung sound analyzer
09:40-10:00	Taplidou et al.	Aristotle Univ of Thessaloniki, Greece On efficiently separating wheezes from breath sound recordings using spectogram analysis
10:00-10:20	Pourazad et al.	University of Manitoba, Winnipeg, Canada Heart sound cancellation from lung sound recordings using adaptive threshold and 2D interpolation in time-frequency domain
10:20-10:40	Gnitecki et al.	University of Manitoba, Winnipeg, Canada Variance fractal dimension trajectory as a tool for heart sound localization in lung sound recordings
10:40-11:00	***Coffee Break***	

SESSION VI TOOLS AND EDUCATION
***Chairing**: George Wodicka & Hans Pasterkamp*

11:00-11:20	Kraman et al.	University of Kentucky, Lexington KY, USA Promise and problems in the design of an artifical crackle generator for testing lung sound transducers
11:20-11:40	Murphy R et al.	Faulkner Hospital, Boston MA, USA Objective documentation of the traditional teachings of chest physical diagnosis
11:40-12:00	Murphy M et al.	Boston College School of Nursing, Boston MA, USA A multimedia instructional CD-ROM for teaching lung auscultation

12:00-13:00 ***Lunch***

13:00-14:00 ***Meeting of Advisory Council***

14:00-16:00 ***Annual General Meeting***

16:00- ***Closing Remarks Hans Pasterkamp***

SESSION I

COUGH SOUNDS

RELATIONSHIP BETWEEN PEAK FLOW AND TOTAL SOUND ENERGY PRODUCED DURING VOLUNTARY COUGHS

W. T. Goldsmith, A. A. Afshari, J. Barkley and D. G. Frazer

E&CTB, HELD, NIOSH, Morgantown, WV 26505

Sound energy produced during a cough is a function of flow rate. As structural changes in the airways occur, such as during disease onset, this relationship may be altered. The purpose of this study was to examine differences in the correlation between total sound energy (TSE) and peak airflow (F) for control subjects and those with obstructive pulmonary disease. Forms of the equation $TSE = k \cdot F^{\alpha}$ have been previously used to describe this relationship where k and α are constants. Following standard lung function testing, volunteer subjects, were classified by physicians at the West Virginia University Pulmonary Clinic as either normal (men, N = 27: women, N = 25) or with obstructive lung disease (men, N = 27: women, N = 21). The subjects coughed into a system [1] which measured the flow and sound pressure wave that emanated from the mouth. Peak flow values were plotted versus TSE and a MATLAB based curve fitting algorithm was used to calculate α. Results indicate that values of α were significantly higher for normal subjects (men: 2.14, women: 1.90) than those with obstructive lung disease (men: 1.45, women: 1.27).

1] Goldsmith WT, JS Reynolds, WG McKinney, KA Friend, D Shahan, and DG Frazer. A System for Recording High Fidelity Cough Sound Measurements. *Proceedings of the 3rd International Workshop on Biosignal Interpretation*, 1999; 178-81.

VOLUNTARY COUGH ANALYSIS AS A PREDICTOR OF OBSTRUCTIVE LUNG DISEASE IN MEN AND WOMEN

J. B. Day, W. T. Goldsmith, A. A. Afshari, J. Barkley and D. G. Frazer

E&CTB, HELD, NIOSH, Morgantown, WV 26505

Following standard lung function testing, volunteer subjects, were classified by physicians at the West Virginia University Pulmonary Clinic as either normal (men, N = 27: women, N = 25) or with obstructive lung disease (men, N = 27: women, N = 21). The same subjects performed three voluntary coughs which were recorded using the system and procedure previously described by Goldsmith *et al.,* ILSA 2000. A series of cough sound pressure wave and airflow analyses were conducted for each cough. The sound pressure wave analyses included the calculation of a cough sound index (Goldsmith *et al.* Am. J. Respir. Crit. Care Med. 157:A86 1998), octave filter analysis, determination of β in a $1/f^{\beta}$ spectral analysis and wavelet decomposition. Airflow signal analysis included measurement of the peak flow, average flow, mean transient time, β in a $1/f^{\beta}$ spectral analysis, and flow pattern shape indices. A principal component analysis of all the data was performed and the 10 most significant components were selected as inputs to a quasi-Newton back propagation neural network classification system. The neural network was trained with all but one subject. The remaining subject was then classified based on that training set. The same procedure was repeated for each subject. The results were used to construct ROC curves for men and women to compare the results of the cough analysis technique with the physicians' interpretation of their pulmonary function measurements. The sensitivity and specificity of the cough analysis method for men were equal at 0.875, and the area under the ROC curve, or test discrimination, was 0.92. For women the sensitivity and specificity were equal at 0.72 and the test discrimination was 0.76.

BIOACOUSTIC FEATURES OF COUGH IN PATIENTS WITH PARALYSIS OF A SINGLE VOCAL CHORD DUE TO LUNG CARCINOMA.

F.Dalmasso, E.Isnardi, A. Mazzucato, L. Sudaro.

**Dept. of Pneumology - Respitatory Physiopathology and Acoustics Lab.
Mauriziano "Umberto I" Hospital of Turin ITALY**

Acoustic features of cough can point out the underling pathology and cough peak expiratory flow (CPEF) express the efficacy of cough for facilitating secretion clearance In patients (Pts) with vocal chord paralysis due to lung's carcinoma, cough assume typical features. In twelve patients, male, (mean age 58±11years), spontaneous and voluntary cough sounds where recorded using "Tascam" DAT recorder DA-PI and "Beyer-dynamic" back electret microphone MM1, and then analysed in time, frequency domain by "Spectra LAB-FFT System" and "Audio card Tahiti" for control. Duration (Dt in ms) of each cough event and of its different components (Bursts) were calculated and spectral analysis by Fast Fourier Transform performed and relative 'Sonogram'. Typically in all Pts the first cough event is characterised by only one component (1°burst) without 2°-3°Bursts. Mean Dt of 1°Burst is 485 ±295 ms.. Second and third bursts can appear in the successive cough events suggesting a compensating mechanism of the non paralytic vocal cord to restore efficient cough. The presence of 2°-3° bursts in successive cough events are more common in paralysis due to lung carcinoma then in other paralysis. The spectrum of first cough event in all Pts presents one first peak at about 100-150 Hz and another two at about 1200-1250, and 2100 Hz. and typically differs from successive events which present peak values at about 180, 950, 1500 Hz. as in conventional cough. Cough forced expiratory peak flow (CPEF) of first cough event (without 2°- 3°Bursts) is very low in all Pts:1.9 ± 0.255 L/s and then not useful in mucus clearance. When in successive cough events, 2°-3° bursts appear also CPEF magnitude increases of about 40% and then the effectiveness of mucus clearance.

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COUGH SOUNDS TRANSMISSION TO THE CHEST SURFACE IN NORMALS AND ASTHMATICS

S. ISHIKAWA, S. ZEINELDINE, S. DASARI, K.F. MacDONELL and B.CELLI

**TUFTS LUNG STATION, ST ELIZABETH'S MEDICAL CENTER ,
TUFTS UNIV. SCHOOL OF MEDICINE BOSTON, MA. U.S.A.**

We measured the time it took 'cough sounds' to travel from the trachea to the chest surface (transit time) in 25 normal and 25 asthmatic subjects.

Subjects were instructed to make several voluntary coughs within 10 seconds, at sitting position.

Lung sounds signals were recorded at the neck and 15 sites on the chest surface with contact microphones using Murphy's STG 16 system. Sound signals were digitized and time expanded wave form displayed. Transit time was measured by using a cross correlation technique.

Transit time were greater in value in lower lobes than upper lobes in both normal and asthmatic subjects.

The time it took cough sounds to travel from the trachea to the various sites on chest surface (transit time) on average in 25 normal subjects were 0.66+/-0.342 msec. and 25 asthmatic subjects were 3.22+/-0.725 msec.

In asthmatic subjects the transit time becomes greater in value while in acute exacerbation comparing to in stable state.

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SESSION II

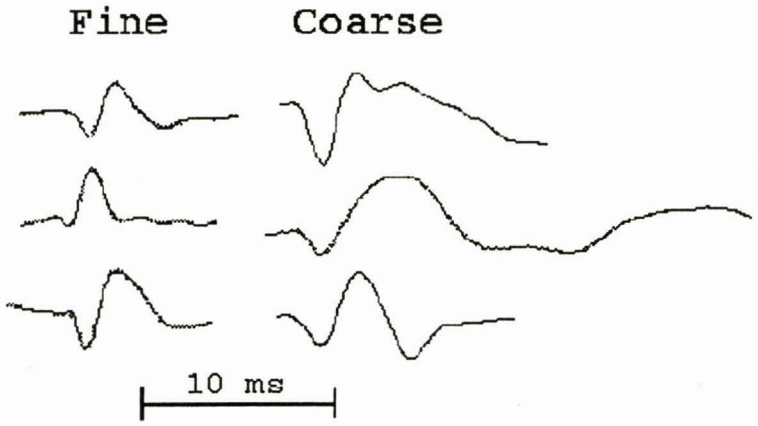
CRAKLES AND WHEEZES

UNFILTERED CRACKLE WAVEFORMS IN 18 PATIENTS WITH A VARIETY OF LUNG DISEASES.

Steve Kraman, M.D. and Ketan Buch, M.D.

VA Medical Center and Univ. of Kentucky, Lexington, KY, USA

Over more than 25 years, the standard description of the shape of the crackle waveform has followed the original report of Murphy et al (NEJM 1977 296[17]:968-971). In 1991, Katila *et al* (JAP 1991;71[6]:2173-2177) suggested that the shape of the crackle waveform was significantly distorted by the high-pass filtering commonly used to suppress muscle and cardiovascular noise. This raised the question of whether some of the crackle measurements previously (and subsequently) reported are substantially artifactual. Katila *et al* only tested their hypothesis on the crackles of one patient. We studied 18 patients who had crackles from a variety of restrictive and obstructive lung conditions to assess the shapes of the crackle waveforms when recorded without audio filtering. We used a condenser microphone embedded in an air-coupled chest piece attached to the chest with a double-sided tape ring. Recording was done at the bedside with a minidisk recorder and the sounds were transferred for display to an iMac computer. RESULTS: Most of the fine crackles displayed a single wave with a narrow (~1 ms) positive initial deflection followed by a wider negative deflection and a total duration of < 5 ms. These were similar to those of Katila *et al* except that they had reported a negative initial deflection. Coarse crackles typically displayed a lower frequency version of the same pattern. We conclude that the waveforms of crackles recorded without filters generally consist of one wave.



Downward deflection is positive

WHEEZE DETECTION DURING SPONTANEOUS BREATHING IN ASTHMA PATIENTS

+J.A. Fiz, *R. Jané, +J Izquierdo, *A. Homs, +M.A García ,+R Gomez, +J. Morera.

+ Department of Respiratory Medicine, Hospital Universitario Germans Trias i Pujol. Badalona, Spain.
*** Dept. ESAII, Centre de Recerca en Enginyeria Biomèdica, Universitat Politècnica de Catalunya, Barcelona, Spain.**

The present study seeks to identify asthma patients that have wheezes during spontaneous breathing and also to assess the bronchodilator effect in such patients.

Material and Methods: Twenty-five asthma patients (14 men/11 women), (40.9[13.6] yrs) with moderate obstruction (FEV_1 62.8[24]%) were enrolled. A contact sensor was placed on the trachea to record sound during two minutes of tidal breathing before and after bronchodilator inhalation. Wheezes in each expiratory cycle were detected by a spectrogram adjusting automatic detection to manual (two experts by ear identification).

Results: Wheezes were heard in 5 asthma patients. Automatic identification was positive in all of these patients. The mean frequency of wheezes was 848.4[335.0] (238-1336 Hz). The mean duration was 0.30[0.11] seconds (0.2-0.63 seconds). Wheezes were not identified in 3 of these patients after bronchodilator. In the other two, the mean frequency of wheezes showed significant changes (mean frequency: first patient 526.3[251.1]–964.9[25.4] Hz, second patient 1028[367.0]–313.0[34.0] Hz).

Conclusion: This technique can complement spirometry by helping to monitor the effects of bronchodilator therapy.

IS THERE A DEPENDENCE BETWEEN NOCTURNAL WHEEZING AND SLEEP-POSITION?

V. Gross[1], Th. Penzel[1], L.J. Hadjileontiadis[2], C. Reinke[1], U. Koehler[1], C. Vogelmeier[1]

[1]Division of Pulmonary Diseases, Dept. of Internal Med., Philipps-University of Marburg, Germany
[2]Dept. of Electr. and Comp. Eng., Aristotle-University of Thessaloniki, Greece

It is known that upper airway obstruction in OSA-patients depends on sleep position. In patients with nocturnal bronchial obstructions the interaction between wheezing and sleep position is unknown.
Data of 20 patients (9 male, 11 female) with COPD from a previous study were included. All patients were measured one night in our sleep laboratory with a recording of a polysomnography and of lung sounds in parallel. For lung sound recording we used a Pulmotrack 1010. The system continuously records all incidences of wheezing by piezo-electrical sensors at standard positions. Using the recorded data we calculated the wheezing time rate (WTR: percentage of time wheezing per 30sec.). Body position was recorded as part of polysomnography equipment.
Surprisingly we found that wheezing time rate (WTR) was decreased in lateral position compared to supine position especially in patients with many obstruction episodes (see Fig. 1). This was shown for tracheal- and chest-sounds but it was not significant (p=0,083 and p=0,036, t-test).
From our results we suppose that there is a dependence between wheezing and sleep position. Therefore it is necessary to consider the body position during the measurement of nocturnal wheezing.

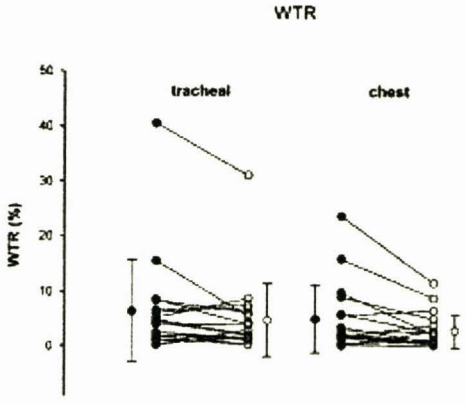


Fig. 1: Mean of wheezing time rate (WTR) during sleep in lateral (o) and supine (•) position for tracheal and chest sounds

This work was partially supported by the German Academic Exchange Program (DAAD) and the Institution of State Scholarships of Greece (I.K.Y.), under the Greek-German Scientific Collaboration Programme 'IKYDA 2000-2003'.

SESSION III

AIRFLOW-SOUND RELATION

CHANGES ON TRACHEAL SOUND INTENSITY (TSI) USING BREATHING RESISTIVE LOADS IN CHILDREN WITH AND WITHOUT SEVERE OBSTRUCTIVE SLEEP APNEA (OSA)

Chi–Lem G., González-Camarena R.*, Velasco M., Mena A. and Pérez-Padilla J.R.

**National Institute of Respiratory Disease (INER) and
*Metropolitan Autonomous University (UAM), Mexico City. MEXICO.**

The purpose of this study was to determine whether the use of breathing resistive loads modify the patency of the upper airways and if this can be reflected on TSI in children with OSA.

Methods: We included eight healthy children, 9.6 ± 1.5 yr (5f) with medical assessment and sleep evaluation (ambulatory monitoring), and 8 children with severe OSA, 9.6 ± 1.9 yr (6f) confirmed by PSG. All were studied with a contact sensor located between cricoid cartilage and the suprasternal notch. Subjects wore a nasal clip, collar and breathed through a pneumotach. Subjects were coached to breath at 1.0 ± 0.2 L/s with resistive loads at 0, 1, 2, 4, 8, 16 and 19 cmH20 for five breathing cycles with 5 sec of apnea. Sound signals were edited and analyzed using the RALE® program at a specific target flow, the spectral energy was expressed as frequency bands: low (L, 150-300 Hz), medium (M, 300-600 Hz), high (H, 600-1200Hz), and very high (VH, 1200-2400Hz), previous background noise subtraction at zero flow. Statistical analysis was done by ANOVA and unpaired T-test with significance set at $p<0.05$.

Results: FEV_1/FVC in OSA was bigger than in healthy subjects (94.2 ±4 vs. 89.9 ±8, p= 0.007). Two patients with OSA had receding mandible and sue tonsil enlargement with smaller crico mental space (0.46 ± 0.6 vs. 1.1 ±0.1; p= 0.000). Healthy children did not show any difference on TSI with or without loads at any frequency bands (ANOVA; $p>0.05$). However, OSA children showed differences on TSI with loads only at low frequencies (ANOVA, p= 0.013). TSI was lower at low frequencies without load in OSA children compared to healthy (48.1 ±5 vs. 42.3 ±2, p= 0.046).

Conclusion: The mechanisms involved on the perfect function of the upper airways are in balance and remain so after using resistive loads in healthy children. In contrast, patients with OSA have different TS at low frequencies, it remarks the unstable upper airways at rest and during the stress test.

RELATIONSHIP OF ACOUSTIC WAVEFORMS TO MODE OF VENTILATION

F. Davidson, A Wong-Tse, R. Murphy

Brigham/Women's/Faulkner Hospitals

Background: We observed that the pattern of the waveform of lung sounds appeared to vary with the mode of ventilation that a patient was receiving and speculated that this was due to differences in flow patterns.

Objective: To study the correlation of ventilatory modes to lung sound patterns.

Methods: Healthy volunteers inspired from Seimens Servo ventilators via a mouthpiece in volume control and pressure modes. Lung sounds were recorded using a multichannel lung sound analyzer (STG16) at 14 sites over the chest as previously described.

Results: When breathing at volumes and flows determined by the subjects, the pressure support mode was associated with higher amplitude breath sounds than were seen when the subjects were breathing in the volume control mode. When inspiratory volumes were similar and flows were adjusted so that the flow rates were the similar in the different modes, the lung sound amplitudes were similar. These observations were similar at all 14 sites.

Conclusion: Lung sound patterns over the chest appear to reflect respiratory flow rather than the mode of ventilation the patient is receiving. They can provide regional information on the efficacy of ventilation.

LUNG SOUND AMPLITUDE AFTER SINGLE LUNG TRANSPLANTATION IN PATIENTS WITH COPD

Mentzer S., Reilly J.J., Paciej R., Vyshedskiy A., Murphy R.

Brigham and Women's /Faulkner Hospitals

Background: The purpose of this investigation was to determine whether computerized quantification of lung sound amplitude differed in the native lung as compared to the transplanted lung in COPD patients who had received single lung transplants.

Materials and Methods: Thirteen patients with chronic obstructive lung disease, who had undergone unilateral lung transplantation, were examined with a 16-channel lung sound analyzer (Stethographics Model STG-1602) as previously described.

Results: In all of the patients studied, the acoustic RMS of the inspiratory phase was greater in the transplanted lung than it was in the native lung. It averaged 12.8 in the transplanted lung and 9.3 in the native lungs ($P = <0.0005$).

Conclusion: The fact that lung sound amplitude is greater in the transplanted lung as compared to the native lung is consistent with ventilation being greater in the transplant. Lung sound analysis can be done on routine clinical visits. It is inherently inexpensive as the calculations can be done on widely available computers. It involves no radiation exposure. As it provides regional information on flow and ventilation it may aid in understanding the physiologic effects of the operation.

ESTIMATION OF AIRFLOW FROM RESPIRATORY SOUNDS

Koray Ciftci[1], Yasemin P. Kahya[2]

[1] Biomedical Eng. Institute, and [2] Department of Electrical Engineering, Bogazici University, Istanbul, Turkey

Total and instantaneous amount of air inspired or expired during the respiratory cycle plays a crucial role in computerized systems designed for the analysis of pulmonary sounds. In computerized respiratory sound analysis, signals are processed according to phase information which is extracted from the measured airflow. Measuring airflow with spirometers may be very cumbersome especially with children and mentally ill patients. In fact, using a spirometer with mouth piece and nose clip makes every patient feel more or less uncomfortable. Moreover, for the development of a wireless respiratory sound recording device, a technique to record respiratory airflow without a spirometer is to be implemented.

This study presents a technique to estimate airflow from respiratory sounds. The goal is to find analytical relationships between airflow and sounds. Recordings were taken from 14 healthy people. Respiratory sound was collected by an air coupled microphone placed on the upper right posterior chest and airflow by a spirometer. Subjects were instructed to make tidal breathing.

Proposed method first decides on the boundary points of the respiratory phases using a phase estimation function. In the second step, each phase is segmented and statistical parameters from respiratory sounds and mean flow rate from airflow signal are calculated for each segment. Different types of polynomials with varying orders are employed to reveal an existing relationship between the sounds and flow. It is observed that estimation performance was best with polynomials based on variance and peak frequency.

After phase estimation and segmentation, a fourth order autoregressive (AR) model is applied to each segment. Correlation coefficient between the first AR coefficient and flow was over 0.85. To improve the performance, principal component analysis (PCA) is applied to AR parameters. Estimation success was increased to over 0.95 after PCA.

These findings are in good agreement with previous studies demonstrating the dependence of respiratory sounds on airflow. High correlation of AR parameters with airflow is a promising outcome which shows that airflow estimation from respiratory sounds is possible.

CHARACTERISTICS OF RESPIRATORY SOUNDS STANDARDIZED TO FLOW FROM PNEUMOTACHOGRAPH *VS.* RESPITRACE®

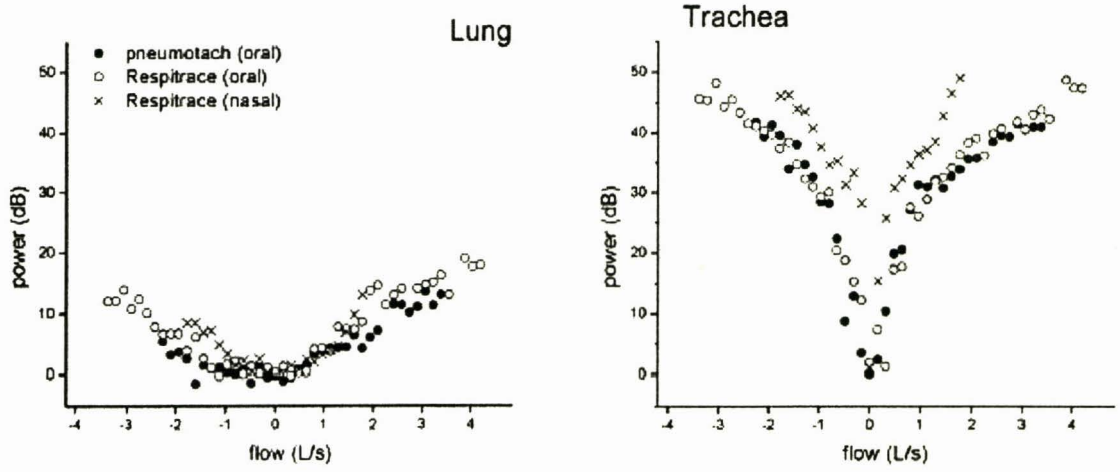
H. Pasterkamp, MD, J. Gnitecki, BScEE and S. Maiti, BSc

Biology of Breathing Group, Manitoba Institute of Child Health and U. of Manitoba, Winnipeg, MB, Canada

Respiratory acoustic research has traditionally focused on the clinical diagnostic value of adventitious sounds. It has now become evident that the relation of normal (basic) lung sounds and air flow carries diagnostic value as well. Airway narrowing causes a decrease in flow-standardized sound intensity whereas bronchodilation has the opposite effect. For meaningful and clinically practical measurements it is important to characterize the effect of the flow sensor on the observed flow-sound relation.

Mussell and Miyamoto (1992) found that a pneumotachograph (PN) affected tracheal but not lung sounds; however, flows during breathing without PN were estimated. We addressed the effect of a PN and of different breathing routes on lung and tracheal sounds by using flow measurements from calibrated respiratory inductive plethysmography (Respitrace®, RIP). The protocol requires subjects to perform 20 sec of nasal breathing, then 30 sec of breathing orally without mouthpiece but wearing a nose clip, and finally 30 sec of breathing through the mouthpiece and PN while continuing the recording of RIP information. Each maneuver is preceded by 5 sec breath hold.

Summarizing our observations from three male subjects (ages 19, 20 and 24 y) studied to date we note that a) RIP flows can accurately replace PN measurements but are technically demanding, b) the effect of PN on tracheal and lung sounds may be minimal (see example below where inspiratory flows are shown as positive and expiratory flows as negative values), and c) as previously shown by Kraman et al. (1998) the route of breathing affects tracheal sounds but may also have some influence on lung sounds.



ASSOCIATION OF LUNG SOUND FREQUENCY AND INTENSITY WITH ANTHROPOMETRIC CHARACTERISTICS

Airaksinen Jukka #, Piirilä Päivi # , Luukkonen Ritva *, Sovijärvi Anssi #

#) Laboratory of clinical physiology, Meilahti hospital, Helsinki, Finland
***) Dept. of epidemiology and biostatistics, Finnish Institute of Occupational Health, Helsinki, Finland**

Objectives. In statistical analysis of lung sounds anthropometric characteristics of the subjects might influence on the results. The aim of this study was to find out the relationship of some anthropometric characteristics with the lung sound signal.

Methods. Lung sound in the back basal part of the lungs of 591 asbestos exposed workers was recorded. Lung sound signal was analyzed with the Helsa (Helsinki Lung Sound Analyzer) system. From the Fast Fourier Transform spectrum the frequency with maximal intensity (Fmax), quartile frequencies (F25, F50, F75), from the phonopneumogram the sound intensity (RMS) and the timing of crackling, and from the time-expanded waveform display the crackle waveform characteristics initial deflection width (IDW), two cycle duration (2CD) and the largest deflection width (LDW) were analyzed. Correlation between the anthropometric parameters and lung sound parameters was studied.

Results. There was a significant negative correlation between F75 and BMI (body mass index) ($p< 0.01$, $r=-0.31$), height ($p<0.01$; $r=-0.12$) and weight ($p<0.01$, $r= -0.32$), and a low positive correlation with age (p 0.01, $r= 0.16$) in the right lung in inspiration. Frequency with maximal intensity had a weak correlation with BMI ($p<0.01$, $r = 0.17$), and a negative one with height ($p <0.01$, $r= -0.15$). LDW correlated with BMI ($p <0.01$, $r = 0.18$) and weight ($p = 0.01$, $r= 0.17$), and 2CD with BMI ($p <0.01$, $r =0.17$) and weight ($p= 0.01$, $r =0.16$).

Conclusions. Significant correlations between the studied anthropometric characteristics and the lung sound frequency and crackle sound parameters were found. Though the correlations were usually weak, in statistical analysis of lung sound characteristics in large populations adjustment of the sound data with BMI or height and weight in addition to age would be suggested.

SESSION IV

TRANSMISSION AND LOCALIZATION

RECURSIVE LEAST SQUARES ADAPTIVE NOISE CANCELLATION FILTERING FOR HEART SOUND REDUCTION IN LUNG SOUNDS RECORDINGS

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Abstract—It is rarely possible to obtain recordings of lung sounds that are 100% free of contaminating sounds from non-respiratory sources, such as the heart. Depending on pulmonary airflow, sensor location, and individual physiology, heart sounds may obscure lung sounds in both time and frequency domains, and thus pose a challenge for development of semi-automated diagnostic techniques. In this study, recursive least squares (RLS) adaptive noise cancellation (ANC) filtering has been applied for heart sounds reduction, using lung sounds data recorded from anterior-right chest locations of six healthy male and female subjects, aged 10-26 years, under three standardized flow conditions: 7.5 (low), 15 (medium) and 22.5 ml/s/kg (high). The reference input for the RLS-ANC filter was derived from a modified band pass filtered version of the original signal. The comparison between the power spectral density (PSD) of original lung sound segments, including, and void of, heart sounds, and the PSD of RLS-ANC filtered sounds, has been used to gauge the effectiveness of the filtering. This comparison was done in four frequency bands within 20 to 300 Hz for each subject. The results show that RLS-ANC filtering is a promising technique for heart sound reduction in lung sounds signals.

Keywords—Adaptive noise cancellation, heart sounds, lung sounds, recursive least squares

INFLUENCE OF MICROPHONES NUMBER AND VOLUMEN DISCRETIZATION ON ALGORITHMS FOR SIMULATED BREATHING SOUND SOURCES ESTIMATION

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Physicians have posed the following question "*what is going on inside the thorax in order to make a sound like that?*". The question establishes what is called an inverse problem (IP), that attempts to identify inaccessible internal sources from accessible external fields. Kompis *et al.* established BS sources (BSs) estimation by formal IP, solving it by overdetermined least-squares (OLS) algorithm. Here, we tested the influence of number of microphones (*M*) and thoracic volume discretization (TVD) on three different IP solution algorithms: OLS, underdetermined minimum norm (UMN) and weighted minimum norm (FOCUSS).

A forward problem for calculating thoracic surface BS was based on known simulated sources and a mathematical model of the acoustical propagating TV. TV was simulated by a parallelogram of 24x30x24 cm. BSs were assumed generated by flow turbulence, while lung parenchyma was considered as an homogeneous mixture of gas and fluid, producing BS intensity attenuation. To generate BSs, different distributed non-point multiples BSs were simulated in the discretized TV.

Eventhough *M* increases, OLS did not improve its BSs estimate while UMN did, but without discern among the BSs. FOCUSS provided a good visual estimate of BSs from 12 *M* per surface. At two and three cm TVD, OLS provided a fuzzy BSs, where to discern BSs location, number and shape was not possible. Estimated BSs by UMN were located more towards the centre of TV, but they were also fuzzy and shifted towards the thoracic surface. At two cm TVD, FOCUSS resolved location and number but not BSs intensity, while at three cm, it resolved adequately for all the simulation parameters.

RESPIRATORY ACOUSTIC THORACIC IMAGING (RATHI): PERFORMANCE EVALUATION OF INTERPOLATING FUNCTIONS FOR SURFACE IMAGING

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During last decades, breathing sounds (BS) analysis, processing and visualization efforts have been increased. In particular, concurrently acoustical information visualization on thoracic wall is getting relevance for studying pulmonary ventilation-BS intensity relationship. On this topic, interpolation is a fundamental operation in computer visualization and represents a powerful tool to explore and analyze data.

This work establishes the bases for evaluating the appropriateness of a given deterministic interpolation to surface RATHI. Therefore, BS were acquired through a multichannel system using a 5 by 5 microphone array on the frontal and back thoracic surfaces. The protocol included healthy volunteers breathing at high (>1.0 L/s) and low (<1.0 L/s) airflow during 10 seconds to include several breathing cycles. Acquisition was carried out in a quiet place, volunteers breathing through a pneumotachograph, seated and wearing nose-clips. The airflow and respiratory frequency (12-15 breathing cycles per minute) were kept by visual feedback. The frequently used interpolating functions (IFs), linear, cubic spline, Hermite and Lagrange as well as the nearest neighbor method were evaluated to form BS intensity images through statistical indexes. Our results pointed out differences among tested IFs; however, Hermite IF achieved the better global performance under good BS acquisition conditions due to the use of second order derivatives, but derivatives also implies higher sensitivity to noise. The linear, Lagrange polynomial and nearest neighbor methods seem to be inadequate, since they could not follow the changing characteristics of BS and were also sensitive to noise.

SOUND TRANSMISSION IN PATIENTS WITH PNEUMONIA

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Background: Transmission of voice sounds is altered by disease states such as pneumonia. We were unaware of objective studies of this phenomenon.

Purpose: to quantify the level of sound of the spoken voice over the chest in normals and in patients with pneumonia.

Methods: Fifty patients with pneumonia and fifty individuals without significant lung disease were recorded with a multichannel lung analyzer (STG, Model 1602) at a teaching hospital. The transmission of e-e-e sounds was studied to determine whether areas of lower or higher intensity could be used as an indicator of pneumonia. The root mean square values of the sound amplitude (ARMS) were calculated at 14 chest sites.

Results: There were no significant differences found between pneumonia and normal subjects in mean ARMS or in values of higher or lower intensity. The mean ARMS values outside the 95% confidence range were 3 (3+/-1.0) in both groups and in both the right and left lungs.

Conclusion: The number of ARMS values that fell outside 2SDs of the mean was similar in the 2 groups. Areas of lower or higher intensity of the transmitted sound do not appear to be a useful indicator of pneumonia.

SESSION V

SIGNAL PROCESSING

DE-NOISING OF DISCONTINUOUS LUNG SOUNDS USING KURTOSIS-BASED FILTERING

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An efficient method for the de-noising of discontinuous lung sounds (DLS), such as crackles and squawks, based on kurtosis is presented in this paper. The proposed method employs an iterative procedure that uses kurtosis (a zero-lag fourth-order statistics parameter) to form a Kurtosis-based Filter (KF). Due to the transient character of the DLS, their non-Gaussianity is high, compared to the one of the stationary background noise. Since kurtosis is a measure of the non-Gaussianity of a process, it could be efficiently used as a means to identify the DLS in the time domain and, through an iterative procedure, to extract them from the noisy background. Analysis of the experimental results (see Fig. 1), when applying the KF to pre-classified DLS recorded from patients with pulmonary dysfunction, justify an efficient performance of the KF to outwit the noise presence by accurately extracting the authentic structure of DLS. Since the KF removes the undesired signal from the DLS recordings, it can easily be used for data-volume reduction when long-term recordings are employed, e.g., in sleep laboratories, intensive care units, homecare telemedical devices. Due to its simplicity, the KF can be implemented in a real-time context and can be used for continuous DLS screening. Further improvements of the proposed algorithm and its application on an expanded database with clinical lung sound recordings are currently in progress, using the Marburg Respiratory Sound (MARS) database.

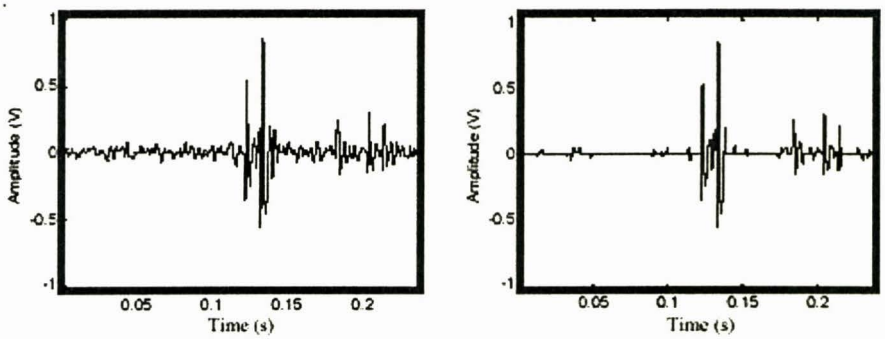

Fig. 1. De-noising of recorded fine crackles (left) after applying the KF (right).

This work was partially supported by the Institution of State Scholarships of Greece (I.K.Y.) and the German Academic Exchange Program (DAAD), under the Greek-German Scientific Collaboration Programme 'IKYDA 2000-2003'.

VALIDATION OF AUTOMATIC LUNG SOUND CRACKLE DETECTORS IN SUPERHELSAII LUNG SOUND ANALYZER

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

Methods. Lung sounds on the back basal part of the lungs of 20 asbestos exposed workers were recorded. The number of crackles obtained from the automatic crackle detector in SuperHelsaII using only the Kaisla method with threshold levels 1000, 2500 dBHz was compared with crackle counts by the combined Kaisla and Vannuccini method as well as with the count of crackles found by two observers in time-expanded waveform display according to Murphy's criteria.

Results. The total amount of crackles validated was 890-932. Pearson´s rank correlation coefficient between the count of crackles obtained by the automatic method and the count by observer A was 0,30 (threshold level 1000dBHz), p=0,059 and 0,41 (threshold level 2500dBHz), p= 0,009. Correspondingly the correlation coefficient between the automatic counts and observer B was 0,34 (threshold level 1000 dBHz), p=0,032 and 0,47 (threshold level 2500), p=0,0028. The correlation coefficient between the crackle counts by the observers was 0,98, p=0,0001. The correlation coefficient between the counts of the adjusted crackle detector (using both Kaisla´s and Vannuccini´s method) and observer A was 0,19 and observer B 0,23 (NS).

Conclusions. Crackle counts with Kaisla´s method obtained at the threshold level 2500 dBHz correlated significantly with the visual counts obtained according to Murphy´s criteria. The combination of Vannuccini criteria did not improve the results in the present patient material.

ON EFFICIENTLY SEPARATING WHEEZES FROM BREATH SOUND RECORDINGS USING SPECTROGRAM ANALYSIS

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Wheezes are abnormal continuous adventitious lung sounds that are strongly related to certain pulmonary pathologies. Efficient separation of wheezes from the breathing recordings would offer the physician an accurate and objective tool to estimate the severity of the associated diseases, such as asthma.
In this study we have created an Automatic Wheezing Episode Detector (A-WED) based on the spectrogram of breath sounds. The proposed method is based on the fact that wheezes are exhibited as peaks in spectrum. It combines an amplitude criterion, which is applied to the spectrogram of the signal in the frequency region of 100-800 Hz, and other criteria that take into account some characteristics of wheezes, such as their time duration and also their continuity, both in time and frequency domains. The A-WED algorithm was implemented using Matlab 6.5 (The Mathworks, Inc., Natick, MA). Experimental results (see Fig. 1) from the analysis of pre-classified lung sounds (14 cases), drawn from Marburg Respiratory Sound (MARS) database, show that the A-WED performs very accurately (92% detectability) when compared to experts' (clinicians) scoring. Due to its low computational cost and its simple implementation, it can easily be used in clinical medicine for long–term recordings, i.e. in intensive care units, sleep laboratories, resulting in data volume reduction. Further improvements of the proposed algorithm and its application on an expanded database with clinical lung sound recordings are currently in progress.

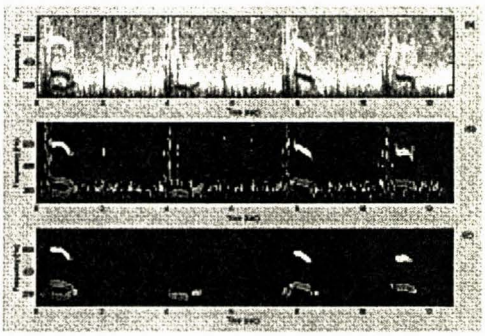

Fig. 1. Experimental results from an asthmatic case. Up: The spectrogram of the signal. Middle: An intermediate result after applying the amplitude criterion. Bottom: The final output of the A-WED scheme.

This work was partially supported by the Institution of State Scholarships of Greece (I.K.Y.) and the German Academic Exchange Program (DAAD), under the Greek-German Scientific Collaboration Programme 'IKYDA 2000-2003'.

HEART SOUND CANCELLATION FROM LUNG SOUND RECORDINGS USING ADAPTIVE THRESHOLD AND 2D INTERPOLATION IN TIME-FREQUENCY DOMAIN

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Abstract—During lung sound recordings, an incessant noise source occurs due to heart sounds. The heart sound interference on lung sounds is significant especially at low flow rates. In this paper a new heart noise (HN) cancellation method is presented. This algorithm uses an image processing technique to detect HN segments in the spectrogram of the recorded lung sound signal. Afterwards the algorithm removes those segments and estimates the missing data employing a 2D interpolation in the time-frequency domain and finally reconstructs the signal in the time domain. The results show that the proposed method successfully cancels HN from lung sound signals while preserving the original fundamental components of the lung sound signal. The computational load and the speed of the proposed method were found to be much more efficient than other HN cancellation methods such as adaptive filtering.

VARIANCE FRACTAL DIMENSION TRAJECTORY AS A TOOL FOR HEART SOUND LOCALIZATION IN LUNG SOUND RECORDINGS

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Abstract—Methods by which to deduce information regarding respiratory mechanics via respiratory acoustics would present favourable additions to traditional pulmonological testing for determination of respiratory conditions. The interference originating from heart sounds in sound signals acquired on the chest wall complicates the establishment of a firm definition of flow specific lung sounds as a function of airway narrowing. In this study, the variance fractal dimension trajectory (VFDT) algorithm has been applied to lung sounds data to examine its use as a heart sounds locator regardless of pulmonary airflow. Lung sounds were recorded from anterior-right chest locations of six healthy male and female subjects, aged 10-26 years, under three body-mass-standardized flow conditions (low flow: 7.5 ml/s/kg, medium flow: 15 ml/s/kg, high flow: 22.5 ml/s/kg). Suitable window sizes and increment values (chosen based on signal characteristics) were tested, and parameters were gauged in terms of number of successful heart sound detection relative to the total number of heart sounds per file. The results show that the VFDT is most successful for heart sound localization at low and medium flow, which are also of most interest. Overall, the method shows promise as a viable technique for this purpose.

Keywords—Heart sounds, lung sounds, variance fractal dimension

SESSION VI

TOOLS AND EDUCATION

PROMISE AND PROBLEMS IN THE DESIGN OF AN ARTIFICAL CRACKLE GENERATOR FOR TESTING LUNG SOUND TRANSDUCERS

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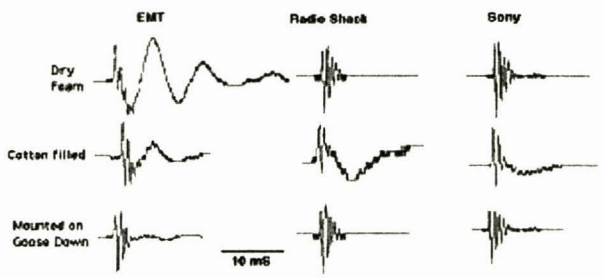
Standardization is a technical issue of great importance to the lung sound research community. Currently, there are neither universally accepted types of lung sound transducers nor a sound generation standard that would serve to test such transducers. As a result, investigators use a wide variety of instruments to access lung sounds and ignore the possibility that their findings could be uniquely colored by their microphones and attachments. Therefore, we began to design a potential "standard" crackle generator to use in transducer comparisons. We used a Sony headphone speaker tightly coupled to a 4.8 cm long, 3.3 cm wide (ID) plastic tube that we filled with either dry foam or water-saturated foam with or without cotton to fill the remaining space. The end of the tube was covered by a latex membrane on which the microphones were placed using double-sided tape. The electrical input to the speaker was a slowly repeating square wave producing repeating positive and negative step pulses. Test microphones were: Sony ECM 150 and Radio Shack electret condenser microphone (ECM) (both air-coupled with a conical chamber) and a Siemens EMT 25C accelerometer. We analyzed the recorded waveforms when the setup was mounted on a solid surface and when supported on several inches of goose down in a nylon envelope. RESULTS: The two electret microphones yielded similar waveforms under all conditions. The water-soaked sponge filling attenuated the pulses to an unacceptable extent. With dry foam filling, the ECMs showed a hi-freq. (~1Khz) wave followed by a low-freq. (~50Hz) 1/2 wave overshoot. The overshoot disappeared on the goose down support. Cotton filling in the coupler tube made little difference. With the EMT using dry foam filling, the low-freq. deflection overwhelmed the high-freq deflections and lasted for ~2 waves before dying out. These low-freq. waves also disappeared on the goose down support but, unlike the ECMs, filling the tube with cotton also attenuated these waves. We conclude that the type of transducer, coupling and support are all important in designing an artificial lung sound generating device. The quality of the support appears to be the most critical.



OBJECTIVE DOCUMENTATION OF THE TRADITIONAL TEACHINGS OF CHEST PHYSICAL DIAGNOSIS

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Background: Few objective studies of the clinical correlation of many of the teachings on physical diagnosis have been done.

Purpose: Our purpose was to provide more reliable information on auscultation.

Methods: We used a multichannel lung sound analyzer as previously described to examine 700 patients with a variety of common lung disorders.

Results: Examples of the numerous observations we have made are as follows: Normals have neither a wheeze rate of greater than 4% nor a crackle rate of greater than 3 per breath. Crackles can be found in patients with asthma, but they are usually few in number, i.e. 3+/- 3. When wheezing and crackles are present in the same afebrile patient, 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.
Very high numbers of crackles, i.e. 25 +/-12, are characteristic of interstitial pulmonary fibrosis (IPF). Squawks are not found in normals.

Conclusion: Objective data on physical findings can be obtained. Hopefully this information will be useful in placing the teachings of physical diagnosis on a firmer scientific foundation.

A MULTIMEDIA INSTRUCTIONAL CD-ROM FOR TEACHING LUNG AUSCULTATION

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Background: While there have been a variety of teaching tools available for lung auscultation including texts, tapes and cassettes, there are few multimedia programs available for this purpose.

Methods: We used data available from computerized recordings of sounds from normal subjects and patients with a variety of common lung disorders to assemble illustrative examples of these conditions. A CD-ROM was created that presents common lung sounds and their acoustic characteristics; their patterns of distribution on the chest are presented together with the relevant clinical information. The CD-ROM was designed to be easily used on most modern computers. It also contains a quiz based on actual clinical cases presented as unknowns for the students to test themselves using virtual auscultation.

Results: Students and teachers, as well as Journal reviewers, have given excellent feedback on the usefulness of this teaching tool.

Conclusion: The multimedia approach facilitates teaching physical diagnosis.

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