FIFTEENTH INTERNATIONAL CONFERENCE ON LUNG SOUNDS

第15回 国際肺音学会

OCTOBER 3-5, 1990

TULANE UNIVERSITY
NEW ORLEANS, LOUISIANA

PRESENTED BY

INTERNATIONAL LUNG SOUNDS ASSOCIATION

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15th International Conference on Lung Sounds

New Orleans, Louisiana

Program

Wednesday, October 3, 1990

Workshop and Posters - Warwick Hotel ------------------------3:00 PM

Thursday, October 4, 1990

Registration --8:00 AM

Welcome - Dr. Vincent Fulginitti, Dean -----------------------8:30 AM
Tulane School of Medicine

Keynote Address - Dr. David Cugell ---------------------------8:45 AM

Session A - Dr. Kraman & Dr. Rice -------------------9:00 - 11:30 AM

Photo ---11:30- 12:00 PM

Lunch ---12:00 - 1:00 PM

Session B - Dr. Dalmasso & Dr. Sovijarvi -------------1:00 - 3:30 PM

Dinner at Antoines ---7:00 PM

Friday, October 5, 1990

Session C - Dr. Pasterkamp & Dr. Kudoh ----------------9:00 - 12:00 PM

Business meeting -------------------------------------12:00- 12:15 PM

Lunch ---12:15 - 1:30 PM

Session D - Dr. Ball & Dr. Lens ---------------------- 1:30 - 3:40 PM

Cracklefest -- 3:40 - 4:15 PM

Summary - Dr. Will Waring ---------------------------- 4:15 - 4:30 PM

Workshop and Posters

N. Gavriely	Design and characteristics of a new contact sensor
D. Gaver, J. Solway	A model of the re-opening of a pulmonary airway
J. E. Earis, D. Graham	Analysis of lung sounds produced by a patient with tracheobroncho-malacia
D. Spence, I. Pavord D. Graham, S. Bentley D. Evans, M. Morgan	The reproducibility of the power spectra of asthmatic breath sounds following methacholine challenge
H. Pasterkamp	Rale: Respiration Acoustic Laboratory Environment
D. Cugell	

ANALYSIS OF LUNG SOUNDS PRODUCED BY A PATIENT WITH TRACHEOBRONCHOMALACIA

J.E.EARIS MD FRCP, D.GRAHAM MD MRCP.
Regional Thoracic Unit Fazakerley Hospital, Liverpool, England.

A 62 year old non-smoker presented with cough, breathlessness and 'wheeze' which was not responsive to treatment with bronchodilators or corticosteroids. Pulmonary function showed severe airflow obstruction with FEV1 0.9L, FVC 2.4L and FEV1/FVC 37%. Predicted normals 3.0, 4.0 and 75% respectively) with no improvement in the FEV1 after 5mg of inhaled salbutamol. The flow volume loop was compatible with a variable intrathoracic obstruction. Fibreoptic bronchoscopy and cinebronchography showed a marked collapse of trachea and segmental bronchi with coughing and straining confirming the diagnosis of tracheobronchomalacia.

At the mouth and chest wall low pitched sound was present on deep breathing and coughing. This sound was present late in expiration and associated with marked oscillations on the flow trace. Spectral analysis confirmed that this sound was low pitched with the frequency varying between 50 and 150 Hz.

This unusual sound will be demonstrated and evidence that it originates from the lower trachea discussed.

THE REPRODUCIBILITY OF THE POWER SPECTRA OF ASTHMATIC BREATH SOUNDS FOLLOWING METHACHOLINE CHALLENGE

D.P.S. SPENCE, I.D. PAVORD, D. GRAHAM, S. BENTLEY, D.H. EVANS and M.D.L. MORGAN.
Depts of Respiratory Medicine,Glenfield General Hospital, Leicester. Regional Thoracic Unit Fazakerley Hospital, Liverpool and Dept of Clinical Measurement, Leicester Royal Infirmary, Leicester, United Kingdom.

In order to devise a method of monitoring changes in airway calibre as a non-invasive instrument for the study of asthma we have sought to define a relationship between the breath sound spectrum and FEV1, and have examined the reproducibility of the sound spectra from similar spirometric measurements. Breath sounds were recorded in a sound proofed room during tidal breathing before and during methacholine challenge in 6 asthmatic subjects on 2 separate days. Sounds were recorded over the suprasternal notch and recorded digitally (Sony 1000 ES D.A.T.) for off line analysis. A real time spectrograph was displayed using a Fast Fourier Transform spectrum analyser to obtain a 9 second representative sample immediately prior to each FEV1 measurement (F.F. SCHLINDWEIN et al, MED. BIOL.ENG.COMPUT,1988 Vol 26 228-232). For each spirometric measurement the mean power (arbitrary units) and frequency (Hz)were derived. In 11 of 12 challenges at the PD 20 there was an increase in mean power and the power frequency product and in all cases the mean frequency increased (mean 323 ± 287 Hz). However, the starting sound frequencies within and between patients were widely different (range 204-287 Hz) and did not correspond to FEV1. Furthermore, there was no correlation of power or frequency with FEV1 and no reproducable level of FEV1 at which wheeze appeared. These results suggest that even with digitally recorded and processed breath sounds the relationship between airway calibre and sound spectra remains elusive.

Session A

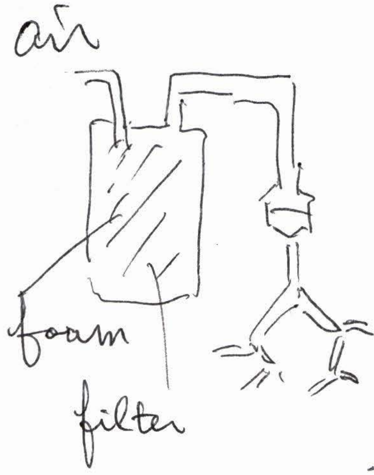
Dr. Steven Kraman & Dr. David Rice, Co-Chairmen

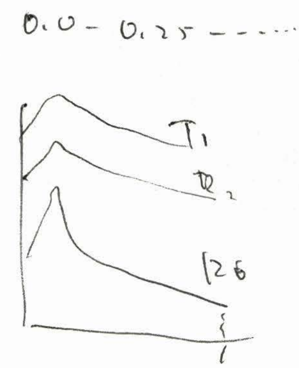
9:00 - 9:20	Airflow-generated sound within a human airway model	Kraman Wang
9:20 - 9:40	Muscle sounds data acquisition: The respiratory muscles	Dalmasso Benedetto Garati Righini Spagnolo
9:40 -10:00	Measurement of attenuation of pseudo-lung sounds by animal lung and chest wall	Stoneman Earis
10:00-10:30	Coffee Break	
10:30-10:50	Effect of ECG-gating on the measurement of flow-standardized tracheal sounds	Pasterkamp
10:50-11:10	Spectral analysis & data compression for lung sounds	Jamieson Cheetham Moruzzi Earis
11:10-11:30	A new model of a microphone for a portable phonopneumograph	Yumoto Kudoh Shibuya Matsuki
11:30-12:00	Photo	
12:00- 1:00	Lunch	

AIRFLOW-GENERATED SOUND WITHIN A HUMAN AIRWAY MODEL.

S. S. Kraman and P. M. Wang, VA Medical Center and University of Kentucky, Lexington, KY. (Correspondence to Dr. Kraman, VAMC (11), Lexington, KY 40511)

In a previous experiment, we examined the distribution of airflow-generated sound within a flexible model of canine airways. We found that, in the inspiratory direction, the greatest amplitude occurred in airways of 5 to 8 mm diameter. At all levels within the model, sound amplitude was approximately linearly related to the square of the airflow. In the present study we examined the sound amplitude within a commercially manufactured human airway model, the ALM-II adult lung model, version II (APM Inc., Raleigh, NC). Air from a muffled, compressed air source was passed through the model in the inspiratory direction at flow rates of 0.5, 0.75, 1.0, 1.25, 1.5 & 1.75 l/s. The resulting airflow-generated sounds were picked up by 5 microphones sealed to capsules overlying 1.0 mm holes in the airway walls at locations corresponding to 1) trachea, 2) right mainstem, 3) right mainstem at RUL bifurcation, 4) RLL-RML bifurcation, and 5) RLL at the Lateral Basal airway bifurcation. The sound amplitude and median frequencies were determined at each flow rate. RESULTS: Amplitude followed the square of the airflow at all locations with best fit at the trachea (Pearson's "R"=1.000) and worst at the RUL bifurcation ("R"=0.934).where a 3-fold increase in amplitude occurred between 1.0 and 1.25 l/s airflow. Median frequencies correlated with amplitudes ("R" from 0.754 to 0.995). The frequency spectra were similar to lung sound spectra normally noted on the human chest.





[illegible] Spectrum. [illegible]

MUSCLES SOUNDS DATA ACQUISITION : THE RESPIRATORY MUSCLES

F.DALMASSO*,G.BENEDETTO,P.GARATI*,G.RIGHINI,R.SPAGNOLO

***Divisione di Pneumologia,Ospedale "Mauriziano Umberto I" di Torino L.F.Turati 62,10100,Torino, ITALY**

Dipartimento di Acustica,Istituto Elettrotecnico Nazionale 'Galileo Ferraris',Str.delle Cacce 91,10100,Torino, ITALY

Low frequency and weak intensity sounds,not detectable by human ear are produced by contracting skeletal muscles.When these sounds are detected on the chest wall some problems should be taken into account: the coupling transfer function;the mechanical impedance of the thorax wall;the mass and the contact diameter of the pick-up.Seven normal subjects,male,aged 25 to 45 years,were studied.The sound signal was detected by a piezoelectric,contact microphone Hewlett-Pakard 21050 A,low weight type(3.5 Oz),size 1.1 inch,which is a standard phonocardiographic microphone with a flat frequency response from 0.2 Hz to 2 KHz;this microphone although less sensitive than an air-coupled one,is preferred for its insensitivity to airborne sounds and its small size.The skeletal muscles(Biceps,Flexor carpi,Vastus lateralis)were first examined at different loadings.Three other signals were recorded simultaneously on a tape recorder(Nagra T),to define the measurement technique:the surface EMG;the needle EMG and the physiological tremor detected by a vibration transducer.Inspiratory muscles (diaphram,intercostals) were examined during quiet ventilation and hyperventilation on the chest wall at the V,VI,IX and X intercostal spaces on anterior axillary line.The airflow at the mouth and the surface EMG were simultaneously recorded with the sound.The acoustical analysis was performed in TSL language,by a Digital PDP 11/05 mini-computer with 28 K words memory.The spectral analysis of the muscles sounds was performed using FFT algorithm.The time pattern of sound signal,during a quiet inspiration,shows a series of oscillations, spike like,repeatable from contraction to contraction with progressively increasing and decreasing amplitude.The sound signal seems not exactly correlated,in time,to EMG signal.As to frequency distribution the muscle sound energy results mainly concentrated below 40 Hz. Some potential artifacts that could have produced the sounds were checked,particularly the heart vibrations and the overlap of accessory muscles sounds.A development of this,non invasive technique, with a specially designed ultralight pick-up(Verburg model)for recording the quasi-unloaded wall muscles,might give further characterization of respiratory muscles in healthy subjects and in patients with different diseases.

MEASUREMENT OF ATTENUATION OF PSEUDO-LUNG SOUNDS BY ANIMAL LUNG AND CHEST WALL

BY

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The paper will present results of an experimental investigation of the attenuation of pseudo-lung sounds by section of animal lung and chest wall. These were mounted in a purpose designed, two chamber acoustic rig, where the sections were subjected to white noise from a loudspeaker. The difference in sound levels from one side of the section to the other was detected by two matched microphones, spectrally analysed and a transfer function computed.

The results of the investigation were as follows:

(a) pseudo-lung sound was, on average, attenuated by 35 dB as it traversed the chest wall and by 25 dB as it traversed a similar, representative distance through lung tissue.

(b) a significant degree of attenuation of sound, in the auscultation frequency range from zero to 2000Hz, by the chest wall, appeared to be caused by the subcutaneous fat layer and the skin, as distinct from the bone and muscular tissues.

chest wall -36 db/oct

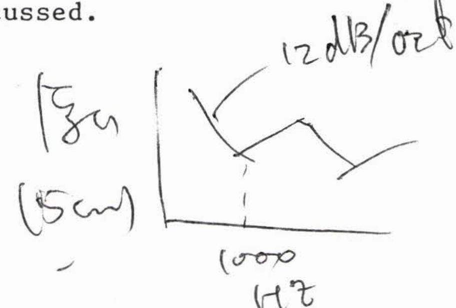
lung. -25 dB.

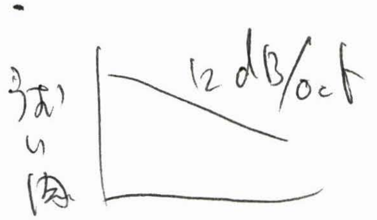
(c) as expected, the absolute value of the attenuation in both tissues was greatest at the highest frequencies. However, the relationship between attenuation and thickness for varying frequencies was complex and appeared to be non-linear.

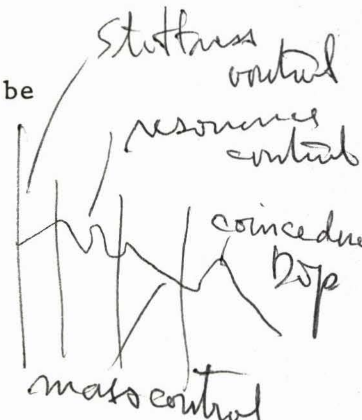
(d) specifically, in both lung and chest wall tissue, there was evidence of a 'coincidence' effect at a frequency of 2 KHz.

(e) the above result appeared to contradict the commonly accepted 'cut-off' of sound circa 2000Hz, as reported by Forgac et al, when comparing lung sounds heard through the chest wall with those heard at the mouth.

The acoustic and clinical implications of the results will be discussed.







EFFECT OF ECG-GATING ON THE MEASUREMENT OF FLOW-STANDARDIZED TRACHEAL SOUNDS

Hans Pasterkamp, MD
Dept. of Pediatrics and Child Health
University of Manitoba, Winnipeg, CANADA

ECG Gate (55-98% of RR)

Cardiovascular sounds are often clearly audible in recordings of tracheal sounds. To test the hypothesis that the measurement of flow-standardized tracheal sounds may be biased toward lower frequencies by these cardiovascular sounds, I used ECG gating on recordings from 8 healthy male adults. From each subject, between 40 to 50 seconds of tracheal sounds (contact transducer, Siemens EMT25C), calibrated airflow and ECG were recorded on tape. On playback, the signals were digitized at 5.12 kHz per channel. Sounds were low-pass filtered at 1200 Hz (6th order Butterworth filter). Analysis was by FFT (1024 data points, 50% overlap of adjacent segments, Hanning data window, averaging bandwidth 50-1500 Hz). Flow-gated spectra at 2 l/sec ± 10% tolerance were used for measurement of peak frequency (Fpeak), median frequency (Fmed), upper limit (UL) beyond which power is less than 10% of peak power, spectral edge frequency (SEF95) below which 95% of spectral power are contained, and power in the averaging bandwidth (Pavg). In all subjects, ECG gated analyses showed less variance and were less biased toward lower frequencies. Figures 1a and 1b show an example of the effect of ECG gating on the measurement of inspiratory tracheal sounds in one subject. ECG gating reduced the number of available segments within the target flow range from 65 to 21. However, the variability of measurement was less, particularly for UL and SEF95. The range for Fmed was smaller and, in contrast to measurement of the same sound without ECG gating, did not include frequencies below 150 Hz. Thus, cardiovascular sounds may bias the analysis of tracheal sounds toward lower frequencies and may introduce greater variability of measurements. These concerns exist whenever cardiovascular sounds are prominent in respiratory sound recordings, i.e. in studies of newborn infants and young children or in subjects after exercise. I suggest to use ECG gating under those circumstances to allow a more accurate characterization of the inherently variable signals of respiratory sounds.

Fig. 1a

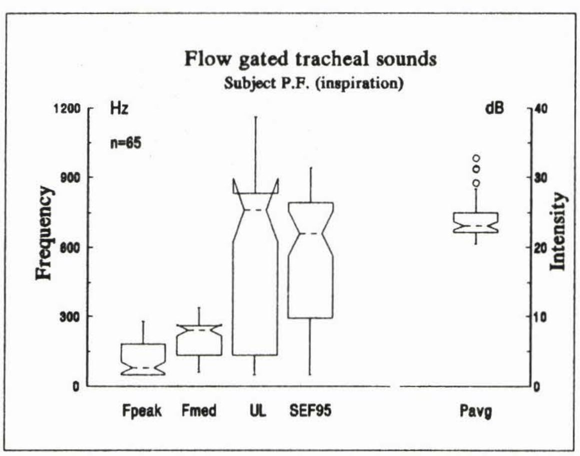
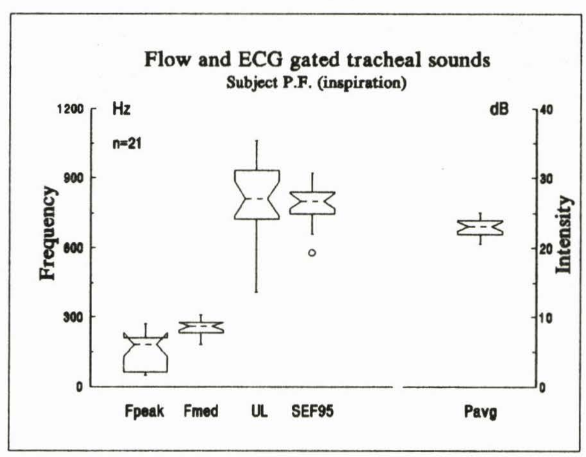


Fig. 1b



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SPECTRAL ANALYSIS & DATA COMPRESSION FOR LUNG SOUNDS.

Abstract: This paper is concerned with the use of digital signal processing for monitoring the lung sounds produced by patients suffering from asthma and other related chest disorders. The requirement is to perform spectral estimation on these sounds, to store the spectra, and to display them in an informative manner to the medical user. In order to perform long term continuous analysis and storage (e.g. overnight monitoring of nocturnal asthma) the results are compressed so as to make efficient use of the storage media. The spectral estimation is achieved using Prony's data model as the underlying signal production mechanism. Prony's Method was chosen over other spectral estimation techniques (in particular the commonly used Fast Fourier Transform method) because of its ability to extract non-harmonically related damped sinusoidal components from the lung sound. Results show that when the signal to noise ratio of the pulmonary signal is in excess of 20 dB, then Prony's Method will calculate accurate spectrographs for the lung sound. Analysis presented includes signals of a continuous nature e.g. 'wheezing' conditions, and also sounds of a discontinuous nature e.g. 'crackles'.

Prony's analysis.

A NEW MODEL OF A MICROPHONE FOR A PORTABLE PHONOPNEUMOGRAPH

M.Yumoto[1*], S.Kudoh[2*], A.Shibuya[3*], H.Matsuki[4*]

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2* Tokyo Metropolitan Komagome Hospital, Bunkyo-ku, Tokyo

3* Research Institute for Polymers & Textiles, Yatabe, Ibaraki

4* RION Co. Ltd., Kokubunji, Tokyo

At the 14th conference in Winnipeg, we reported our second model of a phonopneumograph. For clinical application of a phonopneumograph, a microphone plays an important role in the system. Because, the microphone is greatly responsible for the total S/N ratio of the system and for the clinical convenience at the bed-side.

The new model ME-35 is a pen-shaped, handy type microphone(L 144^{mm} x ϕ 19.7^{mm}max). The head, microphone case, which contains an ultra-miniature microphone and the tail, grip, are connected with silicon rubber which acts as a vibration buffer. This silicon rubber also gives the head flexibility to some extent and makes it easy to contact with the skin.

The specification of this model is appreciating. The acoustic sensitivity of this model is about 10dB higher than that of SONY ECM-150 with a rubber adapter. The sound insulation effect to surrounding noise is also about 10dB better than that of the same control. On the whole, total S/N ratio would be progressed by 20dB. And the suppression effect of hand-trembling noise is good enough for practical use.

Recently, we have been trying to develop a portable phonopneumograph from the standpoint of clinical application of lung sounds analysis, at the bed-side. We think this microphone could be a chestpiece of an "objec tive stethoscope".

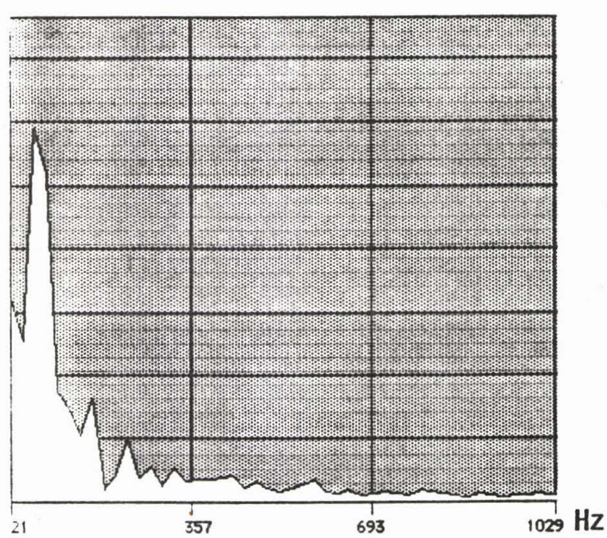
Session B

Dr. Filiberto Dalmasso & Dr. A.R.A. Sovijarvi, Co-Chairmen

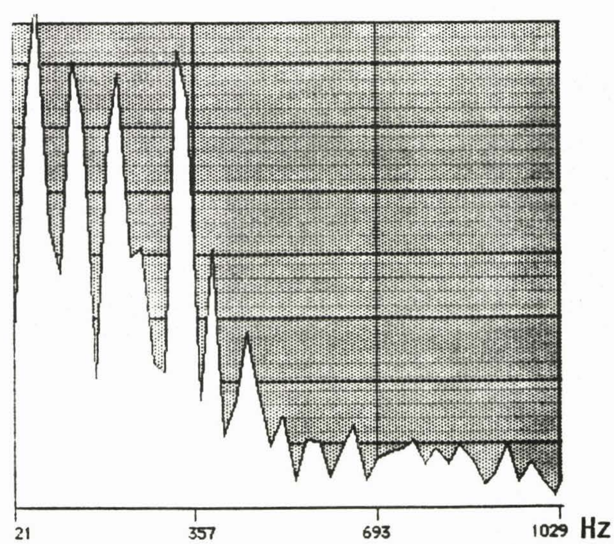
1:00 - 1:20	Histamine challenge using computerized lung sounds analysis in young children	Beck Dickson Montgomery
1:20 - 1:40	Response to inhaled salbutamol in infants with bronchiolitis studied by distal respirosonography	Sanchez Tal Pasterkamp
1:40 - 2:00	Spectral analysis of wheezing in asthmatic patients associated with different patterns of breathing	Graham Calverley Pearson Earis
2:00 - 2:40	A study on frequency analysis of tracheal stenosis in relation to the area of tracheal stenotic region	Kikuchi Kobayashi Ishihara Mori Kawashiro Yokoyama Yonemaru
2:40 - 3:00	Break	
3:00 - 3:45	Guest Speaker: Dr. Charles Berlin Director, Kresge Hearing Research Laboratory, LSU Medical Center	

HISTAMINE CHALLENGE USING COMPUTERIZED LUNG SOUNDS ANALYSIS IN YOUNG CHILDREN. R. Beck, U. Dickson, M. Montgomery, I. Mitchell. Department of Paediatrics, University of Calgary; Alberta Children's Hospital, Calgary, Alberta, Canada.

The use of Histamine (or Methacholine) Challenge Test (HCT) has so far been limited to children who can perform spirometry consistently. Avital et al have recently demonstrated that tracheal auscultation with analog recording by tape-recorder can be utilized to replace spirometry in young children. In our present study we used digital (8 bit A/D converter, sampling rate: 22kHz) recording with a Macintosh SE computer, and performed spectral lung sounds analysis (LSA) after each histamine dose. To validate the method, six older children (age 6 - 14 years) with mild or moderate asthma were tested. The identification of typical wheezing pattern (discrete, high amplitude power peaks) on LSA was compared to 20% fall in FEV_1 (PC_{20}), appearance of wheeze on tracheal auscultation and symptoms (cough, wheeze, or chest tightness). In five patients, characteristic wheezing pattern on LSA appeared one step (1/2 the histamine concentration) before the 20% fall in FEV_1. In the sixth patient, wheezing on LSA and PC_{20} occurred at the same histamine concentration. Symptoms and wheeze on tracheal auscultation coincided with PC_{20} in all patients. Six young asthmatic children (age 2.5 - 4 years) were then tested. All children showed the wheezing pattern on LSA at a histamine concentration of 25% or 50% (1 or 2 steps prior) of that producing symptoms or wheezing on tracheal auscultation. Four children with no asthma (controls) did not show this spectral pattern on LSA and did not develop any symptoms on HCT. This is a sensitive method enabling application of HCT to young children who are unable to perform spirometry.



Inhaled normal saline



Inhaled histamine 0.125 mg/ml

RESPONSE TO INHALED SALBUTAMOL IN INFANTS WITH BRONCHIOLITIS STUDIED BY DIGITAL RESPIROSONOGRAPHY

Ignacio Sanchez, Asher Tal, Hans Pasterkamp
Dept. of Pediatrics, University of Manitoba, Winnipeg, CANADA

To study the effect of inhaled salbutamol in infants admitted with bronchiolitis, we analyzed recorded lung sounds from 16 patients (4 girls and 12 boys), aged 1 to 23 months (mean 9.4). Four infants also had bronchopulmonary dysplasia. Viral studies were positive in 8/16 (6 RSV, 1 Adeno and 1 Influenza virus). Lung sounds (contact transducer) and breathing pattern (Respitrace) were simultaneously recorded on tape before and after a single salbutamol inhalation (0.02ml/kg). Analysis was done using digital respirosonography.[1] Wheezing was quantified as a proportion of total respiratory time (Tw/Ttot). A decrease of ≥15% in Tw/Ttot was taken as a positive response to salbutamol. There were 7 responders (R) and 9 non-responders (NR). Patient characteristics (age, sex, viral studies) were not different between the two groups. In R, Tw/Ttot decreased from 47±26% to 20±25% with no significant change in mean wheeze frequency (avgWf): 230±35 Hz and 255±101 Hz pre and post treatment, respectively. In contrast, NR had unchanged Tw/Ttot (31±13% pre and 38±12% post); in this group avgWf decreased significantly from 273±68 Hz to 206±21 Hz ($p<0.03$). R had a significant decrease in respiratory rate (RR) from 65±8 to 57±7 bpm ($p<0.05$) whereas RR in NR remained unchanged (53±10 pre and 56±9 post). I:E ratio was similar in both groups (0.7±0.2 in R and 0.7±0.1 in NR) and did not change after salbutamol. In one NR infant, Tw/Ttot was 11% greater after salbutamol, and avgWf was higher compared to baseline. Some infants had typical wheezing with sinusoidal sound waves (Fig.1). However, complex periodic waveforms (Fig.2) were observed in 10/16 infants. Automated spectral characterization of wheezing in these infants was therefore more difficult since our method for computer detection of wheezing in older patients is based on sinusoidal waves with frequency above 200 Hz and duration >100 msec.[2] We conclude that the response to bronchodilators in infants with bronchiolitis can be objectively measured by lung sound analysis.

1. Pasterkamp et al. Chest 1989;96:1405
2. Pasterkamp et al. ARRD 1985;62:16

Figure 1 Typical expiratory wheeze

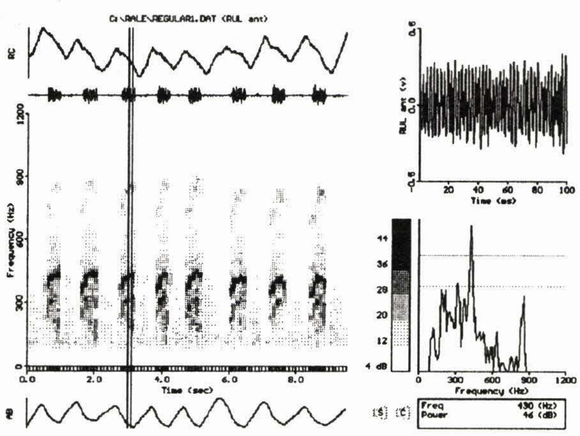
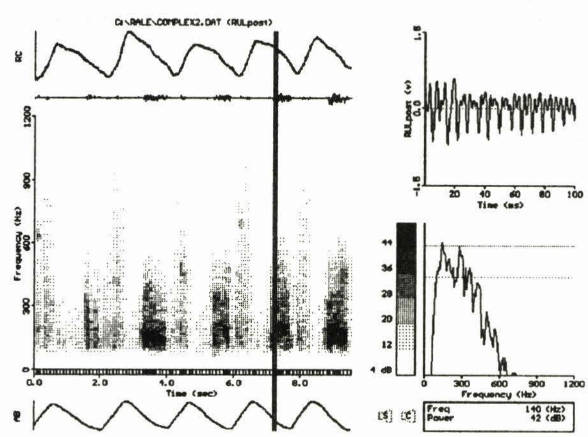


Figure 2 Complex periodic sound waves



5 no. 1 deep 5 no. 5 deep. 1 max.

THE EFFCT OF BREATHING PATTERN ON THE SPECTROGRAPHIC ANALYSIS OF WHEEZE.

DR Graham, G Jamieson, PM Calverley and J Earis.
Fazakerley Hospital and University of Liverpool.
Liverpool, Merseyside, England.

Auscultation of wheeze has not proved to be a reliable guide to the severity of airflow obstruction in asthma. However, spectrographic analysis has improved understanding. Wheeze duration has been shown to increase with worsening airflow obstruction (Louden 1984) and the median wheeze frequency increases with airflow obstruction (Anderson 1990). Clinically it is well recognised that wheeze alters with different patterns of breathing thus the depth of respiration is likely to be of importance in the analysis of wheeze. We have performed a study to evaluate how wheeze alters with different patterns of breathing and attempted to relate the changes to physiological parameters. Spectrographic analysis of wheeze was carried out on patients with acute asthma and the wheeze characteristics were compared at tidal and deep breathing. Six patients were studied, 3 Male and 3 Female the age range was 22 - 58yrs. Sounds were recorded by a microphone applied to the chest wall by a suction cup, the signal was passed to a pre-amplifier and then to an FM Tape recorder (Racal) and via an amplifier (Rotel) to the analysis system. Patients were asked to breathe normally then deeply. Flow and volume were measured using a pneumotachograph (PK Morgan) and recorded onto separate channels of the FM Tape Recorder. Flow, volume and sound were also recorded onto paper. Spectrographic analysis was carried out using a digital signal processing system based on the Texas TMS 320 chip linked to a host IBM compatable computer.

During normal breathing the mean tidal volume was 0.84 (0.24)l and on deep breathing the volume increased to a mean of 1.45 (0.7)l. At both tidal and deep breathing the principal wheeze frequency changed from the start to the end of an individual wheeze. In all 6 patients the mean wheeze frequency altered from tidal to deep breathing. In 3 patients the wheeze frequency increased and 3 it fell. Half of the patients developed a new, higher pitched, separate wheeze on deep breathing. There was a significant increase in wheeze intensity (Tidal -26.1 dBs and Deep -21.1dBs $p<0.005$). Wheeze duration also increased comparing tidal and deep breathing (407 (112) to 507 (179) millisecs $p<0.05$).

The depth of respiration affects the characteristics of wheeze in patients with acute asthma, thus, the breathing pattern should be carefully regulated in any spectrographic analysis of wheeze.

STUDY ON THE FREQUENCY ANALYSIS OF TRACHEAL STENOSIC SOUND IN RELATION TO THE AREA OF TRACHEAL STENOTIC REGION

K.Kikuchi[1], K.Kobayashi[1], T.Ishihara[1], M.Mori[2], T.Kawashiro[2], T,Yokoyama[2] and M.Yonemaru[3]
Department of Surgery[1], Department of Medicine[2], School of Medicine, Keio University, Department of Medicine, Tokyo Medical college[3], Tokyo, Japan

Acoustic technology was applied to analyze the frequency of tracheal stenotic sounds in patients with tracheal stenosis. We studied on the frequency analysis of tracheal stenotic sound in relation to the area of tracheal stenotic region.

A microphone specialy prepared for recording of the respiratory sound was attached to the cervical region; through which the respiratory sound was detected and recorded on a data-recorder, Model A-614 made by Sony-Magnescale Co. The recorded respiratory sound was reproduced and its signals were converted from analog to digital. Then the frequency was analysed using fast Fourier Tranform.

The cross-sectional area of the region showing the most stenotic site in the CT image was measured to represent the area of tracheal stenotic region.

When the area of tracheal stenotic region was less than 0.8 cm^2, the spectral peak in the frequency band around 1000 Hz was elevated. Also, when the area of stenotic region was less than 0.5 cm^2, the spectral peak was markedly elevated in the frequency band around 1000 Hz.

We believed that the above new findings obtained by analyzing the frequency of tracheal stenotic sound in patients may serve as an objective index for those cases of tracheal stenosis. Also, as a result of the comparison between the frequency analysis of tracheal stenotic sound and the area of stenotic region, it was noted that there was a marked elevation of spectral peak in the frequency band around 1000 Hz when the area was less than 0.5 cm^2.

Session C

Dr. Hans Pasterkamp & Dr. Shoji Kudoh, Co-Chairmen

9:00 - 9:20	Classification of lung sounds by using self-organizing feature maps	Kallio Rosqvist Haltsonen Karp Katila Paajanen Piirila Sovijarvi
9:20 - 9:40	Effect of highpass filtration on measured spectral characteristics and waveform of crackling lung sounds	Piirila Sovijarvi Kallio Rosqvist Karp Katila
9:40 -10:00	Spectral analysis of crackles and surrounding respiratory sounds	Postiaux Lens
10:00-10:30	Coffee Break	
10:30-10:50	Computer analysis of structure and timing of lung sound crackles in fibrosing alveolitis, bronchiectasis, COPD and heart failure	Sovijarvi Piirila Kaisla Kallio Rajala Rosqvist Katlia
10:50-11:10	Crackles in interstitial lung disease: comparison between sarcoidosis and fibrosing alveolitis	Baughman Shipley Lower Loudon
11:10-11:30	PC based sound data capture and multivariate analysis	Druzgalski Luo
11:30-12:00	Business Meeting	
12:00- 1:30	Lunch	

CLASSIFICATION OF LUNG SOUNDS BY USING SELF-ORGANIZING FEATURE MAPS

K. Kallio (1), T. Rosqvist (1), S. Haltsonen (1), P. Karp (2),
T. Katila (1), E. Paajanen (1), P. Piirilä (3), A. Sovijärvi (3)

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3 Pulmonary Function Laboratory, Helsinki University Central Hospital, SF-00290 Helsinki, Finland.

Signal processing and information technology offer effective tools for lung sound analysis. One of these is self-organizing feature mapping (1, 2) which has successfully been utilized in speech recognition. We have applied the method of self-organizing feature mapping to the basic classification of lung sounds. The method consists of two stages: teaching and recognition. In the teaching stage we compute 256-point FFT-spectra and pick up sixteen frequency components from them. These components are then given as dimensions to the mapping process in which they are euclidically compared to each of the sixteen-dimensional member vectors of the map. The closest member vector of the map is chosen and it is, with its nearest neighbours, drawn closer to the sound spectrum. In the beginning the neighbourhood parameter is large and decreases during the teaching period. This leads to an ordering process among the map members. It is possible for the user first to choose the representing samples of the lung sounds and save them as teaching files. As a result an organized map is obtained describing the lung sound features and taking into account the generality of the data in each part of the space. The map also quantizes the frequency space used reducing the amount of calculation.

In the recognition stage we use the taught map for the classification of unknown lung sounds. The distances of the unknown sound spectra from the member vectors of the map are measured and the classification of each spectrum occurs according to the closest member of the map. We have carried out pilot experiments and the results indicate that the method is suitable for mapping of lung sounds. The organizing map well follows natural lung sound spectra saving their features and it can be used for automatic classification of various lung sound types.

References:

(1) Teuvo Kohonen: Self-Organization and Associative Memory, Springer-Verlag, New York Tokyo (1984)

(2) Teuvo Kohonen: The "Neural" Phonetic Typewriter, Computer, March, pages 11-22 (1988)

EFFECT OF HIGHPASS FILTRATION ON MEASURED SPECTRAL CHARACTERISTICS AND WAVEFORM OF CRACKLING LUNG SOUNDS

P.Piirilä (1), A.R.A.Sovijärvi (2), K.Kallio (3), T.Rosqvist(3), P.Karp (4), T.Katila (3)
Institute of Occupational Health, Helsinki (1), Department of Pulmonary Diseases, Helsinki University Central Hospital (2), Laboratory of Biomedical Engineering, Dept.of Technical Physics, Helsinki University of Technology (3) and Dept. of Medical Engineering, Helsinki University Central Hospital(4), Finland

Signal filtration is an essential part of all signal processing and also the lung sound signal is influenced by the method of filtration. We studied the effect of different cutoff levels of highpass filtration on several spectral and waveform characteristics of crackling lung sounds of a patient with fibrosing alveolitis by filtering the sounds with a cutoff frequency from 95 Hz to 600 Hz and with A-weighting. In lung sound analysis the frequency with maximum intensity and the upper sound limit at -20 dB intensity bandwidth became higher when the cutoff level of highpass filtration was raised. The crackle structure characteristics, initial deflection width, two cycle duration and largest deflection width became shorter, as the highpass filtration was raised. The results from the experiment are presented in the table below.

Highpass filtration	Frequency with maximal intensity (Hz)	Upper frequency limit at -20dB bandwidth (Hz)	Initial deflection width (ms)	Two cycle duration (ms)	Largest deflection width (ms)
95 Hz (24dB/Oct.)	212 ± 50	471 ± 235	1.33 ± 0.16	9.00 ± 0.95	1.94 ± 0.03
200Hz (24dB/Oct.)	247 ± 28	591 ± 54	1.03 ± 0.15	6.32 ± 0.30	1.85 ± 0.10
600Hz (12dB/Oct.)	282 ± 13	1008 ± 364	0.97 ± 0.10	5.33 ± 0.17	1.46 ± 0.19
A-weighting	328 ± 86	1065 ± 303	0.79 ± 0.05	4.61 ± 0.05	1.06 ± 0.81

As a conclusion, the methods of filtration during recording of crackling lung sounds can markedly modify the waveform and spectral characteristics of crackling lung sounds. Standardization of sound recording and filtration systems is needed to ensure that results from different laboratories are comparable.

(Grants: Finnish Association Against Tuberculosis)

SPECTRAL ANALYSIS OF CRACKLES AND SURROUNDING RESPIRATORY SOUNDS.

Postiaux G., Lens E.

Department of internal medicine, Clinique Reine Fabiola, and Groupe d'Etude Pluridisciplinaire Stéthacoustique - Charleroi (Belgium).

This preliminary study to characterize the relationship between ear perception and acoustical features of Crackles/Respiratory sounds-ratio (C/R).

On the right posterior base, we sampled crackles from patients with COPD, Bronchiectasis, Interstitial fibrosis.

We performed measures in time and frequency domain of 1) crackles: IDW, 2CD (Murphy), the First one Cycle Wave (1CW), the Resonant Segment (RS), the Total Duration (TD: 4, 6 or 8... cycles), and of 2) respiratory sounds surrounding each crackle to appreciate C/R.

We support the observation of Mori (1980) about the two segments crackle's shape. As observed in music acoustic analysis, we suggest following interpretation of the two segments.

1. First segment results from the mechanical source and corresponds to the excitative system serving to induce excitation of the resonant system.
2. The second segment is the resonator whose spectral analysis is similar to the spectral analysis of the surrounding lung sounds. So, this resonator segment of the crackle is determined by the resonant frequency of surrounding pulmonary structures.

C/R allows to distinguish several subgroups among the three main groups (coarse, medium and high pitched crackles). A large multicentric study correlating acoustic analysis and several respiratory diseases may be of clinical interest.

COMPUTER ANALYSIS OF STRUCTURE AND TIMING OF LUNG SOUND CRACKLES IN FIBROSING ALVEOLITIS, BRONCHIECTASIS, COPD AND HEART FAILURE

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We have compared the structure and timing of crackles in 10 patients with fibrosing alveolitis (FA), 10 with bronchiectasis (BE), 10 with chronic obstructive pulmonary disease (COPD) and 10 with heart failure (HF). During breathing the lung sounds were recorded with two condenser microphones attached dorsally on the chest and the air flow recorded at mouth with a pneumotachograph. The signals were analyzed with computerised signal processing methods with special emphasis to findings in phonopneumography, waveform and sound spectrum. The inspiratory period of crackling was shorter in COPD than in FA ($p<0.001$) or in BE ($p<0.005$). The end point of crackling occurred later in FA than in BE ($p<0.005$), COPD ($p<0.001$) or in HF ($p<0.05$). Furthermore, in COPD the end point of crackling occurred earlier than in BE and HF ($p<0.05$). The upper frequency limit of sound measured at -20 dB intensity bandwidth was in inspiration higher in FA than in COPD ($p<0.005$) or in HF ($p<0.001$). In expiration the upper frequency limit was both in FA and BE higher than in COPD ($p<0.005$) or in HF ($p<0.001$). The number of crackles during an inspiration was smaller in COPD than in FA ($p<0.01$) or in BE ($p<0.05$). The crackle structure characteristics were shorter in FA than in the other patient groups due to the higher spectral contents of the crackle sounds in FA. The initial deflection width was shorter in FA than in BE, COPD or HF ($p<0.001$). The two cycle duration was the shortest in FA ($p<0.001$). The largest deflection width was shorter in FA than in BE ($p<0.005$), HF or COPD ($p<0.001$) and in BE shorter than in HF ($p<0.05$). The study indicates that crackles in the diseases studied contain distinctive features which can be of diagnostic value in diseases with discontinuous adventitious lung sounds.

(Grants:Finnish Association Against Tuberculosis)

CRACKLES IN INTERSTITIAL LUNG DISEASE: COMPARISON BETWEEN SARCOIDOSIS AND FIBROSING ALVEOLITIS.

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Crackles on chest auscultation are characteristic of most interstitial lung diseases (ILD), but may not be heard in sarcoidosis. All patients with sarcoidosis (SARC - 17 pts) or cryptogenic fibrosing alveolitis (CFA - 11 pts) seen during a four week period were studied. Two independent observers auscultated five sites (both bases and apices, mouth) for crackles and reviewed four roentgenogram quadrants for ILD changes. Crackles were noted at > 2 sites in all 11 CFA pts, but only 1 of 16 SARC pts (p<0.001). Roentgenogram changes were seen in >2 quadrants in 9 of 11 CFA pts and 8 of 17 SARC pts (p=n.s.). In a second study to correlate ausculatory findings with anatomy, 11 SARC and 9 CFA pts underwent vital capacity (VC) measurement, auscultation, and high resolution computer tomography (HRCT) scans. All pts had fibrotic changes on chest roentgenogram. The VC was similar in the two groups: SARCOID: 1.96±.90 l (Mean±S.D.), 58±20.4% predicted; CFA: 1.81±.33 l, 59±9.2% predicted). Only 1 of 11 SARC pts had crackles in >1 area, while all 9 CFA pts had crackles at >2 sites. HRCT studies were read by a radiologist unaware of the underlying diagnosis. The presence and degree (0-3 scale) of subpleural and peribronchial fibrosis were scored and the presence of septal thickening, bronchiectasis or honeycombing noted. Ten of 11 SARC pts, had peribronchial changes (mean score 1.8±1.08) while only 6 had subpleural fibrosis (mean score .5 ±.52). In comparison, 4 of 9 CFA pts had peribronchial fibrosis (mean score=.9±.78, p<0.05) and all 9 had subpleural fibrosis (mean score=1.6±.73, p<0.01). There was no difference in septal thickening, bronchiectasis, or honeycombing between the two groups. We conclude that crackles are more frequent in fibrosing alveolitis than in sarcoidosis and this difference may be due to the distribution of parenchymal fibrosis.

PC BASED SOUND DATA CAPTURE AND MULTIVARIATE ANALYSIS

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Proliferation of PCs in clinical setting suggests utilization of a PC as a storage oscilloscope for viewing respiratory sounds and flow/volume data as well as its concurrent configuration for frequency domain analysis and analytical data processing. A broad spectrum of instruments for monitoring of vital signs, including pulmonary function parameters and specialized instrumentation for recording of respiratory sounds necessitate, electrical and/or video interface. In particular, a video capture of signals from a variety of patient monitoring systems or other monitors, as well as special purpose signals analyzers, provide a flexibility in data collection in intensive care units. The system can also be utilized for the retrieval of data stored on a magnetic tape using analog oscilloscopes. This provides data entry in a digitized form and allows correlation of pulmonary function and respiratory sound data.

Specifically, a PC-controllable system allows programmable capture of acoustic data and is particularly suitable for long term monitoring of respiratory sound characteristics. The graphic data is entered into a computer in a digitized form and can be merged with other files for further processing. A conversion from digital oscilloscope peripheral files to other file formats allows utilization of a broad spectrum of software. The sound and pulmonary data waveforms can be correlated , scrolled in any direction and compressed or expanded to a time base suitable for a given signal. The analysis includes spreadsheet sound data presentation and multivariate analysis in frequency and time domains.

The system characteristics, applications, as well as formats of data analysis and presentation will be discussed.

Session D

Dr. Wilmot Ball & Dr. E. Lens, Co-Chairmen

1:30 - 1:50	Snoring on-line monitoring system	Dalmasso Gurati Ono Prota Righini
1:50 - 2:10	Lung sounds associated with secretions in patients with artificial airways	Hoogendoorn Murphy
2:10 - 2:30	On the diagnostic utility of babies' cries	Rice Rice Ricard Beckerman
2:30 - 2:50	Effect of nasal patency on the frequency spectrum of sleep dependent breath sounds	Schafer
2:50 - 3:00	Break	
3:00 - 3:20	Position dependent changes of flow-standardized tracheal sounds in patients with obstructive sleep apnea	Pasterkamp Kryger Sanchez Tal
3:20 - 3:40	Value of lung sounds on a consult service	Lacy Loudon
3:40 - 4:15	Cracklefest	
4:15 - 4:30	Summary	

SNORING ON LINE MONITORING SYSTEM

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The most precise and sophisticated techniques for upper airways obstruction **(UAO)** analysis need the collaboration of the patient or does not permit sleep monitoring.Snoring sounds data in time and frequency domains and L_{eq} measurements do not permit the identification of precise patterns of snoring between subjects who simulated snoring and COLD and OSA patients. Analysing the snoring sounds of COLD and OSA patients we found poor reliability and poor stability in the estimates of the obstruction site from cross-sectional area functions achieved by linear predictive coding **(L P C)** techniques (Dalmasso et al.1989).It is a fact that L P C forces,an all-pole model for the sound source,disregards the effective acoustic properties of the upper airways apparatus (for istance the coupling of oral and nasal cavities). However,despite these limitations,we have studied six COLD patients who are habitual snorers and four O S A patients in relation to other polysomnographic parameters. We found the progress of the obstructive process up to O S A paroxysm may be related to the minimum of the cross-sectional area function in a sequence of successive estimates, providing a continuous processing of **LPC** data. Optimizing the LPC analysis parameters (i.e. predictor order,window length,......) and the algorithm implementation,it has been possible to realize (on a personal computer,Olivetti M-380/C,equipped with data acquisition card,Metrabyte DAS-16,) an efficient real time monitoring system useful for clinical purposes. A **VIDEO CASSETTE** shows the evolution in time of the size of the upper airways during snoring in patients with different diseases.

LUNG SOUNDS ASSOCIATED WITH SECRETIONS IN PATIENTS WITH ARTIFICIAL AIRWAYS

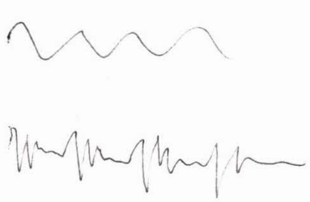
Mels Hoogendoorn
Raymond L.H. Murphy, Jr.

Patients with artificial airways have a variety of sounds that seemed to us to not fit readily into the ATS classification of lung sounds. We hypothesized that such sounds have acoustic characteristics that differ from sounds that have been clearly described in the current nomenclature. We recorded lung sounds in eight (8) patients with artificial airways at five (5) chest sites before and after suctioning. These sounds were subjected to analysis in the time and frequency domains and classified in accordance with current guidelines. The majority of sounds that we observed could be conveniently classified as rhonchi. However, the "classical" picture of a relatively uniform undulating pattern longer than 250 msec was not always found; to our surprise, a second pattern of irregular indurations was about as common (see Table)

TABLE (Sites Positive for Adventitious Sounds)

	Before Suctioning		After Suctioning	
	Inspiration	Inspiration	Inspiration	Expiration
Rhonchi				
I	19	17	4	6
II	19	27	10	10
Wheeze	0	3	0	8
Crackle	0	1	0	1

We concluded that most sounds associated with secretions in these patients could be conveniently classified as rhonchi; that is, they are relatively continuous, low-pitched sounds, having either uniform or irregular waveforms. In approximately 5% of cases, this irregular pattern became so intermittent that it was similar to coarse crackles. In general, these patterns tended to change to normal after suctioning. Five patients cleared at all five sites, one patient cleared at three sites, and two patients did not clear after suctioning. This suggests that such patterns have the potential for guiding suctioning in patients with artificial airways.



ON THE DIAGNOSTIC UTILITY OF BABIES' CRIES

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This psychoacoustic study investigates whether babies cries are useful in determining disease state, age, and weight, and whether observer profession or experience improves observer performance. We recorded cries from 17 infants under 1 year of age, including four normals (N), four each with respiratory distress (R) and mental retardation (M), and five with gastrointestinal distress (GI). Seventeen observers characterized and classified all cries according to disease state. The observers included three pediatricians, six pediatric nurses, four mothers, and four college seniors.

Heart disease was included in the ratings as a distractor, making five possible outcomes and a 20% correct classification by chance. Thirty percent of the diseases were classified correctly, and there was no difference between observer groups ($P>0.5$) nor self-reported experience ($P>0.25$). The ability to classify a disease correctly is a function of the disease ($P<0.001$). N's were correctly recognized 56% of the time, while GI's were correctly recognized only 15% of the time. The observers estimated age and weight. Groups did similarly except that the seniors were less able to predict age ($P<0.01$). Weights and ages were over- or underestimated depending on disease ($P<0.01$).

The observers rated each cry for the extent to which it had each of 11 characteristics (e.g. piercing, grunting). Discriminant function analysis indicates that there are three dimensions to the description of the disease groups based on these characteristics. The first dimension places N's at one extreme, M and GI's at the other, with R's in between. Normal cries are intense, while M + GI cries are weak, hoarse, grunting, and abnormal. The second dimension separates R's from the others. R's are sharper and higher-pitched. The third dimension separates M from GI with the others in between. M's cries are more hoarse, growling, and intense than the GI's.

Observers classified disease correctly at levels better than chance from listening only to babies cries. Profession or experience with babies did not improve diagnostic ability. Ratings of cry characteristics do separate the various diseases. These facts suggest that with a good set of descriptors, well tested scales, and training specifically directed towards diagnosis, listening to babies cries may be of value in diagnosing disease.

EFFECT OF NASAL PATENCY ON THE FREQUENCY SPECTRUM OF SLEEP-DEPENDENT BREATH SOUNDS

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Snoring is a sleep-dependent acoustic event due to increased upper airway resistance. The site of increased resistance can be located anywhere from the nares to the glottis. The role of the nose in snoring is largely unknown. In order to find out how compromised nose-breathing will influence snoring, sleep-dependent breath sounds in patients with different degrees of snoring and obstructive sleep apnea syndrome were recorded and analyzed. The records were made before and after septo/rhinoplasty or turbinate reduction and with and without artificial nasal obstruction (anterior nasal packing). For comparison snoring noises of patients treated by nasal CPAP, dental appliances and UPPP were recorded and analyzed. Analysis was in terms of sound pressure level and frequency spectrum.

Sound pressure levels in patients with nasal obstruction were higher than in patients without obstruction. The frequency spectrum of patients with obstruction showed a shift to higher frequencies. The results support the hypothesis that in healthy subjects the contribution of the nose to upper airway resistance during sleep decreases in comparison to the awake state. Thus increased nasal resistance contributes to snoring and obstructive sleep apnea.

POSITION DEPENDENT CHANGES OF FLOW-STANDARDIZED TRACHEAL SOUNDS IN PATIENTS WITH OBSTRUCTIVE SLEEP APNEA

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Patients with obstructive sleep apnea (OSA) have increased pharyngeal compliance and a decreased cross sectional pharyngeal area in the supine position even while awake.[1] To study whether this leads to changes of flow-standardized tracheal sounds we analyzed data from 5 male subjects with documented OSA. Their mean age was 53.6 years (range 43 to 66). Tracheal sounds were recorded at the suprasternal notch (contact transducer, EMT25C Siemens) while the patients were breathing through a calibrated pneumotachograph. They were instructed to breathe at target flows of 1 l/s and 2 l/s, first in the sitting and then in the supine position, while they observed the flow signal on an oscilloscope. Between 40 to 60 s of tracheal sounds and flow signal were acquired per patient, target flow and body position. The signals were digitized at 5.12 kHz and average power spectra were computed by FFT from sound segments at target flows $\pm$ 10% tolerance, both for inspiration and expiration. There was a significant increase in sound intensity when the patients were supine: 8.7 $\pm$ 1.9 dB during inspiration and 9.5 $\pm$ 2.4 dB during expiration at 1 l/s (mean $\pm$ SD). This was also observed at flows of 2 l/s, where inspiratory sounds increased by 8.4 $\pm$ 3.4 dB and sounds during expiration increased by 10.9 $\pm$ 4.8 dB. Median frequencies and SEF95 (spectral edge frequency = frequency below which 95% of the spectral power is found) were higher in the supine position but spectral shape above 300 Hz was not significantly different (see Fig.1). We had previously described position dependent tracheal sound changes in 6 healthy young male non-smokers.[2] The observed increase of sound intensity in supine patients with OSA was much greater than in those normal subjects. We are currently gathering data from age, sex and weight matched non-snorers without OSA. If position dependent tracheal sound changes in these controls are less than in patients with OSA, it is likely that the reduction of pharyngeal size contributes to the sound increase in the supine position.

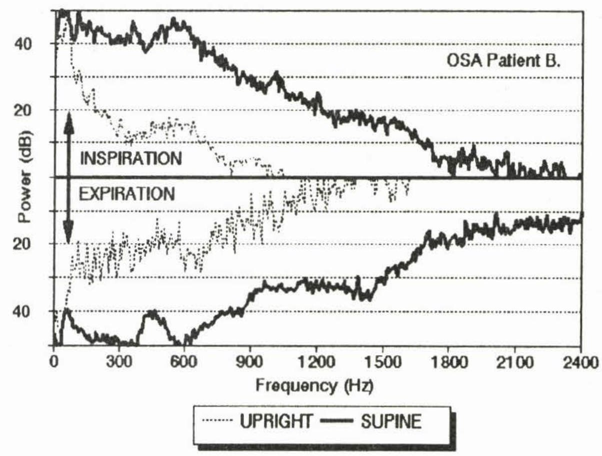

Figure 1

Average power spectra of tracheal sounds in the supine position show a marked increase in intensity at standardized flows of 2 l/s ($\pm$ 10% tolerance), both during inspiration and expiration.

References:

1. Brown IG et al, ARRD 1985;132:211-5
2. Pasterkamp H et al, ARRD 1987;135:A490

VALUE OF LUNG SOUNDS ON A CONSULT SERVICE

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We attempted to identify the value of physical exam in the work-up of pulmonary consultations at a university hospital. Fifty consecutive patients referred to the pulmonary service for consultation were identified by final diagnosis and by initial reason for consultation; diagnosis, management, procedure, teaching, or other. Values for seven sources of information: history, physical exam, x-ray, bronchoscopy, pulmonary function tests, lab, and other were assigned on a scale of 0 to 3. Finally one category was chosen as the most important diagnostic category. For overall value in 50 patients, physical examination ranked second only to x-ray, and above history, bronchoscopy, pulmonary function testing, and other laboratory tests. If the four cases referred to the consult team for teaching interest rather than consultative help are excluded, physical diagnosis falls to third place, behind x-ray and history. We found that physical exam was the most important diagnostic category in 24% of all cases. Physical exam was the most important diagnostic category in all cases of asthma and in 37% of our cases of pneumonia. We conclude that physical exam remains important in the diagnostic work-up of pulmonary consultations.