FOURTEENTH INTERNATIONAL CONFERENCE ON LUNG SOUNDS

第 14 回 国際肺音学会

SEPTEMBER 13-15, 1989

NORWOOD HOTEL & MINAKI LODGE
WINNIPEG, CANADA

PRESENTED BY

INTERNATIONAL LUNG SOUNDS ASSOCIATION

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14th International Conference on Lung Sounds

Winnipeg, Manitoba, Canada

Program

Wednesday, September 13, 1989

Workshop and Posters - Norwood Hotel ------------------4:00 - 6:00 PM

Thursday, September 14, 1989

Registration --8:00 AM

Welcome - Dr. Hans Pasterkamp --------------------------------8:30 AM

Keynote Address - Dr. John Earis -----------------------------8:45 AM

Session A - Dr. Gavriely & Dr. Ploysongsang ----------9:00 - 12:20 PM

Lunch --12:00 - 1:00 PM

Session B - Dr. Cugell & Dr. Dalmasso ----------------1:00 - 3:50 PM

BUS TO MINAKI LODGE LEAVING AT 4:30 PM FROM NORWOOD HOTEL

Dinner at Minaki Lodge -------------------------------------- 8:30 PM

Friday, September 15, 1989

Session C - Dr. Krumpe & Dr. Ball ---------------------8:30 - 12:00 PM

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

Lunch --12:15 - 1:30 PM

Session D - Dr. Ishikawa & Dr. Mikami ---------------- 1:30 - 4:45 PM

Cracklefest -- 4:45 - 5:15 PM

Summary - Dr. Steve Kraman ---------------------------- 5:15 - 5:30 PM

Session A

Dr. Noam Gavriely and Dr. Y. Ploysongsang, Chairmen

9:00 - 9:20	Relationship between the character of lung sounds, gestational age, and the weight of newborn children	Slawinski McMillan
9:20 - 9:40	Use of tracheal sound recordings to evaluate the response to nasal continuous positive airway pressure in patients with obstructive sleep apnea	Krumpe
9:40 -10:00	The analysis of breath sounds at the mouth for the diagnosis of lung disease	Stoneman
10:00-10:20	Pulmonary crackles in fibrosing alveolitis	Piirila Haltsonen Kaisla Katila Raivio Rosqvist Rajala Seitsonen Sovijarvi
10:20-10:50	Coffee Break - Discussion of Posters	
10:50-11:10	A new method for the analysis of individual waveform and spectral characteristics of crackles. I: Device	Ukita Homma Doi Ohtsuka Masaki Kusaka Tanimura Munakata Kawakami
11:10-11:30	A new method for the analysis of individual waveform and spectral characteristics of crackles. II. Standard values for fine and coarse crackles	Ukita et al
11:30-11:50	Cracking sounds in the traumatic subcutaneous emphysema	Dalmasso Benedetto Righini Sirkka Spagnolo
11:50-12:00	Photo	
12:00- 1:00	Lunch	

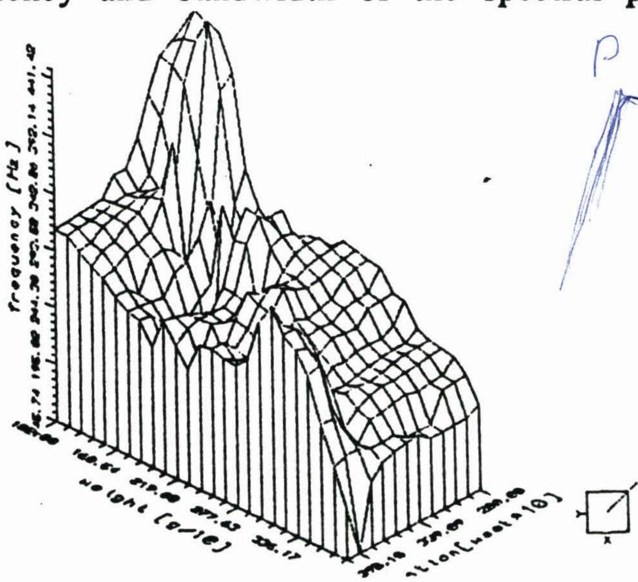
Relationship between the character of lung sounds, gestational age, and the weight of newborn children.

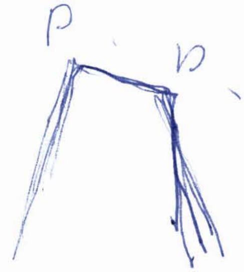
Elzbieta B. Slawinski* and Doug D. McMillan#; * Department of Psychology and # Department of Pediatrics, The University of Calgary, 2500 University Dr. Calgary, Alberta, T2N 1N4

Our subjects were four groups of newborns: 14 term infants of gestational age above 37 weeks, 12 infants born after 33-36 weeks of gestation, 14 infants born after 30-32 weeks of gestation, and 3 infants of gestational age less than 29 weeks. Each of these groups was divided by chronological age of the infants into two groups: <3 days, and 4-7 days of age. The exception was the gestational group <29, where all infants were older than 4 days. Independently of the gestational and the chronological age division, the infants were also classified by weight into three groups.

The procedure of recording and analysis of chest sounds were the same as described at the 1988 Chicago meeting. Recordings were taken from the left side of the neck, right and left upper posterior chest, and right and left lower posterior chest. The sounds were digitized using an analog-to-digital convertor on a VAX 11/730 computer. Five cycles of respiration were analyzed for each recording location for each child.

Spectra of inspiratory sounds of newborns are characterized by one peak at low frequencies. For chest sounds recorded at either chest location, this corresponds to frequencies below 500 Hz; for neck sounds, to frequencies around 1000 Hz. The frequencies of these peaks also depend on the gestational age and weight of the infants. With increased gestational age and weight, the peak frequencies decrease, as shown in Figure 1 for chest sounds recorded at the upper right chest. The two-way ANOVA shows the main effects of gestational age and weight on the peak frequency. An analysis of drop-frequency and bandwidth of the spectral peaks was also performed.





USE OF TRACHEAL SOUND RECORDINGS TO EVALUATE THE RESPONSE TO NASAL CONTINUOUS POSITIVE AIRWAY PRESSURE IN PATIENTS WITH OBSTRUCTIVE SLEEP APNEA

Peter E. Krumpe, MD, and the Sleep Laboratory Staff ,VA Medical Center, Martinez, Ca, and the UC Davis School of Medicine, Davis, CA.

Tracheal sound recordings (TSR) have been useful for diagnosing apnea, snoring, coughing and other respiratory events during polysomnographic studies of obstructive sleep apnea (OSA) patients. Continuous positive pressure applied through a nasal mask (N-CPAP) has become the standard treatment for OSA; it stents open the upper airway thus preventing or decreasing OSA. We have evaluated TSR in OSA patients before and after the initiation of N-CPAP by documenting reductions of inspiratory snoring during N-CPAP. We hypothesized that a reduction of snoring would be associated with fewer episodes of less severe desaturation.

Nighttime recordings of TSR, Sat% O_2, and nasal mask pressure were evaluated for 2 or more hours of sleep in twenty OSA patients. N-CPAP levels ranged from 7.5 to 15 cm H_2O. TRS identified epoches of apnea, hypopnea, hypopnic snoring, and/or arousal snoring in all patients before N-CPAP. After N-CPAP, those patients whose TSR had previously shown periodic OSA with arousal snoring manifested hypopnic snoring with improved Sat% O_2. Those patients who had shown predominantly hypopnic snoring had reduction or elimination of snoring. This group also improved or normalized Sat% O_2.

During N-CPAP, white noise from the blower machine is transmitted to TSR and can be identified as an irregular elevation of the baseline. The periodic disappearance of transmitted CPAP noise (presumably due to closure of the hypopharynx during OSA), followed by loud arousal snores is indicative of the need to increase the amount of N-CPAP. The disappearance of transmitted CPAP noise for a prolonged period indicates that the patient has removed the N-CPAP mask during the night; further periodic desaturations and/or snoring during the remainder of the study should not be attributed to lack of efficacy of N-CPAP. The presence of transmitted CPAP noise was also useful for the verification of continued N-CPAP use in several studies during which the pressure monitor disconnected from the patient's mask during the night.

TSR documented both the compliance of the patient in wearing the mask and the efficacy of the N-CPAP in reducing OSA.

The Analysis of Breath Sounds at the Mouth for the Diagnosis of Lung Disease.

by

S.A.T. Stoneman*

ABSTRACT

An investigation has been undertaken to determine whether there is any correlation between the spectral analyses of breath sounds at the mouth and the diagnoses of lung dysfunction in a small number of patients.

The results of the investigation have shown that it is possible to differentiate between the spectral characteristics of the breath sounds of people who are:

(a) Normal,
(b) Asthmatic adult, both before and after the administration of a bronchodilator drug
(c) Asthmatic adult, treated with an inhaled steroid, both before and after the administration of a bronchodilator drug
(d) Asthmatic child, both before and after the administration of a bronchodilator drug and
(e) A patient with a mixture of asthma and bronchitis, both before and after the administration of a bronchodilator drug.

The possible applications of the technique are discussed, with suggestions made for future development both in terms of a commercial product and investigations which could be undertaken at the research level, in understanding the fundamental mechanisms of flow induced noise and vibration in the bronchial system as derived from current Engineering research in advanced aero-engine technology.

PULMONARY CRACKLES IN FIBROSING ALVEOLITIS AND IN BRONCHIECTASIS.

P Piirilä, S Haltsonen, T Kaisla, T Katila, M Raivio, T Rosqvist H-M Rajala, H Seitsonen, ARA Sovijärvi. Helsinki University Hospital, Dept. of Pulmonary Medicine and Helsinki University of Technology, Dept. of Technical Physics.

We have studied 10 patients with fibrosing alveolitis (FA), 8 patients with bronchiectasis (BE) and 10 healthy subjects. Pulmonary sounds were recorded with two condenser microphones and simultaneous air flow monitored at mouth with a pneumotacograph. Five breathing cycles were selected for analysis with phonopneumography, FFT-spectrography and time-expanded waveform. The frequency with maximal intensity of the breathing sounds did not differ in the groups. The highest frequency limit of sound of the -20 dB intensity bandwidth was 350±40 Hz (mean±SD) in healthy subjects and significantly lower than in BE (430±90 Hz; $p < 0.05$) or in FA (565±110 Hz; $p < 0.001$). The healthy subjects had no crackles. Patients with FA and BE showed crackles 47 and 30 percent after the beginning of inspiration, respectively. Patients with FA had 8±4 inspiratory and 0.8±0.9 expiratory crackles and patients with BE 8.0±5.0 inspiratory and 3.0±2.7 expiratory crackles, respectively. The initial deflection width (IDW) was significantly shorter in FA (1.3±0.2 ms) than in BE (1.8±0.2 ms; $p < 0.001$). The two cycle duration (2CD) was significantly shorter in FA (7.7±1.4 ms) than in BE (10.8±1.0 ms; $p < 0.001$). The largest deflection width was shorter in FA (1.8±0.3 ms) than in BE (2.5±0.3 ms; $p < 0.001$). The results of the study indicate that lung sound analysis is helpful in diagnosing pulmonary diseases with discontinuous adventitious lung sounds.

A NEW METHOD FOR THE ANALYSIS OF INDIVIDUAL WAVEFORM AND SPECTRAL CHARACTERISTICS OF CRACKLES. I:DEVICE

H.UKITA, Y.HOMMA, I.DOI, Y.OHTSUKA, Y.MASAKI, H.KUSAKA, K.TANIMURA, M.MUNAKATA, Y.KAWAKAMI. The First Department of Medicine, School of Medicine, Hokkaido University, Sapporo, Japan

We had been examining character of each crackle by time expanded waveform analysis, and a spectral analysis had been performed with the fast Fourier transformation (FFT) algorithm. But previous recording and analyzing systems had some problems as follows:

1) The machinery and the operation of these systems were somewhat complicated.
2) The length of the waves for A-D conversion was fixed and limited (25.6msec. at sampling frequency of 20kHz).
3) It was not easy to extract crackles optionally.
4) It took long time to perform a spectral analysis of each crackle.

To solve these problems, we constructed a new analyzing system using a digital-analog tape recorder and a personal computer.

This new system has following merits.

1) We can perform real-time A-D conversion and recording.
2) The duration of A-D conversion is long enough to sample crackles in one respiratory phase(6.553sec. at sampling frequency of 20 kHz).
3) We can identify every crackles in one respiratory phase on the display.
4) It is possible to pick up any crackles and do FFT analysis at will.
5) It is also possible to display time expanded waveform and FFT simultaneously.

With this system we can examine the characteristics of crackles easily and rapidly. This new device will be a powerful tool for the analysis of lung sounds.

A NEW METHOD FOR THE ANALYSIS OF INDIVIDUAL WAVEFORM AND SPECTRAL CHARACTERISTICS OF CRACKLES. II:STANDARD VALUES FOR FINE AND COARSE CRACKLES

I.DOI, H.UKITA, Y.HOMMA, Y.OHTSUKA, Y.MASAKI, H.KUSAKA, K.TANIMURA, M.MUNAKATA, Y.KAWAKAMI. The First Department of Medicine, School of Medicine, Hokkaido University, Sapporo, Japan

Clinically, it has been recognized that there are two acoustically different types of crackles, fine and coarse . By analyzing these two types of crackles, ATS defined acoustic characteristics for each type of crackles. Since these acoustic criteria are subjective, we have been working hard to get the objective criteria for discrimination of these two types of crackles. During this process, we realized the difficulty in exact selection of fine and coarse crackles for the analysis, because of the subjectivity of the acoustic criteria.

To solve this problem, so we defined fine crackles as crackles heard in patients with pure IPF without sputa, and coarse crackles as crackles heard in patients with pure chronic bronchitis. We selected 16 IPF patients without any sputum who have crackles only inspiratory phase, and 9 patients with chronic bronchitis who have significant amount of sputa (range 50-300 ml/day). Five crackles in one inspiratory phase of each patient were analyzed with time expanded waveform (Tb, Tf, IDW, 2CD) and FFT analysis (PF; peak frequency, MF; maximum frequency) with our new lung sound analyzing system.

Results were as follows;

	Fine crackles(n=80)	Coarse crackles(n=43)
Tb	0.63±0.31 msec	1.18±0.17 msec
Tf	5.07±2.55 msec	8.72±1.86 msec
IDW	1.00±0.52 msec	1.94±0.29 msec
2CD	4.31±2.22 msec	7.73±1.51 msec
PF	446±160 Hz	233±124 Hz
MF	723±216 HZ	392±149 Hz

(mean±SD)

When compared with the criteria proposed by Holford, for fine crackles, mean IDW was almost the same and mean 2CD was shorter in our study. For coarse crackles, mean IDW was longer and mean 2CD was shorter in our study.

CRACKLING SOUNDS IN THE TRAUMATIC SUBCUTANEOUS EMPHYSEMA

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Crackling sounds can be heard over the middle upper chest wall after a trauma without pneumothorax. They can be easily identified as crepitations under the palpating finger. Since this maneuver is hardly ever performed and the x-ray films are often normal,other conditions are suspected: mediastinal emphysema,traumatic pericarditis,broncho-alveolar leaks. Six patients,after a 'closed' chest shock,showed auscultatory and palpatory signs of subcutaneous emphysema;only 3 patients showed this at x-ray picture and were exactly diagnosed. The crackles were heard independent from respiration,louder at the end of inspiration and profuse when stethoscope was pressed. They were detected with an air coupled microphone fixed and pressed on the affected area of the skin,recorded on a cassette tape recorder and played-back. The sound signals were sent to a two channels FFT analyzer and 'clean' samples of 10-24 ms analyzed. On the same site the signal showed a similar pattern at different microphone pressures ; the signal had the features of discontinuous sounds and they did not cange during cough or Valsalva maneuver. Continuous sounds ('leak squeak') were not detected in that condition. The expanded waveform is similar to the crackles of some lung diseases but it is diffficult to classify them as 'fine' or 'coarse'. The first deflession width(IDW) is $<$0.8 ms and the duration of two cycles (2CD) $>$1.2 ms . The amplitude reduction of subsequent emiperiods is rather slow and this is due to a less decay factor. The frequency analysis shows a spectrum limited to near 3,000 Hz and the most energy content below 1,500 Hz . The sounds spectra of the affected area are very different from those of non crackling area. According to Forgacs,in the subcutaneous emphysema only one mechanism of production can be postulated,that is an 'explosive equalisation' of the numerous air mini-pokets squeezed from an inflated into an airless zones of the skin.

Session B

Dr. David Cugell and Dr. Filiberto Dalmasso, Chairmen

1:00- 1:20	Application of respirosonography in the sleep lab	Pasterkamp Oh Miller Steljes Kryger
1:20- 1:40	Digital signal procesing of snoring sounds in habitual snorers and patients with obstructive sleep apnea syndrome	Schafer
1:40- 2:00	Time-expanded wave-form and spectral characteristics of snores in humans	Beck Slawinski
2:00- 2:20	Snoring sounds analysis and acoustic tube model of upper airways	Dalmasso Benedetto Righini Spagnolo
2:20- 2:30	Coffee Break	
2:30- 2:50	Tracheal sounds analysis in patients with tracheal stenosis	Kikuchi Kato Kobayashi Ishihara Mori Yonemaru Kawashiro Yokoyama
2:50- 3:10	Auscultation over the neck during bronchial provocation test in asthmatics	Kusuhara Katagiri Yanase Honda Abe Tomita
3:10-3:30	Acoustic properties of forced expiratory wheeze and cough in "asthmatic" and "healthy" subjects in relation to flow rates and lung volumes	Ishikawa Allard Patel Gill Wargovich MacDonnell
3:30-3:50	Use of cough counts in evaluating local anaesthesia for fiberoptic bronchoscopy	Hay Clague Nisar Earis

APPLICATION OF RESPIROSONOGRAPHY IN THE SLEEP LAB

Pasterkamp H*, Oh Y, Steljes D, Kryger M
Children's Hospital Winnipeg and Sleep Laboratory,
St. Boniface Research Center, Winnipeg, Canada

We have applied a system which permits the recording and analysis of acoustic and other respiratory variables over extended periods of time to the study of patients with obstructive sleep apnea (OSA). The audio tracks on a video tape (Sony B HiFi) are used to record respiratory sounds which are low-pass filtered at 3 kHz. The dynamic range of the video tape recorder allows 2 frequency modulated DC signals (i.e. respiration inductive plethysmography [Respitrace], chest and abdomen) to be simultaneously recorded in the frequency range between 10 and 20 kHz. On playback, the respiratory sounds are rectified and integrated, and the resulting sound envelope, together with the frequency demodulated Respitrace signals, is played through an A/D converter into an IBM compatible personal computer for automated detection and quantification of abnormal acoustic events. Such events are then more closely examined using our customized Respiration Acoustics Laboratory Environment software. Analyses are performed both in the time and frequency domain, including waveform expansion, power spectral analysis by fast Fourier transformation, and sonographic imaging, in order to characterize the typically complex waveforms of upper airway noises in patients with OSA. Preliminary observations on 10 adult patients who underwent polygraphic studies in the sleep laboratory indicate different patterns of snoring, requiring characterization both in the time and in the frequency domain. We speculate that respirosonography may help to differentiate benign snoring from the malignant type associated with significant airway obstruction and hypoxemia.

*Scholar of the Manitoba Health Research Council

This study was supported by the Children's Hospital of Winnipeg Research Foundation.

J.W. Schäfer

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Digital Signal Processing of Snoring Sounds in Habitual Snorers and Patients with Obstructive Sleep Apnea Syndrome

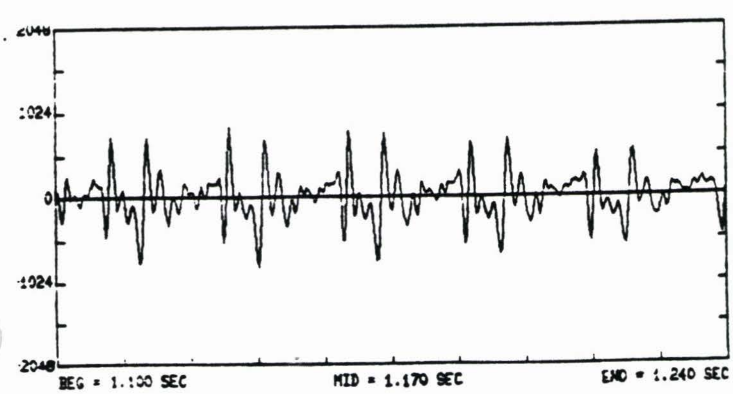
Habitual snoring can be treated successfully by uvulopalatopharyngoplasty in about 80 per cent of cases. In patients with OSAS success rates of this treatment drops to 40 to 60 per cent according to parameters of patient evaluation and severity of disease. In order to investigate the reason for this difference snoring sounds in 40 patients with habitual snoring and OSAS were recorded before and after UPPP in addition to polysomnography. The snoring sounds of the two groups of patients were evaluated in terms of sound pressure level and frequency spectrum. Sound pressure levels in OSAS patients were higher than in habitual snorers which is in accordance with the literature. Frequency spectra of snoring sounds were altered by surgical treatment in a characteristic manner. Changes of the frequency spectrum after surgery in habitual snorers had more impact on sound pressure level than in patients with OSAS which is in accordance with other polysomnographic parameters. The changes in frequency spectrum of the snoring sounds are related to anatomical properties of the upper airway in both groups of patients. Methods and results are presented and discussed.

TIME-EXPANDED WAVE-FORM AND SPECTRAL CHARACTERISTICS OF SNORES IN HUMANS.

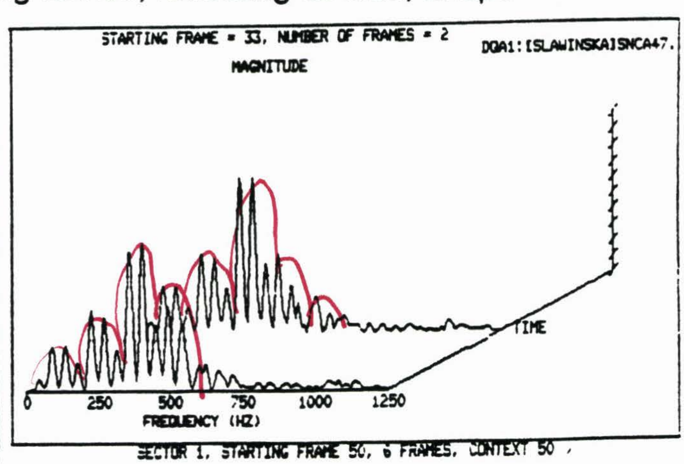
Raphael Beck,M.D., Elzbieta B. Slawinski, PhD.
Departments of Pediatrics and Psychology, Univ. of Calgary, Alberta, Canada.

Last year we presented time-expanded wave-form and spectral characteristics of snores in a dog model of upper airway obstruction. We have now extended these studies to humans. We analyzed snores from 6 patients with suspected Obstructive Sleep Apnea (2 females, 4 males),who had sleep studies performed in our sleep laboratory. 10-20 minutes of snoring were recorded during different stages of sleep. Snores were divided into normal/benign, heavy, pre-apnea and post-apnea types. Four to six snores of each type were analyzed from each patient. Snores were recorded with a Sony electric condenser microphone attached to the right upper chest (2nd ICS) with a small conical coupler. Sound was amplified and recorded unfiltered by a high resolution Hi-Fi tape recorder (TASCAM). Analysis was performed off-line by digitizing individual snores (sampling rate 10kHz) using a VAX 11/730 computer and appropriate software.

Results: Snores of all types showed a characteristic wave-form and spectral pattern, similar but often more complex than in the dog model. Time-expanded wave-form analysis consistently revealed repetitive complex wave-forms consisting of 3-8 waves and spikes. These tended to remain unchanged for 100-300 msec and changed with the evolution of the snore. Some waves were of simple configuration indicating a single vibrating structure or 2 structures vibrating in synchrony, whereas others were more complex, compatible with structures vibrating in asynchrony or at different fundamental frequencies. Spectral analysis always showed a pattern of multiple comb-like spikes. The fundamental frequency ranged from 50-100Hz, with very low amplitude. Spikes then increased, with the highest amplitudes being in the 300-600Hz range. Frequency did not exceed 1000Hz. We believe that this amplification is the result of the intrinsic resonance of the cavity (pharynx, hypopharynx, etc.) between the sound source and the recording device, reflecting its size, shape and structural characteristics.



complex wave-forms



3D FFT - 2 frames

SNORING SOUNDS ANALYSIS AND ACOUSTIC TUBE MODEL OF UPPER AIRWAYS

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Snoring is a sign of upper airways obstruction(UAO) and the most consistent sign of obstructive sleep apnea(OSA).In 7 asymptomatic subjects,who simulate snoring and in 7 patients who snore during sleep,the sound signal was detected by a microphone near the mouth and a microphone on the sternum.The two signals were recorded simultaneously on a cassette tape recorder and also monitored by headphones.The recordings were subsequently transferred to the Lab for analysis,display and printing.The signals were sent to a two channels FFT analyzer for the power spectrum of snoring sounds(SS) and for the three-dimensional spectrum which allows to see the spectrum variations as a function of time.The upper airways cross section area(UACSA) was estimated by the same SS with an acoustic tube model (ATM);an algorithm based on a linear prediction model was applied using a simplified tube model of 16 segments with the same lenght, each with different cross section area. The snores detected at the mouth give the most significant information and similar waveform and spectra were found in subjects and in patients. The greatest energy content is concentrated below 6,000 Hz and the main frequency components are in the low range. The fundamental frequency ranges from 110 to 190 Hz with the highest components almost independent of the fundamental frequency. In all 'clean' samples the spectrum has the typical "Formants structure" of vocal sound. The preliminary application of ATM shows the variation of the snoring process,the changing upper airways and gives the means to evaluate the site and severity of the UAO from the same SS. The SS recording is simple, easy at home and in hospital and reflects the sleep state. The processing techniques are sophisticated but available if the SS are transferred on a dedicated computer programme. Further acoustic analysis are needed and should be related to data by X-scans or CT scans,to standardize this method.

TRACHEAL SOUNDS ANALYSIS IN PATIENTS WITH TRACHEAL STENOSIS

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

There are few reports about characteristics of tracheal stenotic sounds. We analysed frequency domain of tracheal stenotic sounds auscultable in patients with tracheal stenosis.

A recording miscrophone was attached at the neck in patients with tracheal stenosis and tracheal sounds were recorded to data-recorder (A-614, SONY-MAGNESCALE INC.). After the signals of tracheal sounds was transformed from analog to digital data, spectral analysis by fast Fourier transform was performed. Tracheal sounds in healthy man were analysed by same method as control.

Tracheal sound analysis in healthy man revealed that main components in these subjects were below 500 Hz and their spectral peak of components about 1000 Hz was -50 dB. The tracheal sound analysis in the patients with tracheal stenosis revealed that their main components were below 500 Hz but maximal spectral peak of components about 1000 Hz increased to -25 dB. After the tracheoplasty, tracheal sound analysis in the patients revealed maximal spectral peak of components about 1000 Hz decreased to -35 dB.

This tracheal sounds analysis is safe and non-invasive and may be useful for detecting patients with tracheal stenosis.

Auscultation over the Neck during Bronchial Provocation Test in Asthmatics.

Noriyuki Kusuhara, Masato Katagiri, Nobuo Yanase, Jun Honda, Tadashi Abe, Tomoyuki Tomita.

Department of Medicine, School of Medicine, Kitasato University.
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We tried to assess the clinical significance of continuous sounds audible over the neck during bronchial provocation test with methacholine in 28 asthmatics. It is well known that continuous sounds are audible over the neck during asthmatic attack. We detected tracheal sounds in asthmatics with a microphone placed over the neck during bronchial provocation test. Bronchial responsiveness was displayed with respiratory resistance (Rrs) measured by 3 Hz forced oscillation method during continuous inhalation of methacholine. The concentration of methacholine was increased in increments from 49 µg/ml to 25,000 µg/ml. It has been reported that Rrs begins to increase at a specific concentration of methacholine and that it increases with a curvilinear slope. When Rrs increased significantly, provocation was discontinued and Salbutamol was inhalated. There was a tendency for continuous sounds to appear before Rrs increased significantly. Therefore, we were able to detect bronchial responsiveness earlier by detection of tracheal sounds than by measuring Rrs. We conclude that auscultation over the neck of asthmatics during bronchial provocation test is useful for the early detection of bronchial responsiveness.

ACOUSTIC PROPERTIES OF FORCED EXPIRATORY WHEEZE AND COUGH IN `ASTHMATIC' AND `HEALTHY' SUBJECTS IN RELATION TO FLOW RATES AND LUNG VOLUMES

Sadamu Ishikawa, Jeffrey P. Allard, Jetish Patel,
Germit Gill, James Wargovich, and Kenneth F. MacDonnell
Tufts Lung Station at St. Elizabeth's Hospital of Boston

The subjects performed maximum inspiratory and expiratory flow volume (FV) curves before and after methacholine inhalation challenge (5 breaths) in five incremental concentration. FV curve and tracheal lung sounds were recorded simultaneously. Three measurements were recorded on each step of the challenge. Voluntary and spontaneous coughs were recorded as well, after each steps of inhalation challenge. Tracheal lung sounds were recorded with an electronic stethoscope with FM magnetic tape recorder and analyzed by a computer.

In `Responders' (FEV1 drop of >20%) (considered as `Asthmatic'), Forced Expiratory Wheeze (FEW) occurred earlier in timing and longer in period while concentration of the methacholine increased and FV loop became smaller. In `Nonresponders' (considered `Healthy'), FEW also occurred earlier in timing and longer in period while concentration of the methacholine increased without significant change of FV loop from the baseline. FEW always appeared when flow started to taper off; the acoustic characteristics were similar on both groups. High frequency (Asthmatic type) cough developed in both groups following higher concentration of methacholine challenge.

USE OF COUGH COUNTS IN EVALUATING LOCAL ANAESTHESIA FOR FIBREOPTIC BRONCHOSCOPY

J Hay, J Clague, M Nisar, JE Earis.

Regional Thoracic Unit, Fazakerley Hospital, Liverpool, UK.

Patients' tolerance of Fibreoptic bronchoscopy depends on the effectiveness of local anaesthesia. We compared 18 patients given 4 mls of 2.5% cocaine injected transtracheally with 19 who had the cocaine sprayed through the bronchoscope. The procedures were otherwise identical and additional 4% lignocaine via the bronchoscope was given as needed. Patients and Bronchoscopists scored the procedure using visual analog scales (VAS). Cough counts and stridors were recorded objectively with phonopneumography.

Both groups of patients were well matched for age, lung function and diagnosis. The patients VAS showed a clear preference for the transtracheal technique ($p<0.001$) with less coughing ($p<0.05$) and less distress during intubation of the larynx ($p<0.001$). The bronchoscopists also preferred the transtracheal route ($p<0.001$) again reporting less coughing and easier laryngeal intubation ($p<0.001$). The mean numbers of single coughs recorded objectively was 102 (58) for the bronchoscopic and 60 (49) for the transtracheal route ($p<0.01$). There was no difference in cough counts during induction of local anaesthesia, biopsies or lavage. Comparison of both patients and bronchoscopists VAS for coughing with the objective cough counts was significant ($p<0.01$) suggesting unbiased observations. Stridor occurred in 17 patients immediately after intubation of the larynx (15 in the bronchoscopic group). Extra local anaesthesia was needed during the bronchoscopy in 16 patients in the bronchoscopic group compared with only one of the other patients. Transtracheal anaesthesia produced no extra complications and was preferred by both patients and bronchoscopists.

Phonopneumographic recording of cough counts enabled objective evaluation of these techniques and provided evidence that only 4 mls of 2.5% cocaine injected directly into the trachea provided excellent local anaesthesia for fibreoptic bronchoscopy.

Session C

Dr. Peter Krumpe and Dr. Wilmot Ball, Chairmen

8:30-8:50	A study of the frequency partition of chest wall sounds	Gross Sahakian Gavriely Cugell
8:50-9:10	Absorption of sound in fat	Earis
9:10-9:30	The characteristics of the transmission of the continuous adventitious sounds	Choh, Shioya Koyama Kasuga Narita Shibuya Kudoh
9:30-9:50	Measurements the speed of sound through lungs and clinical preliminary study	Qiyuan Jianpin Liangbin Gonghua Zhongzhen Peiyong Likung
9:50-10:10	Numerical classification of respiratory sound patterns	Druzgalski
10:10-10:30	Coffee Break	
10:30-10:50	The second model of a phonopneumograph for an "objective stethoscope"	Kudoh Shibuya Matsuki
10:50-11:10	Coherence analysis of breath sounds	Kandori Yagi Nakayama
11:10-12:00	Guest Speaker - Dr. Jackie Duffin	
12:00-12:15	Business Meeting	
12:15-1:30	Lunch	

A STUDY OF THE FREQUENCY PARTITION OF CHEST WALL SOUNDS

Pamela G. Gross, MD, PhD[1], Alan V. Sahakian, PhD[2],

Noam Gavriely, MD, DSc[3], David W. Cugell, MD[4]

The goal of this research was to investigate the nature of muscle sounds (MS) and to subsequently study the frequency partitioning of chest sounds into lung sounds (LS) and MS. Fifteen adult, male subjects were tested in three experiments. First, MS resulting from isometric contraction of the wrist flexors were split into two frequency bands (4-75 Hz and 75-250 Hz), transformed into the frequency domain, and correlated with force output. Then, chest wall MS collected during the static, open-glottis maintenance of inspiratory pressure were studied at different lung volumes in a similar manner. Finally, in the third experiment, chest wall lung and muscle sounds resulting from inspiration at different flow rates with variable inspiratory resistive loading were analyzed. All sounds were collected simultaneously using both a standard Hewlett-Packard (HP) contact sensor, and an experimental transducer that is based upon a piezoelectric form of polyvinylidene difluoride (PVDF) film which was shielded and insulated.

The results showed that the PVDF transducer and the HP sensor performed comparably, although the PVDF was easier to use and was associated with less artifact. The muscle sound power level was quadratically related to force output or effort for all three experiments. The MS signal spectra peaked between 6 - 11 Hz, but extended to higher frequencies and was responsible for the majority of the chest sound signal in this higher range (75 - 250 Hz). This overlap of MS into the presumed LS frequency range raises questions concerning the true nature of LS. Therefore, further investigation of the contribution of LS and MS to the total chest wall signal is warranted.

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ABSORBTION OF SOUND IN FAT

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A simple model to investigate sound transmission through fat is described.

A sound generator and microphone were placed into a well cut into a block of condensed fat. This was closed by 1 to 4 cms thickness of fat and an identical microphone attached to the surface. Pure tones between 50 to 4000Hz were fed into the chamber from a signal generator. The output was varied so that the signal from the chamber microphone when amplified produced an arbitrary peak to peak voltage of 4 (Pk/volt). The output from the surface microphone (in millivolts) was measured in an identical fashion. This procedure was repeated over the full frequency range for each thickness of fat.

With all thicknesses of fat there was marked attenuation with increasing frequency. The mean for all experiments was 751mv $\pm$145 for 50 to 1000Hz and 253mv $\pm$21 for 1000 to 3000Hz ($p<0.001$). Plotting log10 Pk/volt against frequency approximated to a straight line ($r=0.95$), suggesting that attenuation was inversely proportional to frequency squared.

Graphs of Pk/volt against frequency showed peaks which varied with the model design and thickness of fat suggesting that resonance was occurring in the fat itself. Because of this the percentage absorption across 1cm, 2cm and 3cms thickness of fat was difficult to determine, however typical values for 1 cm were 41.56% $\pm$18.88 and for 3cms 63.48% $\pm$ 19.96.

This simple model suggests that the main absorption of sound occurs when it enters fat. The evidence of resonation within the fat raises the possibility that this may be an important determinant of sound intensity heard at the chest wall.

THE CHARACTERISTICS OF THE TRANSMISSION OF THE CONTINUOUS ADVENTITIOUS SOUNDS

Sumito Choh[1], Naohisa Shioya[1], Yasuhiro Koyama[1], Hirotomo Kasuga[1], Nobuhiro Narita[1]

Atsuo Shibuya[2]

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3: Pulmonary Division, Tokyo Metropolitan Komagome Hospital

We studied the characteristics of the transmission of the continuous adventitious sounds, by means of the analysis of the correlation function between the continuous sounds recorded on the two points of the thorax.

The subjects were the patients whose bronchial stenosis had been confirmed by bronchoscopy. In addition to that, the patients of bronchial asthma were studied and compaired with the cases of bronchial stenosis.

1) The continuous adventitious sounds recorded on the chest site near the sound source and those recorded on the neck over the trachea were closely correlated.

2) The correlation between the continuous sounds recorded on the chest site near the sound source and those recorded on the opposite site was less close than that between the continuous sounds of the chest site near the sound source and those of the trachea.

3) The possibility of the measurements of time delay between the continuous adventitious sounds recorded on the two points of the thorax was suggested, by the analysis of the cross correlation function.

MEASUREMENTS THE SPEED OF SOUND THROUGH LUNGS AND CLINICAL PRELININARY STUDY

Qian Qiyuan Wang Jianpin* Hu Liangbin

Hu Gonghua Jin Zhongzhen Wu Peiyong Wang likung

<Biomedical Engineering Institute of Fudan University, Shang Hai, China >

ABSTRACT Single-frequency sound was transmitted into patients' lungs through a pipe, then one microphone was placed on the neck beneath the tracheal while the other was placed on the four locations on the chest wall one by one. When the time and distance of the two sensors have been compared the speed of sound through human lungs can be measured.

The time dclay between normal men and patients is different. The speed of sound of 20 health men is of an average of 81.35±38.34 m/s while 7 cases of acute tracheitis and bronchitis are of an average of 384.57±125.79 m/s $(p < 0.01)$. The difference between them is very obvious. < $p<0.01$ > This method can beused to discover diseases which the X-ray examination fail to discover.

· key words:

Lung

speed of sound

disease

human

* First Hospital of Suzhou Medical College, China.

NUMERICAL CLASSIFICATION OF RESPIRATORY SOUND PATTERNS

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A simple numerical characterization of acoustic events associated with respiration may provide a useful tool for comparative assessment of auscultatory findings. A common deficiency of spectral characteristics is that they provide complex spectra for intricate acoustical signals. Thus, this can be particularly suitable when recorded respiratory sounds result in complex spectral characteristics of these signals.

Three dimensional images of respiratory sound patterns are presented and corresponding numerical models are established based on a series of linear equations approximations. Basically, these equations represent a set of three filtering processes. The order of these linear approximations defines values of parameters. Consequently numerical values of these parameters characterize a pattern of respiratory sounds.

The model development and a pattern characterization includes hardware/software system developed around IBM PC XT/AT. Initially, the respiratory sounds are represented as a discrete set of sequentially recorded observations with a fixed interval. Specifically, a current value represents a finite linear aggregate of previous values and a random factor. The iterative processes attempt to define values of coefficients and the order of the equations at which this random error factor is minimal. A set of equations define the relationships between amplitudes of successive observations and their variations from a moving average and provide basis for model development and pattern characterization.

The PC based numerical characterization of a pattern of respiratory sounds provides a simple supplementary description of acoustic events associated with respiration. These automatically derived models eliminate subjective description of auscultatory events and allow the studies of interdependence between various sounds.

THE SECOND MODEL OF A PHONOPNEUMOGRAPH FOR AN "OBJECTIVE STETHOSCOPE"

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At the 12th conference in Paris, we stressed the importance of simplification of methods for lung sound analysis and reported on a portable phonopneumograph model for bedside use which contained a personal computer. In this first model, an analogue tape-recorder was used as the recording unit and the analyzing unit produced a photograph as a hard copy of the image.

In the second model presented in this paper, a semiconductor memory card and a video-printer are used instead of a magnetic tape and a photograph. This resulted in the recording unit becoming smaller and the hard copy becoming available more easily.

Capacity of the memory card is 256 KB. Lung sounds of six seconds were sampled at the frequency of 5 KHz with respiratory phase signals from the impedance-pretysmograph or the flow meter. Four different samples can be stored in the memory card.

On analysis, the following functions are made available by the personal computer (NEC-PC-9801) and video-printer(UA-455), i.e., time-domain soundwaves with respiratory phase for monitoring, soundspectrograms with respiratory phase for diagnosis of lung sound properties, time-expanded waveform and a power spectrum as needed in the soundspectrogram, and time-expanded waveform of a whole six seconds. A sonundspectrogram is recorded from 0 to 2,500 Hz with 16 steps of darkness within 37.5 dB dynamic range.

This device is useful at the bedside, and is the second model of an "objective stethoscope".

COHERENCE ANALYSIS OF BREATH SOUNDS

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Department of Electrical and Electronics Engininering, Sophia University Tokyo Japan

We recorded breath sounds on DAT (digital audio tape) with two microphones. Measurement points were over both the trachea and each intercostal space of one normal nonsmoker (male age.23). Recorded sounds were analyzed by coherence and correlation techniques. We found that the coherency was almost unity in 700Hz-1kHz, and we calculated transit time for the corss-correlation of the band pass filtered data (700Hz-1kHz). From this transit time, the distances between two microphones were estimated based on the free-air velocity (340m/s). These estimated distances well agreed with the actual distances. Thus we can conclude that the breath sounds above 700Hz detected on the chest wall come from the trachea propagating through the airways with the free-air velocity. The breath sounds are essentially the white Gaussian noise since it is generated by air flow turbulence. The transfer characteristics of the sounds from the trachea to the alveoli has low-pass nature. Thus it is quite natural to suppose that the breath sounds on the chest wall below 700Hz also come from the trachea propagating through the airways, although we could not directly verify it because of the presence of noise. Although we need more cases of study, we might conclude that most of the vesicular breath sounds are just the transmitted tracheal breath sounds.

Session D

Dr. Sadamu Ishikawa and Dr. Riichiro Mikami, Chairmen

1:30-2:15	Guest Speaker - Dr. Paul Strong	
2:15-2:35	Density dependence of flow-standardized tracheal and lung sounds	Pasterkamp Tuazon Avital Oh
2:35-2:55	Velocity disturbances within small airways	Olson Hartig Taleb Hammersley
2:55-3:15	Spectrum analysis of lung sounds	Zhang Zu Chen Liu
3:15-3:25	Coffee Break	
3:25-3:45	An algorithm for automatic detection of respiratory crackles	M. Herzberg N. Gavriely
3:45-4:05	A simple method of examining lung sound frequency spectra uncontaminated by cardiac sounds	Wang Kraman
4:05-4:25	The characteristics of lung sound and its detecting	Xu Chen Zhang Liu
4:25-4:45	Discriminant analysis of lung sound signals	Chen Xu Zhang Liu
4:45-5:15	Cracklefest	
5:15-5:30	Summary	

DENSITY DEPENDENCE OF FLOW-STANDARDIZED TRACHEAL AND LUNG SOUNDS

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We studied power spectral changes of flow-standardized tracheal and lung sounds during air vs 80% Helium - 20% Oxygen (Heliox) breathing. Eight healthy male volunteers, ages 22 to 42 years, participated in the study. Air flow, sound over trachea (TS) and right posterior lower lobe (LS), and electrocardiogram were recorded on tape and played back into a microcomputer. Sounds were low-pass filtered at 1200 Hz to avoid aliasing. The sampling rate was 5120 Hz per channel. ECG-gated samples of 100 msec duration were collected at in- and expiratory flows of 2 and 3 L/sec ± 10% tolerance. Analysis by FFT provided data on the overall spectral power from 100-1200 Hz (P_{TOT}), regional power from 100-400 Hz (P_{LOW}) and 900-1200 Hz (P_{HI}), median frequencies in the lung sound range of 100-400 Hz (FM_{LOW}) and in the tracheal sound range of 100-1200 Hz (FM_{TOT}).

Compared to air, Heliox decreased P_{LOW} of TS by 3.1 ± 0.4 dB at 2 L/sec and by 4 ± 0.9 dB at 3 L/sec during inspiration ($p<0.05$) (mean ± SEM). P_{LOW} of expiratory TS decreased by 5.5 ± 1.2 dB and 6.1 ± 1.2 dB, respectively ($p<0.05$). P_{LOW} of inspiratory LS was significantly lower on Heliox in only 4 of 8 subjects (from 1.1 to 2.9 dB), whereas P_{LOW} of expiratory LS was reduced in most subjects (by 1.3 ± 0.4 dB at 2 L/sec and 2 ± 0.6 dB at 3 L/sec, $p<0.05$). At 2 L/sec, there was a positive correlation between the reduction in P_{LOW} of inspiratory TS and LS ($r=0.72$, $p<0.05$), which was not seen for expiratory sounds or those at higher flows. Interestingly, P_{HI} of TS showed an increase with Heliox, most noticeably at 3 L/sec (by 3.6 ± 0.9 dB during inspiration and 8.6 ± 1.1 dB during expiration, $p<0.01$). Correspondingly, FM_{TOT} of TS shifted upward, from 338 ± 22 Hz to 471 ± 37 Hz during inspiration and from 505 ± 41 Hz to 725 ± 62 during expiration ($p<0.01$). Gas density changes did not affect FM_{TOT} and FM_{LOW} for LS during in- or expiration. Over the trachea, FM_{LOW} did not change significantly with Heliox.

Inspiratory lung sounds were audibly and measurably quieter on Heliox in only half of the subjects. This is in accordance with previously published data on the density dependence of lung sounds. However, in our subjects the changes of lung vs tracheal sounds with Heliox were more closely related during inspiration than expiration. We observed frequency changes of tracheal sounds on Heliox which occurred in the range above that of lung sounds and which may be comparable to the well known vocal 'register shift' in Helium environments.

* Scholar of the Manitoba Health Research Council
This study was supported by the Children's Hospital of Winnipeg Research Foundation and by the Manitoba Lung Association

Velocity Disturbances within Small Airways

D.E.Olson,M.D.,Ph.D., D.Hartig, A.A.Taleb,Ph.D., J.R.Hammersley,M.D.; Univ. Kansas - Wichita.

It can be shown that airflow in the small bronchi and bronchioles is laminar and quasi steady. Usually such flows create no velocity disturbances to initiate pressure fluctuations and are thus silent. Hardin et al, has theoretically shown that the high degree of swirling currents in a laminar flow through a tight bend (such as might be projected in a bifurcation) may be the source of instabilities which may ultimately create flow sounds.

We have previously observed that flow in a simple symmetrical bifurcation model at high Reynolds numbers can exhibit behavior, in part explained by Hardin. We have also observed local (pseudosound) and regional (sound) pressure variations within cast replicas of human central and peripheral airways. However the energy frequency spectrum of these two observations are very poorly correlated. As such no fundamental mechanism for the origin of small airway breath sounds could be projected.

We have recently observed the flow patterns in more complex, asymmetrical, large scale bifurcation models which incorporate the details of small airway geometry and branching patterns. These observations suggest a more complex mechanism of small airway aerodynamic sound generation than hypothesized by Hardin.

In general the in vitro inspiratory flow patterns within the complex bifurcation models show the unexpected result of flow partitioning into each, unequal daughter branch, proportional to the number of alveoli distal to each branch, by a unique combination of inertial, viscous, and centrifugal forces and from a "flow separation" phenomena created just prior to the entrance of the smaller daughter branch. This means airway "resistance" is proportioned equal to the distal parenchymal compliance throughout the smaller airways. The flow separation initiates velocity disturbances which are rapidly convected throughout the core of the flow (only) into the smaller daughter bronchi(ole) by the high degree of swirl. The flow direction also has impact on the nonisotropic transmission of the resultant pressure fluctuations, giving preference to sound propagation down the axis of the small airway toward the chest wall during inspiration. A complex relation is empirically developed between the flow rate, airway geometry and branching pattern to the power spectrum of observed velocity disturbances.

SPECTRUM ANALYSIS OF LUNG SOUNDS

Yili Zhang, Jingping Xu, Qimin Chen and Shuyan Liu

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The power spectra of vesicular breathing, rale and wheeze from 40 people (including normal people and people with lung diseases) were analysed by BSFA (or Zoom FFT) in present study. The distribution of spectrum peak frequencies was estimated. It is noted that the vesicular breathing of normal people and abnormal breathing (rale and wheeze) are significantly different in distribution of spectrum peak frequencies. The results of statistics analysis indicate: 1. The main componants of power spectrum of vesicular breathing of normal people are within 300 Hz, and componants above 1 kHz are not seen. 2-5 peak values exsist between 80 Hz and 300 Hz. The highest peak frequency is within 150 ± 10 Hz. The second higher one is in 250 ± 10 Hz. The exsistance of lung disease should be considered if significant spectrum peak values are found abouve 300 Hz. 2. The peak frequencies of power spectrum of rale are at 112 ± 10 Hz, 151 ± 10 Hz, 200 ± 10 Hz, 248 ± 10 Hz, 351 ± 10 Hz, 456 ± 10 Hz, and 551 ± 10 Hz. 3. The peak frequencies of power spectrum of wheeze are within 400 Hz(Fig.1). It can be seen that the power spectrum of rale and wheeze includes more high frequency componants than that of vesicular breathing of normal people and the power spectrum of rale has more low frequency componants, and the number of spectrum peak and high frequency componants of respiration increase with pathological changes. From pathological point of view, the mode of lung sound generation would be different from normal case becouse of pulmonary state changes (air componant increase, water increase, cavity in lung or calcification). On the other hand, changes of transform characteristics of lung thoracal system make a part of lung sound signals resonant with cavity or calcific tissue and then make the transmission easier because of resonance and solidification.

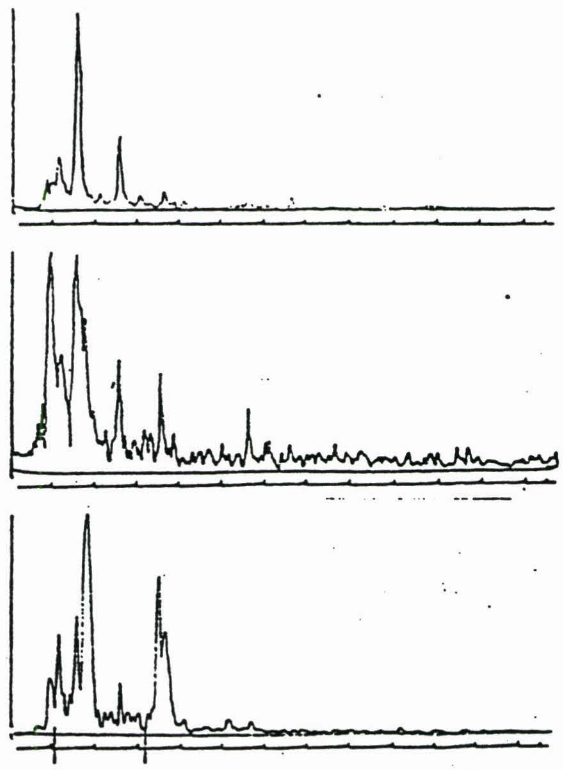

Fig.1 Power spectra of vesicular breathing (top), rale (median) and wheeze (bottom) (X axis: amplitude, Y axis: 635 Hz/div.).

An algorithm for automatic detection of respiratory crackles

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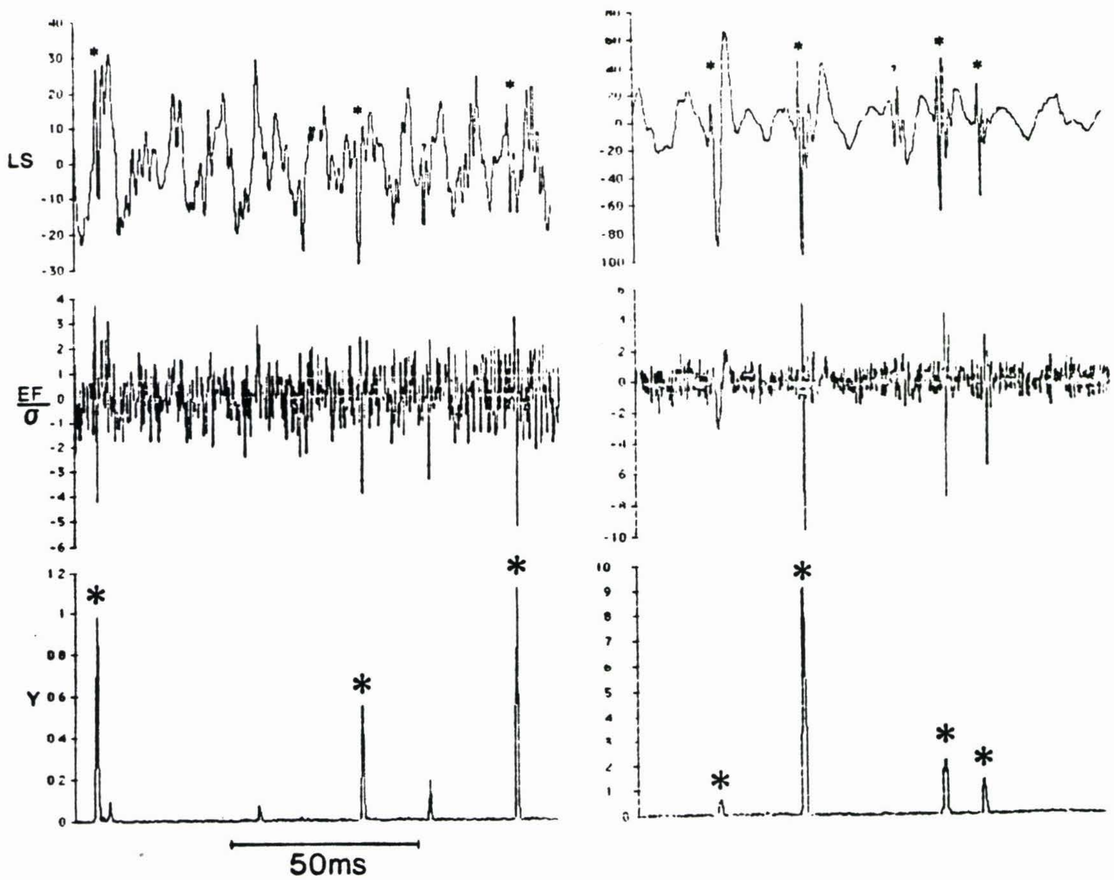
Separation of crackles from lung sounds was recently demonstrated using an adaptive stationary-nonstationary nonlinear filter (Ono et al, BME-IEEE, Feb. 1989). We present a method for automatic detection of crackles that is less sensitive to non-crackle transients such as heart-sounds and onset of a breath. Normal and crackles-containing successive sound segments of 128 ms were used (sampling rate of 4000 samp/s). The following steps were used:

1) Calculation of the normalized 4th moment of each segment was used as an initial screening procedure.
2) The foreward prediction error (EF) of an autoregressive model was calculated for each segment using the Burg algorithm and normalized to the EF variance.
3) A folding technique was applied to collapse the normalized EF in the range -1 to 1.
4) The output of (3) was subjected to smoothing with a weighted running average method and squared to reduce fragmentation and to amplify selectively the remaining peaks.

The following are examples of time-expanded lung sounds, the respective raw EF tracings and the final output of our algorithm.



A SIMPLE METHOD OF EXAMINING LUNG SOUND FREQUENCY SPECTRA UNCONTAMINATED BY CARDIAC SOUNDS.

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There is considerable interest in determining the true frequency spectra of vesicular lung sounds. The upper limits of the lung sound frequency spectrum has been well examined and described. However, the lower limits have been difficult to examine because of the overlap with cardiac sounds. This had led to the convention of using high-pass filters to eliminate the heart sound and only examining the remaining lung sound. To determine the shape of the lung sound frequency spectrum below 100 Hz without cardiac interference, we devised the following experiment. Recordings were made at the right and left upper lobes anteriorly and right and left lower lobes posteriorly in four subjects. Sounds were recorded at inspiratory airflow rates of 0 (subject relaxed in apnea) and 0.5, 1, 1.5, and 2 l/s inspiratory airflow rates. The sounds were picked up with a electret condenser microphone, air coupled to the chest wall and held in place with a double sided taped ring. The sounds were amplified, antialiased at 800 Hz and digitized at 2048 Hz by a 14 bit A to D converter. For each microphone location and for each target flow rate, ten breaths were taken and 10 magnitude spectra were generated, averaged and smoothed. During the active breathing maneuvers, the A to D converter was triggered by the target airflow rate. During the apneic period, 10 spectra were generated in succession without regard to the cardiac cycle. Spectra resulting from the apneic recordings were then subtracted from the spectra resulting from the active breathing maneuvers.

The pre- and post-subtraction lung sound spectra were compared. The subtracted lung sounds displayed considerable variation among subjects and locations but generally showed a peak between 50 and 100 Hz that rolled off sharply at lower frequencies with rarely any detectable energy below 25 Hz.. Above 100 Hz in some subjects and locations the frequency rolled off gradually towards 400 and 500 Hz whereas in others there was a plateau of variable length before eventual roll off.

We conclude that the lung appears to behave as a bandpass filter with its lower shoulder at approximately 50 to 100 Hz and upper shoulder between 100 and 200 Hz. We were able to find very little evidence of lung sound energy below 25 Hz.

THE CHARACTERISTICS OF LUNG SOUND AND ITS DETECTING

Jingping Xu, Qimin Chen, Yili Zhang and Shuyan Liu

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The power spectrum of normal and abnormal lung sounds from 40 people (normal people and people with lung diseases) were analysed in present study. Lung sounds are the physical signals which generate from the turbulances in various bronchi and transmit through airways to chest wall. In order to eliminate the distuebances of environmental noices and other signal generated in human body, such as heart beat, certain procedures were adopted in detecting the lung sound signal. A polyvinyl chloride tube was covered ahead of a inductance microphone (B.K. 4166, Denmark). The opening of the tube was laid on a proper location of the chest wall against the lungs. Lung sounds transmitted through a very narrow air crevice to the diaphragm of the microphone and converted to electric signals. A high-pass filter with cutoff frequency 80 Hz was used to eliminate disturbances such as chest wall vibration and pulse signals. The lung sound signals were processed by a 7T08 signal processor (San-ei Instruments).

The study results of waveform and power spectrum of lung sounds suggest that the lung sound signal is a local stationary, quasi-periodic stochastic signal. The inspiration phase and expiration phase of each breath cycle are different in some way. However, the methods currently used in the spectral analysis of lung sound is to emphasize the expiration and inspiration respectively in a small period of time which may cause certain randomness and inconstancy. Therefore, the spectrum characteristics of lung sound signal were picked up and analysed as a whole in the present study. We suggest that to consider the respiration signals as a whole is more close to the real situation and the statistical analysis of respiration in a period of time (include several breath cycles) could provide more information of respiration process.

DISCRIMINANT ANALYSIS OF LUNG SOUND SIGNALS

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In this study the pattern recognition technique was used in lung sound signal processing. In accordance with the particularities of lung sounds, we discussed how to choose the characteristics of lung sounds and recognize algorithm. Since the common periodogram method causes certain variance and a low resolution, following procedures were applied in spectrum estimation: (1) window processing averaged periodogram, (2) zoom FFT (BSFA), (3) sampling data segment and 50% overlap. The main components of the obtained power spectrum were utilized as spectrum characteristic parameters for automatic classification of lung sounds. The statistical pattern recognition and fuzzy pattern recognition were used in the pattern classification of lung sounds. The fuzzy classifier can be used in recognizing mixed respiration sound and the statistical pattern recognition method can be used for recognizing different kinds of respiration sounds. Fuzzy recognition can reflect the undefined characteristics of the pattern recognition better. In most cases lung sound recognition is performed under the condition of disturbance or insufficient information where fuzzy recognition is more applicable. The classification were operated by a software written in advanced language. The unknown respiration sounds were first filtered, sampled and then stored in the computer. The autorecognition of respiration sound can be performed by calling the recognition program.

POSTERS

Poster Session - Norwood Hotel

Wednesday, September 13th

Thursday, September 14th		8:00 - 10:20 AM
Discussion		10:20 - 10:50 AM

Wilkins & Dexter ----	Description of lung sounds by pulmonary physicians
Kaisla, Haltsonen,--- Katila, Piirila, Raivio, Rajala, Rosqvist, Sovijarvi	Automatic detection of lung sound crackles
Koster, Loudon ------	Amphoric breathing: spectral characteristics
Loudon, Koster, ----- Reising, Porembka	Transmission of sounds through flooded lung
Bettencourt, Delbono-Murphy	Lung sound characteristics in common pulmonary disorders
Davidson, Murphy ----	Factors influencing crackle counts
Murphy, Delbono -----	The acoustic basis of lung sound nomenclature: problems and perspectives

DESCRIPTION OF LUNG SOUNDS BY PULMONARY PHYSICIANS

Robert L. Wilkins MA RRT and James R. Dexter MD FCCP,
Loma Linda University, Loma Linda, Ca.

We surveyed 223 North American Pulmonary Physicians (NAPP) at the 1988 ACCP annual convention in Anaheim to identify their choice of terms to describe 8 lung sounds. The 8 examples had been previously subjected to time-expanded wave form analysis which revealed the sounds to be: 1) fine crackles; 2) coarse crackles; 3) fine inspiratory crackles and expiratory polyphonic wheezes; 4) low-pitched, monophonic wheeze; 5) high-pitched, monophonic wheeze; 6) pleural friction rub; 7) normal breath sounds; 8) early inspiratory crackles. **Results:** The terms most frequently used to describe each sound were: Sound 1, "crackles" (44%) and "rales" (40%); Sound 2, "rales" (24%), "rhonchi" (24%), and "crackles" (22%); Sound 3, "wheezes" (39%), "crackles /wheezes" (20%), and "rales/wheezes" (18%); Sound 4, "rhonchi" (30%), "bronchial breath sounds" (21%), and "wheeze" (13%); Sound 5, "stridor" (49%) and "wheeze" (27%); Sound 6, "rub" (32%), "rales" (19%), "crackles" (18%), and "rhonchi" (18%); Sound 7, "normal breath sounds" (79%) and "bronchial breath sounds" (10%); and Sound 8, "rales" (31%), "crackles" (30%), and "rhonchi" (16%). **Conclusions:** 1) NAPP use "crackles" and "rales" with equal frequency to describe discontinuous adventitious lung sounds (ALS) and not at all to describe continuous ALS; 2) polyphonic expiratory wheezes (S3) are uniformly described as "wheezes" while monophonic wheezes (S4 and S5) are described with a variety of terms; 3) the term "rhonchus" is used frequently to describe coarse crackles, low-pitched wheeze and pleural friction rub suggesting that it has little clinical significance; 4) the majority of NAPP recognize normal breath sounds but not a pleural friction rub, and 5) lung sound nomenclature is not well standardized among NAPP.

AUTOMATIC DETECTION OF LUNG SOUND CRACKLES

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Lung sound crackles are characterized by short duration and relatively high frequency. Each individual crackle then corresponds to a peak in the sonagram (Fig. 1; one inhalation of a patient with bronchiectasis). We have detected the number of crackles and the timing of their occurrence by automatically counting the peaks. First, the sonagram was estimated by analysing short segments of sound with FFT, starting from the beginning of the sample and continuing with segments each overlapping its predecessor by 50 %. The sonagram was considered an $M \times N$ digital image, where M is the number of FFTs and N is the length of one transform. The peaks, which were considered vertical edges in the picture, were detected with a spatial mask. The result (Fig. 2) was compared to the time-expanded waveform: over 90 % of the crackles in the sample were found. The method is suitable for determining various parameters related to crackling sound, e. g. flow dependence and mutual distance of crackles.

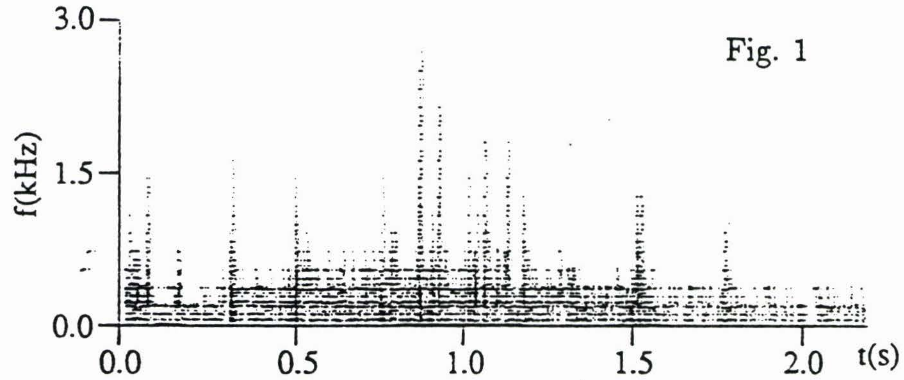

Fig. 1

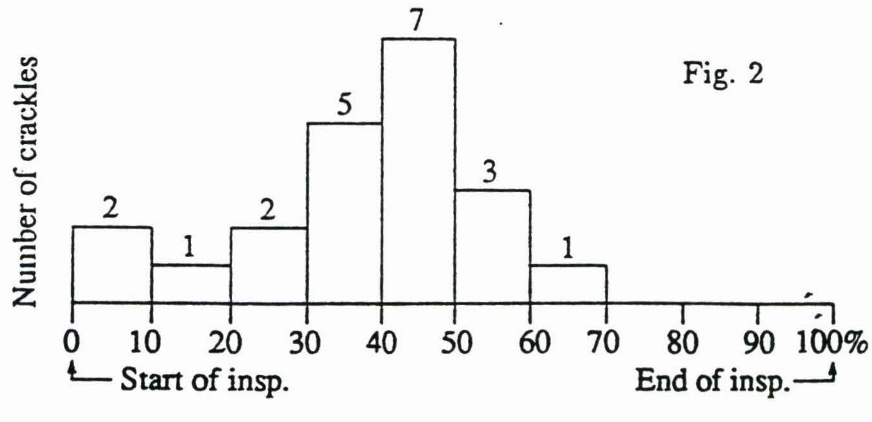

Fig. 2

AMPHORIC BREATHING: SPECTRAL CHARACTERISTICS

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Amphoric breathing is described as resembling the sound produced by blowing across the top of an empty bottle (amphora = jar). It is heard rarely, and only when a cavity in the lung communicates by an open airway with other airways through which air flows. The cavity acts as a Helmholtz resonator, emphasizing a specific frequency determined by the length of the resonating air column. Cavities in the lung are less common than they were, with the decline in prevalence of chronic cavitary tuberculosis. In some respects amphoric breathing resembles bronchial breathing, with the expiratory component louder than the inspiratory component, and with a hollow character to the sound; but the hollowness of a jar rather than the hollowness of a tube.

A patient presented recently with far advanced cavitary pulmonary tuberculosis. Several cavities up to five centimeters in diameter were present in the left upper and lower lobes and in the right upper lobe. Breath sounds were recorded during tidal breathing at several sites, including both upper and lower zones anteriorly. Amphoric breath sounds were present at the right apex and the left lower zone. Over the left lower zone anteriorly an interesting and unusual pattern of sounds was heard; amphoric sounds accompanied the cardiac as well as the respiratory cycle, presumably as a result of displacement of air by the beating heart.

Sound spectrum analysis was applied to the amphoric breath sounds. The spectrum showed two components: a basic pattern resembling the pattern of vesicular sound and high frequency components, representing the resonance of air in the cavity. These were seen at frequencies of 610 Hz, between 1100 and 1250 Hz, and between 1600 and 1800 Hz. These observations tend to confirm the generally assumed mechanism for production of amphoric breath sounds.

TRANSMISSION OF SOUNDS THROUGH FLOODED LUNG

Loudon RG, Koster ME, Reising J, Porembka DT.

The lung is an excellent acoustic filter. Sounds heard at the chest wall represent only part of the sound being produced in the depths of the lung. Consolidated lung transmits sound better than healthy lung, and the bronchial breathing characteristic of lobar pneumonia is accepted as being the result of better transmission, particularly of the higher sound frequencies, from the central airways to the chest wall surface.

A patient with a right lung which was hypoplastic from an early age presented at the age of 40 with suddenly increasing dyspnea on exertion; she was shown by open lung biopsy to have pulmonary alveolar proteinosis of the left lung. Her respiratory insufficiency disabled her to the extent that efforts were made to lavage the left lung a segment at a time. When this was unsuccessful her left lung was lavaged during extracorporeal oxygenation. This provided an opportunity to record lung sounds during a sequence of washes in which her lung was filled with normal saline, drained, and artificially ventilated. The lavage fluid was introduced by gravity from a series of plastic bags of the type used for peritoneal dialysis, one liter at a time. Twenty liters were used during the procedure.

Sounds were recorded continuously during the procedure by a microphone at the patient's left base, using a portable tape-recorder to record the sound signal. The sound signal was analyzed off-line to provide a series of sound frequency plots during each wash. The fluid was introduced by gravity, via plastic tubing and a limiting orifice, through a cuffed endobronchial tube placed in the left main stem bronchus. No sound was introduced other than that which resulted from the procedure itself.

During each wash the sound recorded at the chest wall increased in loudness and in high-frequency content as the flooding of the lung proceeded. These changes are attributed to the changes in transmission of sound associated with flooding of the lung, analogous to that produced by processes such as consolidation or pulmonary edema. This unusual procedure provided an opportunity to study changes in lung sound transmission as a lung was alternately filled and emptied.

LUNG SOUND CHARACTERISTICS IN COMMON PULMONARY DISORDERS

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Using the techniques of lung sound mapping and time expanded analysis of lung sounds we studied the lung sound characteristics of four groups of patients with the following diagnoses: chronic obstructive pulmonary disease (COPD), interstitial fibrosis (IF), congestive heart failure (CHF) and pneumonia (Pn). When studying the discontinuous adventitious lung sounds, several factors were useful in separating the four groups. When compared with the other diagnoses IF was notable for the fact that far more sites were positive for the presence of crackles. Patients with IF had a larger number of fine crackles which tended to occur later in the respiratory cycle and were characterized by a shorter IDW. Pn was characterized by the presence of coarse crackles and analysis of the ZCS helped to separate Pn from COPD and CHF. COPD had the longest 2CD.

FACTORS INFLUENCING CRACKLE COUNTS

Frank F. Davidson, M.D.
Raymond L.H. Murphy, Jr., M.D.

The number of crackles heard over the chest likely relates to disease severity in certain lung disorders. Crackle counts, however, are influenced by the size of the stethoscope chest piece and can be in error if adjacent microphones count the same crackles. Alternatively, crackles will not be counted by microphones placed far apart. In previous studies, we observed that the number of crackles counted increased with increasing stethoscope diameters in the range of 20 to 42 mm. In this study, we examined the relation of crackle counts to stethoscope size for diameters of 19, 14 and 8 mm. Average crackle counts were 13.5, 12.7 and 8.4 respectively. We will discuss the implications of these findings and the results of studies of the spatial distribution of crackles over the chest wall. These studies were performed by recording simultaneously with multiple microphones and examining the waveform analysis from each microphone for identical crackles (as defined by timing and shape).

THE ACOUSTIC BASIS OF LUNG SOUND NOMENCLATURE: PROBLEMS AND PERSPECTIVES

Raymond L.H. Murphy, Jr., M.D.
Elizabeth A. DelBono, M.P.H.

Clear acoustic definition of the various types of lung sounds is necessary to ensure that a workable nomenclature will be acceptable to clinicians, lung sound investigators, editors and others interested in lung sounds. This presentation is to review the acoustic characteristics of common lung sounds in order to point out areas of general agreement and areas where additional work is necessary.