TWELFTH INTERNATIONAL CONFERENCE

ON LUNG SOUNDS

第 12 回 国際肺音学会

SEPTEMBER 16-18, 1987

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (C.N.R.S.)
PARIS, FRANCE

PRESENTED BY
INTERNATIONAL LUNG SOUNDS ASSOCIATION

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TWELFTH INTERNATIONAL CONFERENCE ON LUNG SOUNDS
CNRS, 15 QUAI ANATOLE FRANCE
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PROGRAM

WEDNESDAY, SEPTEMBER 16, 1987

Workshop - Breath monitoring during sleep disorders	3:00 PM

THURSDAY, SEPTEMBER 17, 1987

Registration	8:30 AM
Opening Remarks - Gerard Charbonneau	9:00 AM
Keynote Address - Monique Sudraud	9:05 AM
Session A	9:15 - 12:10 PM
Photograph	12:10 - 12:20 PM
Lunch	12:20 - 1:30 PM
Session B	1:30 - 4:50 PM

COCKTAILS AND BUFFET DINNER — 6:30 PM

FRIDAY, SEPTEMBER 18, 1987

Session C	9:00 - 11:35 PM
Japan Revisited - David Cugell	11:35 - 12:00 N
Lunch	12:00 - 1:00 PM
Business Meeting	1:00 - 1:15 PM
Session D	1:15 - 3:50 PM
Cracklefest	3:50 - 4:20 PM
Summary - David Cugell	4:20 - 4:50 PM

SESSION A : MODERATORS J. CHRETIEN, R.L.H. MURPHY, JR.

9:15-9:35	AUTOREGRESSIVE MODELING OF LUNG SOUNDS	V. IYER Y. PLOYSONGSANG P. RAMAMOORTHY
9:35-9:55	MODIFICATION OF CRACKLE-SEPARATING FILTER BY THE USE OF RANK-ORDER FILTERING	M. ONO K. ARAKAWA M. IGUCHI T. HISADA H. KINO M. MORI S. KOIKE T. SUGIMOTO H. HARASHIMA
9:55-10:15	COMPARISON OF AUDITORY AND VISUAL QUANTIFICATION OF CRACKLES	F. DAVIDSON E. DEL BONO R. MURPHY, JR.
10:15-10:30	COFFEE BREAK	
10:30-10:50	COMPARISON OF LUNG SOUNDS ANALYZED IN THE TIME AND FREQUENCY DOMAINS	R. MURPHY, JR. R. BERKOVITZ E. Del BONO M. MURPHY
10:50-11:10	VALIDATION OF A DEVICE FOR AUTOMATIC CRACKLE (RALE) CLASSIFICATION AND QUANTIFICATION	R. MURPHY, JR. R. BERKOVITZ E. Del BONO
11:10-11:30	APPLICATION IN BEDSIDE MEDICINE OF AUTOMATED SPECTRAL ANALYSIS OF BREATH SOUNDS, WHEEZES AND CRACKLES	E. LENS G. POSTIAUX P. CHAPELLE
11:30-11:50	DIGITAL RESPIROSONOGRAPHY	H. PASTERKAMP D. DAIEN
11:50-12:10	PHONOPNEUMOGRAPH AS AN "OBJECTIVE STETHOSCOPE"	S. KUDOH A. SHIBUYA S. INUI N. SHIOYA N. NARITA R. MIKAMI
12:10-12:20	PHOTOGRAPH	
12:20-1:30	LUNCH	

AUTOREGRESSIVE MODELING OF LUNG SOUNDS

V. K. Iyer
Y. Ploysongsang
P.A. Ramamoorthy

Departments of Internal Medicine &
Electrical and Computer Engineering
University of Cincinnati Medical Center
Cincinnati, Ohio

We applied the autoregressive (AR) modeling technique to analyze lung sounds, using the following model. Breath sounds at the chest wall are produced by the transmission of a random white noise source, sounds with a distinct pitch (such as a wheeze) by a source consisting of a periodic train of impulses, and "crackling" sounds by a source consisting of compulsive bursts, through an acoustic filter consisting of the lung parenchyma and chest wall. The acoustic filter is characterized by an all-pole model. To test this hypothesis, sounds from teaching tapes were digitized and subjected to autoregressive analysis. The sources, characterized by the residue signals, were found to be as hypothesized. The transmission filter, characterized by the autoregressive coefficients (or partial correlation coefficients) showed a lowpass response for normal sounds. When the lung was consolidated by fluids, more higher frequency sounds were transmitted. In the case of pitched sounds, the filter response showed distinct resonances (peaks).

We concluded that the AR model applies well to lung sounds, separating the source and transmission characteristics for specific diagnoses. This advantage is in addition to the high resolution in time and frequency domain characterization and information compaction advantages of the AR method. The method is implementable in real-time for clinical applications.

MODIFICATION OF CRACKLE-SEPARATING FILTER BY THE USE OF RANK-ORDER FILTERING

Mariko Ono(1), Kaoru Arakawa(2), Mari Iguchi(1), Tetsuya Hisada(1)
Hiroyoshi Kino(1), Masashi Mori(3), Shigeo Koike(1)
Tsuneaki Sugimoto(1), Hiroshi Harashima(2).

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(2) Department of Electrical Engineering, University of Tokyo.
(3) Pulmonary Center, Mitsui Memorial Hospital.

Last year in this conference we discussed about the application of digital filter for the separation of crackles based on the fact that crackles are non-stationary while background vesicular sounds are stationary signals. Though the results were satisfactory as far as the separation was concerned, our system was not good enough for the clinical use. For instance, it was impossible to separate coarse from fine crackles and the filter sometimes interpreted the beginning of each respiration or heart sounds as non-stationary signals. To overcome some of these drawbacks we tried rank-order filter to supplement our system. The signals were first passed through the stationary-nonstationary separating filter, then through our new filter. This filter, which can separate signals according to their widths, is a combination of two types of rank-order filters. By this method we were able to improve our system and make it possible to distinguish coarse from fine crackles.

COMPARISON OF AUDITORY AND VISUAL
QUANTIFICATION OF CRACKLES

F. Davidson, E.A. Del Bono & R.L.H. Murphy, Jr.
Pulmonary Departments
Faulkner & Lemuel Shattuck Hospitals
Boston, MA

Crackles are characterized by spike-like deflections on time expanded waveform analysis. Not all such deflections, however, are caused by crackles. Conversely, it is not known whether all crackles perceived by ear give rise to measurable spikes on waveforms made with current methods. Thus, the true accuracy of crackle counts made on time expanded waveform analysis is not known.

We recorded crackles of patients with a variety of illnesses. Tape recordings were listened to carefully and those believed to be artifact free were analyzed. In most instances, it was difficult to count crackles on direct playback of tapes. Accordingly, the tapes were re-recorded at successively slower speeds until it became possible to count crackles. Auditory counts were compared to waveform counts as seen in Table I.

TAPE PLAYBACK	WAVEFORM COUNTS
10	10
5	5
6	5
7	8
8	8
10	8
12	27
6	6
14	21

The reasons for discrepancies in counts observed using the different methods will be discussed. Examples of the differences and similarities in waveforms of crackles and artifacts will be presented. Based on these observations, the typical waveforms of crackles will be presented.

COMPARISON OF LUNG SOUNDS
ANALYZED IN THE TIME AND FREQUENCY DOMAINS

R.L.H. Murphy, R. Berkovitz, E.A. Del Bono, M. Murphy
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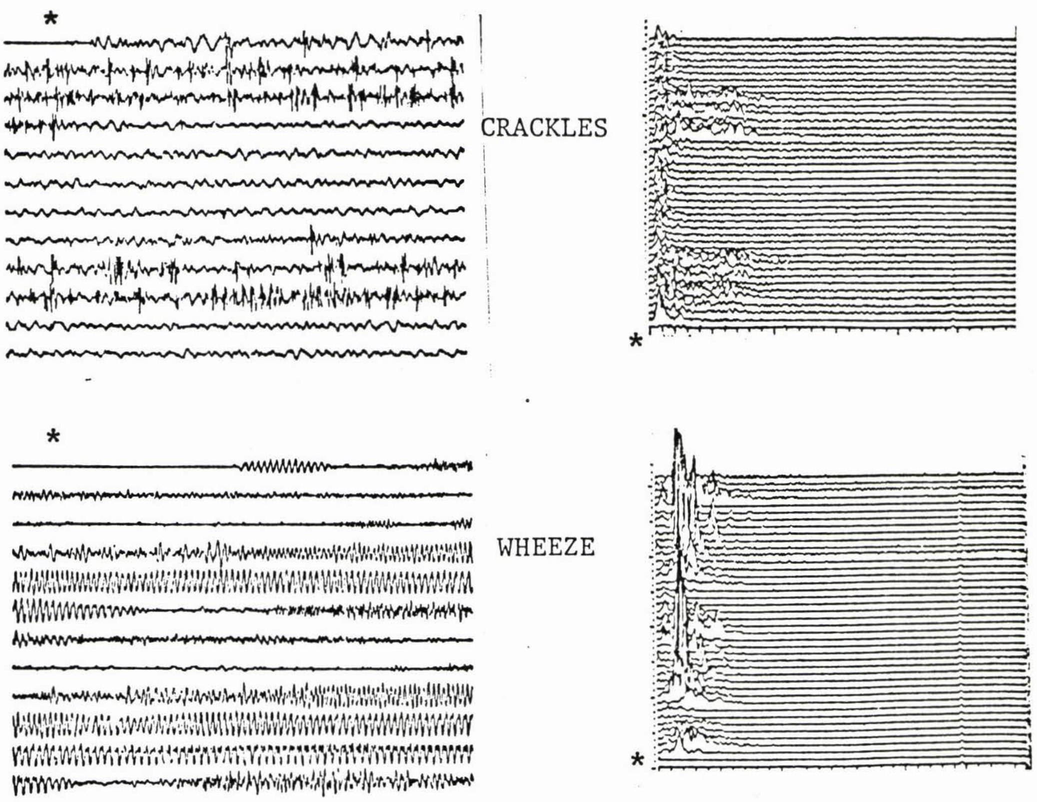
It is generally believed that discontinuous sounds are better examined in the time domain while continuous sounds are more readily analyzed in the frequency domain. With regard to the analysis of lung sounds, however, only a few comparisons of the two modalities have been published. Kraman presented the results of analyses on four lung sounds and stated that "the spectra, although yielding information about frequency content of the signals in question, are by themselves less useful than the display of the time expanded waveform" (1). We examined examples of the most common lung sounds in both domains using a system specifically designed for this purpose (Stethograph Model 7-87). The results of these analyses will be presented and the relative merits of the time and frequency domains discussed. (See Figure 1)

(1) Kraman, SS: New tools in lung sound research. Seminars in Respiratory Medicine. Vol 6, No 3, Jan 1985.



* START INSPIRATION

FIGURE 1: Examples of crackles and wheeze in the time and frequency domains.

VALIDATION OF A DEVICE FOR AUTOMATIC CRACKLE (RALE) CLASSIFICATION AND QUANTIFICATION

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Time expanded waveform analysis (TEWA) has provided an objective method for classification and quantification of crackles and thus has the potential for usefulness in noninvasive diagnosis. We have shown that quantifiable differences exist between the crackles of interstitial fibrosis and some other common lung conditions, such as chronic obstructive lung disease, congestive heart failure and pneumonia.

Quantification of crackles appears to be important because of the common clinical observation that the number of crackles relates to the severity of the illness in lung conditions such as pulmonary edema, interstitial fibrosis and some pneumonias. Unfortunately, both classification and quantification of crackles by TEWA is tedious and is also in part hampered by observer variability. Accordingly, we developed a computerized method for automatic quantification and classification of crackles. We validated this method by comparison of computerized crackle counts and measurements with counts and classifications made by ear, counts and classifications made on waveforms and measurements made in different disease states. The results of these studies will be presented.

APPLICATION IN BEDSIDE MEDICINE OF AUTOMATED SPECTRAL ANALYSIS OF BREATH SOUNDS, WHEEZES AND CRACKLES

E. Lens
G. Postiaux
P. Chapelle

Groupe D'Etude Pluridisciplinaire Stethacoustique
Courcelles,Belgium

We have developed an on-line automated spectral quantification system allowing characterization and quantification of several respiratory parameters picked up by a microphone.

1. This microphone is attached on the sternum notch when used in assessment of wheezing obstruction, for example nocturnal asthma. By this we mean several parameters may be followed: respiratory rate, heart rate, percent duration in respiratory cycle, inspiratory/expiratory ratio, acoustic frequency and intensity of wheezing. Given the already established inter-subject variability of wheezing versus severity when wheezing alone was taken into account, we attempted to draw up a better evaluation of the obstructive status or objective scores by summing up the provided parameters. At the present, the information gathered from these pilot studies has provided information to unmask the prodromic stage of nocturnal asthma attack only in longitudinal monitoring.

2. Conversely, in the case of bronchial obstruction by secretions, the microphone was attached over the region of crackling. Acoustic measurements of crackles has permitted an objective follow-up of both bronchial obstruction and efficacy of several maneuvers of chest physiotherapy. Acoustic quantification of parameters as situation and pitch of the crackles in inspiratory or expiratory phases, provided a significant score of severity or improvement.

With these first results we can presume that further studies with this system may achieve an objective clinical monitoring.

DIGITAL RESPIROSONOGRAPHY*

Hans Pasterkamp‡, MD, David Daien, BScEE
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Graphic display of respiratory sound characteristics, including information on time, frequency and amplitude, is typically achieved by plotting the respective parameters as three vector diagrams (3-D plots). Over 30 years ago, Victor McKusick used sonograms, similar to 'voice prints', to show the acoustical properties of normal and abnormal respiratory sounds. We present an extension of this analog method, using digital data obtained by fast Fourier transformation (FFT) analysis of respiratory sounds.

We analyzed various tape recordings as previously described, using FFT on successive 100 msec segments of breath sounds. This analysis is performed on a PDP 11/53 microcomputer, and the data are subsequently transferred to an IBM AT compatible computer. A program written in the BASIC language presents these data as 'digital respirosonograms', with time on the X-axis and frequency on the Y-axis. Amplitude is shown as different shades of grey, with eight levels of intensity ranging from black to white. This scale allows a resolution of 5 db, as most of our breath sound recordings have a dynamic range of less than 40 dB.

Examples of lung sounds from healthy newborns and from older children, tracheal and lung sounds from asthmatic patients, and lung sounds from a patient with cystic fibrosis will be presented. Typical characteristics of these sounds are more easily appreciated when displayed as digital respirosonograms. Compared to the older analog sonograms, the amplitude scale of the digital display provides clearer resolution. Continuous adventitious sounds can be identified by graphic markers. Discontinuous sounds however, such as in the patient with cystic fibrosis, require a time-expanded wave-form display.

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* Supported by the Children's Hospital of Winnipeg Research Foundation and the Winnipeg Clinic Research Institute

‡ Scholar of the Manitoba Health Research Council

PHONOPNEUMOGRAPH AS AN "OBJECTIVE STETHOSCOPE"

S. Kudoh [1]
A. Shibuya [2]
S. Inui [2]
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1 Tokyo Metropolitan Komagome Hospital, Bunkyo-ku, Tokyo, Japan
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Various recording and analyzing systems have been used in the laboratory of lung sounds. However, they are so elaborate and complicated that it is difficult for clinicians to manage them at the bedside. Today, it has become a subject to develop a compact device of phonopneumograph which can be used as an "objective stethoscope".

We have previously reported a digital phonopneumograph using a micro-computer, in which both respiratory cycle and sound spectrogram of lung sounds are graphically displayed and time-expanded wave-form and power spectrum can be obtained at the arbitrary point on the sound spectrogram.

In this study, a small-sized recording device, including a 4-track, 2-channel audio tape recorder, were designed to standardize a simple method of recording lung sounds at the bedside. By this ddevice, lung sounds and respiratory phase signals are simultaneously recorded into each channel. Respiratory phase signals from an impedance-plethysmograph (or a flow-meter, if necessary) is recorded after modulated to the range of audio frequency.

We can easily record and analyze lung sounds at the bedside by combining this new recording device with the digital phonopneumograph.

SESSION B : MODERATORS W. BALL, R. PESLIN

1:30-1:50	MONITORING AND ANALYSIS OF COUGH	M. MORI M. ONO M. IGUCHI H. KINO T. HISADA S. KOIKE T. SUGIMOTO
1:50-2:10	OBSERVER VARIABILITY IN INTERPRETATION OF VOLUNTARY COUGH OF "BRONCHITICS" AND "ASTHMATICS"	M. ISHIKAWA R. KASPARIAN J. BLANCO D. SOTHERLAND R. CLUBB L. KENNY J. WORKOWICZ K. MacDONNELL
2:10-2:30	ACOUSTIC FEATURES OF COUGH SOUNDS	P. PIIRILA A. SOVIJARVI
2:30-2:50	TWO-CENTER COMPARISON OF COMPUTERIZED ANALYSIS OF WHEEZES FROM 30 DIFFERENT CHILDREN AFTER METHACHOLINE CHALLENGE	A. AVITAL H. PASTERKAMP E. BAR-YISHAY S. GODFREY
2:50-3:10	PREVALENCE AND SIGNIFICANCE OF STRIDOR IN THE INTENSIVE CARE UNIT	R. BAUGHMAN R. LOUDON
3:10-3:30	COFFEE BREAK	
3:30-3:50	FORCED EXPIRATORY WHEEZES ARE CONSTANT UNDER IDENTICAL FLOW CONDITIONS	R. BECK N. GAVRIELY
3:50-4:10	CRITICAL PRESSURE FOR GENERATION OF FORCED EXPIRATORY WHEEZES IN NORMAL MAN	N. GAVRIELY K. KELLY J. GROTBERG S. LORING
4:10-4:30	FLUTTER IN COLLAPSIBLE TUBES: A THEORETICAL MODEL OF WHEEZES	J. GROTBERG
4:30-4:50	STROBOSCOBIC ENDOSCOPY FOR THE STUDY OF SOUND PRODUCTION IN AIRWAYS	R. LOUDON R. BAUGHMAN L. FORNER J. STEMPLE
6:30	COCKTAILS AND DINNER	

MONITORING AND ANALYSIS OF COUGH

M. Mori
M. Ono
M. Iguchi
H. Kino
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and
The Second Department of Internal Medicine
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Cough is very common both in patients and in healthy subjects but evaluation of coughs, especially those during the night, is rather difficult. The system we developed for the monitoring of cough consists of a small microphone which can be plugged in the ear, level detector, amplifier with delay circuit (0.2 sec), tape recorder, and signal processing units. The level detector was to detect coughs and trigger the recorder, and the delay circuit was necessary to preserve the initial portion of the cough signals. After an overnight recording the taped signals were passed through an envelope detector and the numbers of coughs were counted. For the more detailed analysis some of the original signals were digitized (12 bit, sampling frequency:8-10 kHz) and subjected to both time domain and frequency domain analysis.

OBSERVER VARIABILITY IN INTERPRETATION OF VOLUNTARY COUGH OF "BRONCHITICS" AND "ASTHMATICS"

S. Ishikawa
R. Kasparian
J. Blanco
D. Sotherland
R. Clubb
L. Kenny
J. Workowicz
K. MacDonnell

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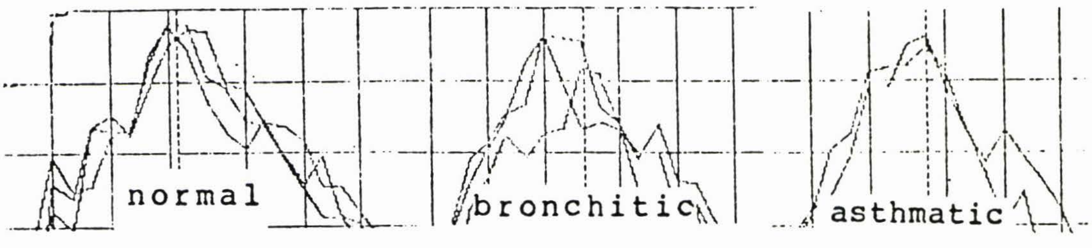
Voluntary cough sounds were recorded by FM tape recorder. It was digitized and white noise was filtered. Then, autoplotted and spectrogram was made (as shown in Figs. 1,2,3).



Time expanded wave forms were also made. Five chest physicians were asked to listen to taped sound and subsequently shown the time expanded wave form and power spectrograph of each case. Prior to testing, 'typical' examples of cough sounds and tracings, regarding the average period of each cough (39 msec in normal, 115 msec in bronchitic, 240 msec in asthmatic), wave characteristics, and peak frequency (200 Hz in normals, 325 Hz in bronchitics, 400 Hz in asthmatics) were demonstrated to them. Observer variability and agreement were determined. Ten bronchitics, ten asthmatics and ten normal cases were studied. Asthma was properly interpreted as asthma averaged 84%. Bronchitis was properly interpreted as bronchitis averaged 80%. Accuracy of diagnosis was 80%.

ACOUSTIC FEATURES OF COUGH SOUNDS

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A.R.A. Sovijarvi

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We studied 20 patients with cough in order to analyze both the spectral characteristics of cough sounds and the simultaneous flow. The reason for cough in 7 patients was worsened obstruction due to asthma and in 13 patients cough occurred without reversible bronchial obstruction. The flow was recorded with a Fleisch pneumotachograph and the cough sounds simultaneously with a condenser microphone placed on manubrium sterni.

The mean peak flow rate ($\pm$ SD) during cough was lower in asthmatics (1.95 $\pm$ 0.78 l/s) than in the nonasthmatic patients (3.2 $\pm$ 0.93 l/s; $p<0.01$). The mean peak flow of spontaneous inspiration preceding the cough was almost similar in the groups (1.4 $\pm$ 0.57 l/s and 1.9 $\pm$ 0.59 l/s respectively). The cough sounds were analyzed with a sound spectrograph (Sonagraph Kay Elemetrics). The mean duration of transient cough sounds was long in asthmatics than in nonasthmatics (0.429 $\pm$ 0.145 s and 0.236 $\pm$ 0.089 s respectively; $p<0.005$). The frequency band of the sound varied between 0-2000 Hz and 0-5000 Hz. In 6 of the 7 asthmatics and also in 10 of the 13 nonasthmatic patients the cough sounds contained elements of wheezing.

TWO-CENTER COMPARISON OF COMPUTERIZED ANALYSIS OF WHEEZES FROM 30 DIFFERENT CHILDREN AFTER METHACHOLINE CHALLENGE

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H. Pasterkamp
E. Bar-Yishay
S. Godfrey

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Israel and Health Sciences Centre
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Airways hyperreactivity is generally well assessed by methacholine challenge and measured by the fall in FEV1 in cooperating children or adults. Young children aged 1 to 7 years were exposed to increasing concentrations of methacholine until wheezes appeared. Breath sounds were recorded over the trachea and stored on a magnetic tape. Data were later evaluated in two different centers using a fast Fourier transform program. Normal breathing sounds were compared to audible wheezes in an attempt to reach an objective qualitative and quantitative definition of wheeze.

PREVALENCE AND SIGNIFICANCE OF STRIDOR IN THE INTENSIVE CARE UNIT

R.P. Baughman
R.G. Loudon

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Stridor is a musical, continuous sound attributed to upper airway narrowing. Extrathoracic variable obstruction may be associated with stridor more prominent on inspiration than expiration. Inspiratory stridor is an important clinical finding, since such a lesion can be bypassed by an endotracheal or tracheostomy tube to relieve the patient's respiratory distress. We were interested in the incidence of upper airway sounds in the intensive care unit, especially in patients who had been recently extubated and at high risk for upper airway obstruction. Patients who had been recently extubated or who appeared to have upper airway obstruction for other reasons were studied. Recordings were made using a stethoscope air coupled to a microphone. The signal was recorded on a portable cassette recorder. Recordings were made over the neck and over the right anterior chest while the patient took normal tidal breaths. For two breaths, the inspiratory and expiratory cycle were announced on the tape. At least ten breaths were recorded from each location. The patients were all followed until discharge and any patient requiring reintubation or tracheostomy was noted. The recorded sound signals were played back and analyzed by two methods. First the signal was scored by two listeners who determined whether stridor was or was not present. The signal was also digitized and underwent Fast Fourier Transformation to analyze the signal for frequency content of 0 to 2000 Hz. A continuous sound signal was analyzed using a method originally described by us to analyze wheezes. The signal from the neck and chest were compared and peak frequencies of greater than 200 Hz and longer than 200 msec duration were noted. The continuous sounds from the neck and chest were compared. Of the fifteen subjects in whom adequate recordings were made, fourteen had good comparative recordings from both neck and chest. The final diagnosis of these patients was upper airway obstruction in three, asthma in five, drug overdose in five, congestive heart failure in one and interstitial lung disease in one. A continuous musical sound was heard and seen only in those patients with asthma or upper airway obstruction. In those five patients with asthma, the wheeze was always expiratory, the sound was less prominent over the neck than the chest in four of five, and not heard at all over the neck in three. For the three patients with stridor, inspiratory sound was heard in all three patients, with two patients having only an inspiratory sound. Frequency analysis of the sound of asthmatic and stridor sounds revealed no significant difference in the duration or frequency of the sound heard. The major difference between stridor and asthma was the timing of the sound and the prominence of the sound over the neck.

FORCED EXPIRATORY WHEEZES ARE CONSTANT UNDER IDENTICAL FLOW CONDITIONS

R. Beck
N. Gavriely

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Rambam University Hospital and the Rappaport Institute
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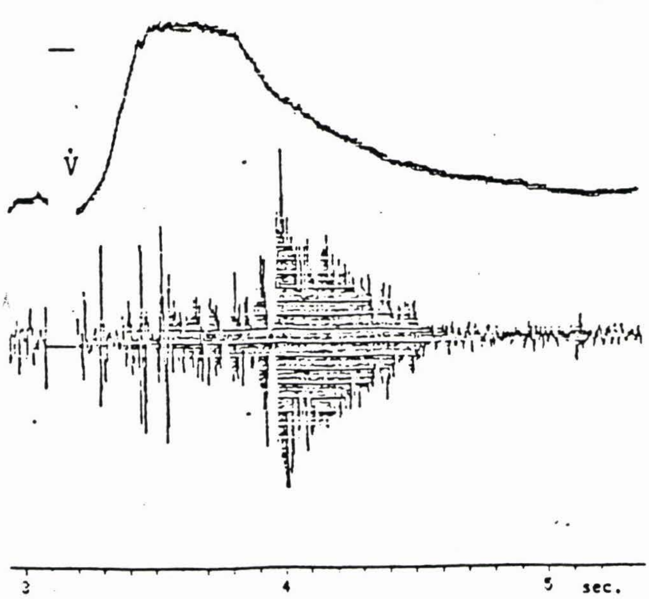
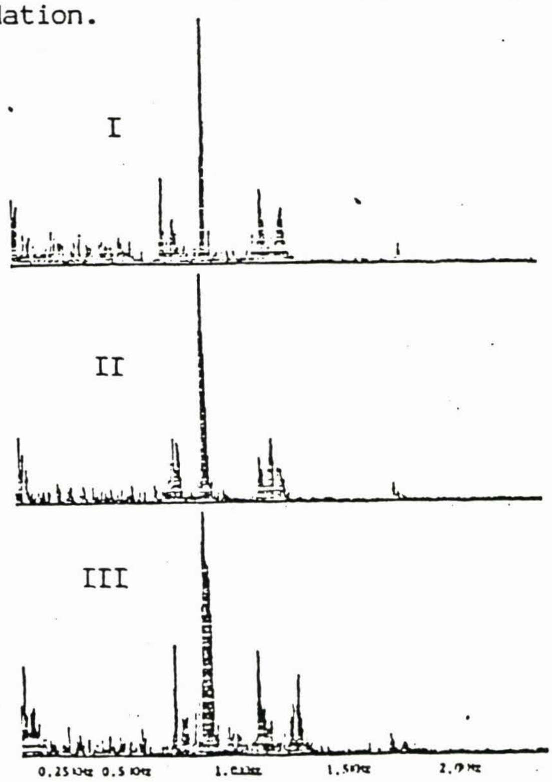
and
Dept of Physiology and Biophysics, Faculty of Medicine, Technion,
and the Rappaport Institute for Research in Medical Sciences,
Haifa, Israel

Forced expiratory wheezes (FEW) have been proposed as a model for studying the wheezes heard in obstructive lung diseases (OLD). Previous work has shown FEW to be associated with onset of flow limitation and to have spectral characteristics similar to the wheezes in OLD. This study was designed to investigate the relationships between the acoustic properties of FEW and the underlying flow conditions. Six healthy non-smoking young adults were studied (ages 31-37). They performed a Forced Vital Capacity maneuver, inhaling to TLC and forcefully exhaling to RV, while blowing through a series of apertures (diameters 14 to 1 mm) which created a step-wise increase in flow resistance. Flow was recorded with a pneumotachograph; lung sounds with a Hewlett-Packard HP20510A contact sensor placed over the trachea. Flow and lung sounds were recorded simultaneously on magnetic tape and analyzed off-line. Three maneuvers were recorded from each subject for every aperture. RESULTS: FEW were generated by all subjects in 95% of all maneuvers. In those apertures where conditions of constant flow rate were obtained, FEW always appeared when flow started tapering off, conditions which have been described before as signifying onset of flow limitation in the airways (figure). The main finding, in all subjects, was the demonstration that, in different maneuvers of each subject through the same aperture (e.g. - identical flow conditions), the main component of the wheeze was of identical spectral frequency in all runs (figure). Our findings suggest that under conditions of identical flow and resistance, flow limitation occurs always in the same airway segment, giving rise to a wheeze of constant frequency. This lends further support to the flutter theory as the mechanism responsible for production of FEW. This study was supported by the United States-Israel Binational Science Foundation.



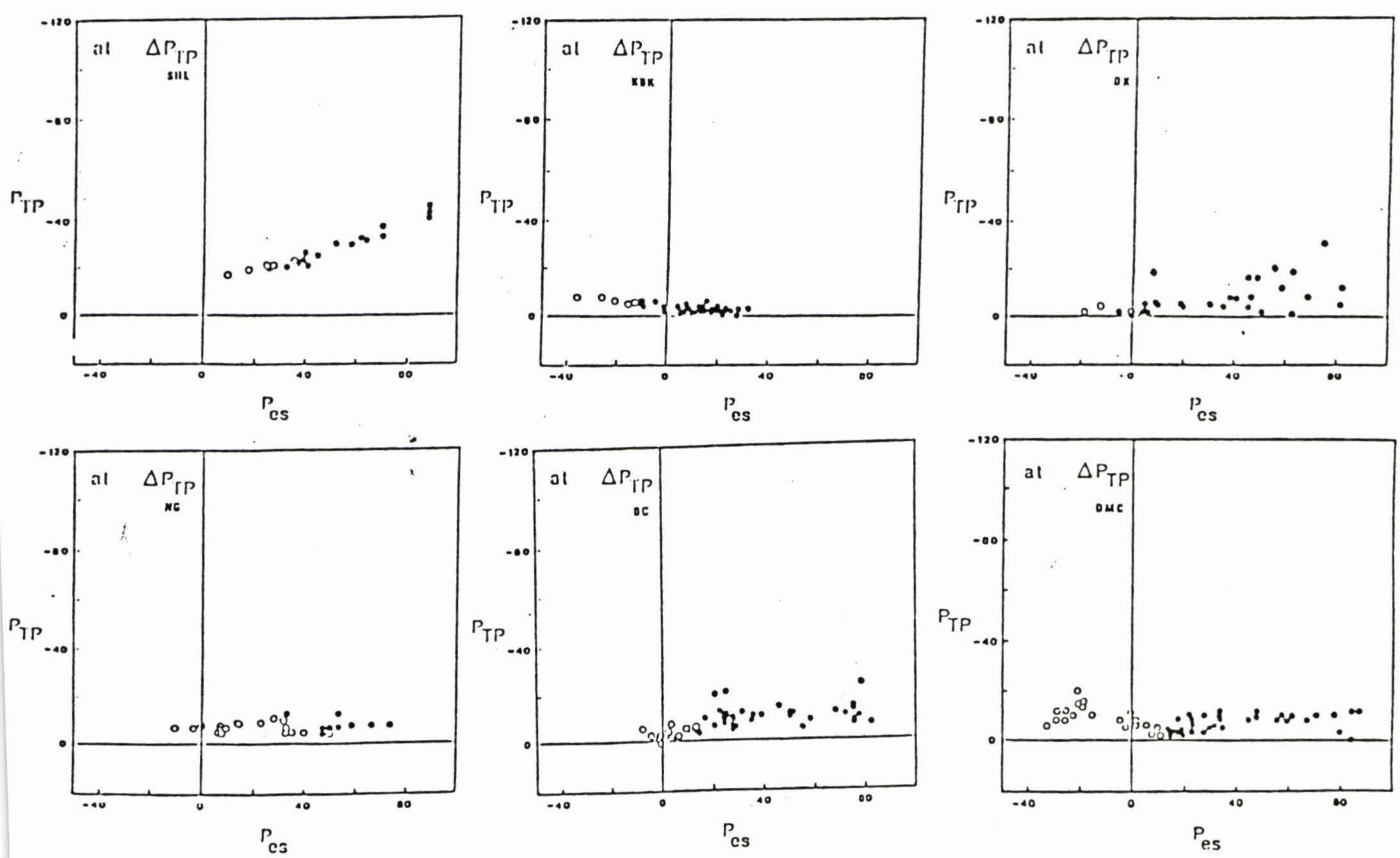


Critical Pressure for Generation of Forced Expiratory Wheezes in Normal Man

Noam Gavriely
Kevin B. Kelly
James B. Grotberg
Stephen H. Loring

Forced expiratory wheezes were recntly shown to be associated with the onset of flow limitation in normal subjects (J. Appl. Physiol. 7/1987). Although it was shown that flow limitation is a necessary condition for the generation of wheezes, it was not always sufficient. I.e. there were runs where no wheezes occured even though flow limitation was present. We investigated this by systematic analysis of the relationships between esophageal pressure and the generation of wheezes. Six normal men were instructed to perform repeated forcrd expiratory manouvers at varying effort. Each subject was instrumented with esophageal balloon and placed inside a body plethysmograph to measure lung volume. Moth pressure, flow rate and tracheal lung sounds were also measured with appropriate transducers. A high impedance vacuum pump in series with an orifice were used to control expiratoey flow. For each subject, it was found that there existed a critical esophageal pressure (Pcrit.) needed for onset of wheezes. The range of Pcrit found was -10 to +30 cmH2O at the onset of flow limitation (i.e. the sudden change in transpúlmonary pressure). These data represent points on the isovolume pressure-flow curves of the subjects. It is apparent that flow limitation must be associated with development of sufficient intrathoracic pressure. This pressure causes airway transmural pressure to increase in the segments downstream from the choke point, so that the critical buckling pressure of the central airways may be attained.

This study was supported, in part, by the United States - Israel Binational Science Foundation, NIH Grants HL19170 and HL00943, and NSF Presidential Young Investigator Award given to Prof. Grotberg.



FLUTTER IN COLLAPSIBLE TUBES:

A THEORETICAL MODEL OF WHEEZES

by James B. Grotberg Ph. D., M. D.

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A mathematical analysis of flow through a flexible channel is examined as a model of flow-induced flutter oscillations that pertain to the production of wheezing breath sounds. The model provides predictions for the critical fluid speed that will initiate flutter waves of the wall, as well as their frequency and wavelength. The mathematical results are separated into linear theory (small oscillations) and non-linear theory (larger oscillations). Linear theory determines the onset of the flutter, while the non-linear theory determines the relationships between the fluid speed and both the wave amplitudes and frequencies. The linear theory predictions correlate well with data taken at the onset of flutter and flow limitation during experiments of air flow in thick-walled, collapsible tubes. The non-linear theory predictions correlate well with data taken as these flows are forced to higher velocities while keeping the flow rate constant. Particular ranges of the parameters are selected to investigate and discuss the applications to airway flows. According to this theory the mechanism of generation of wheezes is based in the interactions of fluid forces and friction and wall elastic restoring forces and damping. In particular a phase delay between the fluid pressure and wall motion is necessary. The wave speed theory of flow limitation is discussed with respect to the specific data and the flutter model.

STROBOSCOPIC ENDOSCOPY FOR THE STUDY OF SOUND PRODUCTION IN AIRWAYS

R. G. Loudon
R. P. Baughman
L. Forner
J. Stemple

University of Cincinnati Medical Center
Departments of Internal Medicine and Communication
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Stroboscopic light sources are used to study laryngeal movement during phonation. A microphone placed externally over the larynx synchronizes light flashes with vibrations of the vocal cords, allowing their motion to be studied in detail. Video cassette recordings can be made, and used to show rapidly vibrating sstructures in stop-motion, or slow backward or forward motion. We have applied this technique to the study of vibrating tracheal and bronchial walls, and to the larynx, during forced expiratory wheezing. Healthy volunteer subjects were bronchoscoped transnasally, using local anesthesia and a flexible fiberoptic bronchoscope. Observations were made during quiet breathing, phonation, forced expiratory maneuvers, and coughs, using standard and stroboscopic illumination, and recording observations with a video cassette recorder. It appears that airways can close almost completely during forced expiratory wheezing; their wall vibration is as yet less cclearly demonstrated. Observation of the larynx during the production of forced expiratory wheezes gives evidence for adduction of the vocal cords as the means of raising intrathoracic pressure during the maneuver, and of vibration of the adducted cords and ventricular folds as a producer of at least some part of the sound produced.

SESSION C: MODERATORS R. LOUDON, M. SUDRAUD

9:00-9:20	VARIABILITY OF FLOW-STANDARDIZED TRACHEAL SOUNDS	H. PASTERKAMP W. WIEBICKE D. DAIEN
9:20-9:40	FLOW VOLUME SPECTRA OF TRACHEAL BREATH SOUNDS	W. McKAY A. REBUCK R. HONG S. McKILLOP
9:40-10:00	A STATISTICAL APPROACH FOR RELATING FLOW-RATE AND LUNG SOUND SPECTRA	G. CHARBONNEAU M. SUDRAUD G. SOUFFLET P. ATTAL C. GAULTIER
10:00-10:20	RESPIRATORY PHYSIOLOGY OF TRUMPET PLAYERS	S. NELSON R. LOUDON
10:20-10:35	COFFEE BREAK	
10:35-10:55	FREQUENCY DEPENDENCE OF ACOUSTIC TRANSMISSION IN THE RESPIRATORY SYSTEM	G. WODICKA D. SHANNON
10:55-11:15	MULTISITE FLOW-DEPENDENT ANALYSIS OF LUNG SOUNDS IN SUBJECTS WITH AND WITHOUT EMPHYSEMA	H. SCHREUR H. VAN KLINK E. Van VOLLENHOVEN J. DIJKMAN
11:15-11:35	CHARACTERIZATION OF NORMAL LUNG SOUNDS BY AUTOREGRESSIVE MODELING TECHNIQUE	Y. PLOYSONGSANG V. IYER V. RAMAMOORTHY
11:35-12:00	JAPAN REVISITED	DAVID CUGELL
12:00-1:00	LUNCH	

VARIABILITY OF FLOW-STANDARDIZED TRACHEAL SOUNDS*

Pasterkamp H[‡], MD, Wiebicke W[§], MD, Daien D, BScEE
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To determine whether flow-standardized tracheal sounds change with body position, we studied 7 healthy male non-smokers, age 20 to 36 years. Tracheal sounds (contact transducer over the left antero-lateral neck) and a calibrated flow signal (pneumotachograph) were simultaneously recorded (FM tape recorder). In both upright and supine positions, 10 samples of 100 msec duration were taken at flows of 1.2 ± .2 l/sec during inspiration and expiration. Median frequency (Fmed), upper limit of spectrum (UL) and average power of spectra (Pavg) were obtained by fast Fourier analysis.

There were significantly higher Fmed, UL and Pavg in expiration as compared to inspiration, both upright and supine. In all subjects, Pavg was greater in the supine position during both respiratory phases. This was significant in 4/7 for inspiration and in 5/7 for expiration. There was a trend toward higher Fmed and higher UL in the supine position. These results were highly variable, however, and the reverse was actually true in 2/7.

On repeat testing 2 to 4 weeks later, the spectral differences between expiration and inspiration were again seen, and in 6/7 a greater Pavg in the supine position was confirmed. Frequency parameters, however, did not show a consistent pattern in 5/7 subjects. Coefficients of variance were 19 ± 1% (SEM) for Fmed, 16 ± 2% for UL, and 44 ± 2% for Pavg.

Supraglottic airways may contribute to respiratory sounds recorded over the neck. Therefore, position dependent changes in airway configuration could influence tracheal sounds at given flow rates. Greater sound intensity in our subjects when supine may reflect changes in the upper airways. Also, a change in the position of sound generating structures relative to the transducer and, less likely, position dependent changes in impedance matching have to be considered. It will now be interesting to study patients with obstructive sleep apnea and abnormally small upper airways.

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‡ Scholar of the Manitoba Health Research Council

§ Fellow of the Manitoba Lung Association

FLOW VOLUME SPECTRA OF TRACHEAL BREATH SOUNDS

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R. Hong
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We recorded the tracheal breath sounds of 30 seated volunteers, 8 normal, 9 smokers, and 13 asthmatics, during 5 respiratory maneuvers: quiet breathing, medium intensity breathing, forced vital capacity expiration, and steady flow inspiration and expiration. The sounds were analyzed with a high resolution signal analyzer and computer to yield a time series of frequency spectra 125 ms apart. Standard signal-analysis parameters were derived for each spectrum: FL = lower corner, the frequency above which 85% of power resides; FU = upper corner; FAC = algebraic mean frequency; FGC = geometric mean frequency; FM = median frequency; BWA = actual bandwidth; BWN = normalized bandwidth; and FD = dominant frequency. Significant relations were examined with SAS General Linear Modeling, Duncan's Multiple Range Test, and Discriminant Analysis programs.

The following measures discriminated between normals and smokers/asthmatics: quiet inspiration - FU, FAC, FGC, FM, BWA, BWN; quiet expiration - FU, FAC, FGC,, BWA, BWN; medium intensity inspiration or expiration - none; forced vital ccapacity expiration - FL, FAC, FGC, FM; steady flow inspiration - FU; steady flow expiration - none. No measures distinguished smokers from asthmatics. FD was never different among groups, but was different for breath phases. BWA separated normals and asthmatics more reliably (P<.001) than other measures, but BWA and BWN were the only variables which did <u>not</u> change significantly with breath phases.

Moment to moment spectral changes were studied during steady flow. neither asthmatic nor normal spectra were affected by lung volume.

These results confirm certain theories of breath sound formation (1,2,3), and reject others.

1. Forgacs P. Lung sounds. London: Bailliere Tindall, 1978.
2. Loudon R, Murphy RLH Jr. Lung sounds. Am Rev Respir Dis 1984; 130:663-673.
3. Olson D. Mechanisms of lung sound generation. Sem Resp Med 1985; 6(3):171.

A STATISTICAL APPROACH FOR RELATING FLOW-RATE AND LUNG SOUND SPECTRA

G. Charbonneau
M. Sudraud
G. Soufflet
P. Attal
C. Gaultier

We simultaneously sampled lung sound and flow-rate at 10240 Hz from normal subjects. Sound is picked up at the trachea with a sensitive microphone held in a small probe. Flow rate is measured at the mouth using a Fleisch #3 pneumotachograph. Subjects performed three recordings, each of them of 24 seconds. The first was made at spontaneous flow-rate (peak value between 0.5 and 1.0 l/s), the second in under-breathing conditions (<0.5 l/s), and the last on over-breathing conditions (>1.0 l/s). Ten subjects participated in the experiment. For each subject, sound and flow-rate are separated and divided in 128-sample blocks. For each block, frequency spectrum of the sound is computed using the Fast Fourier Transform, and the corresponding mean flow-rate is calculated. In order to precise the relationship between sound spectra and flow-rate we chose to apply a hierarchical clustering analysis on the successive spectra corresponding to 24-second maneuvers.

The hierarchic structure shows that spectra are grouped according to the corresponding flows. however, comparisons between recordings made at different peak flow-rates indicate that it does not exist as a unique spectrum associated with a given flow value. Spectrum characteristics depend on the root mean square value of flow. This result seems to prove that spectrum shape could be more likely related to the airways resistance than directly to the flow-rate value.

RESPIRATORY PHYSIOLOGY OF TRUMPET PLAYERS

S. Nelson
R. Loudon

University of Cincinnati Departments of Medicine and College Conservatory of Music

Respiratory physiology has been a major consideration of wind instrument players for many years. Proper control of respiratory muscles is vital to the tone production process. However, the correct procedure for inspiration and especially expiration is a source of controversy among wind instrumentalists. Books and articles on the subject of proper breathing during performance differ greatly. Proper expiration is particularly essential to trumpet players as their demands frequently involve the need to create extreme air velocity. As a professional trumpet player and teacher, it has been my experience that there are many complications involving tension in the throat and abdomen that are created by improper or inadequate instruction. Many novice players compress their air by partially or completely closing their throat using a Valsalva maneuver and try to reopen their throat to begin a tone. In most cases the result is an ineffective high register and/or a lack of endurance.

The research in progress is designed to shed some light on this problem. Using surface electromyography abdominal and throat activity of novice through professional trumpet players is monitored and recorded on a Grass polygraph machine. In addition, a Respigraph monitors abdominal and chest contraction and expansion. This information is recorded by computer and on the Grass polygraph. Each subject performs the same material and is aurally recorded. Approximately 25 subjects are being tested, ranging in experience from high school to professional symphony musicians. The respigraph is calibrated before each subject performs. The entire test takes approximately one hour. The information recorded thus far indicates a consistent difference between the professional and novice trumpet players.

FREQUENCY DEPENDENCE OF ACOUSTIC TRANSMISSION IN THE RESPIRATORY SYSTEM

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We investigated the acoustic properties of the respiratory system by measuring the transmission of noise from mouth to chest wall over a 100 to 1000 hertz frequency range in five healthy adult subjects. At resting lung volume, sound measurements were made simultaneously at the mouth and over the extrathoracic trachea and posterior right lower lung. For the group, maximum transmission occurred at 148 +/- 28 hertz (mean +/- sd), with a quality factor, a measure of the sharpness of a spectral peak, of 4.1 +/- 1.1. This frequency was the same at all measurement sites for each subject. As frequency increased, transmission decreased from this peak value. In addition, a second region of increased transmission was observed in the tracheal spectra at 544 +/- 36 hertz. We have developed an acoustic model which qualitatively predicts these observed frequency characteristics. The model is based upon the structure of the acoustic source, vocal tract, and the thorax. It suggests that the frequency at which maximum transmission occurs is a strong function of the dimensions of the source, vocal tract, and airways while the sharpness of the spectral peak is controlled by acoustic losses associated with airway walls.

MULTISITE FLOW-DEPENDENT ANALYSIS OF LUNG SOUNDS IN SUBJECTS WITH AND WITHOUT EMPHYSEMA

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H.C.J. van Klink
E. van Vollenhoven
J.H. Dijkman

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University Hospital Leiden
The Netherlands

This study concerns the development of a new technique for the descriptive investigation of lung sounds in human subjects with and without emphysema. The object is spectral analysis of natural lung sounds in relation to the air flow at the mouth.

The subjects are requested to breathe in a standardized manner into a spirometer with electrical outputs for volume and flow. The lung sounds recorded by four microphones, built in a stethoscope headpiece and attached to well defined locations on the right chest wall, are fd into an amplifier-filter unit. These signals, together with the simultaneously registered flow and lung volume, are fed into an analog-to-digital convertor and stored on hard disk in a PDP11/23 minicomputer. For all sound channels a Fast Fourier Transform is performed. The data have been further processed so that the spectra of corresponding flow values of the separate in- and expirations are averaged. These averages are plotted in a pseudo-3-dimensional diagram showing amplitude vrsus frequency and flow.

The first results in eight subjects indicate that the multisite flow dependent analysis is a suitable technique for the descriptive study of lung sounds in general and in subjects with and without emphysema in particular.

CHARACTERIZATION OF NORMAL LUNG SOUNDS BY AUTOREGRESSIVE MODELING TECHNIQUE.

Y. Ploysongsang
V.K. Iyer
P.A. Ramamoorthy

Departments of Internal Medicine &
Electrical and Computer Engineering
University of Cincinnati Medical Center
Cincinnati, Ohio

Lung sounds were recorded in five normal subjects from the apical area of the heart during both tidal and vital capacity breathing on magnetic tape. The recorded sound signals (heart and lung sounds) were high-pass filtered at 25 Hz and then digitized at KHz and stored for further manipulation. Heart sounds and ambient noise were eliminated from the recorded sound signals to obtain purer lung sounds by an adaptive filtering technique. The pure recorded lung sounds were characterized by an autoregressive analysis. One complete breath from each subject was analyzed. The recorded lung sounds from the chest wall are generated by sound sources in the lung which are modified by the transmission properties of the lung parenchyma and chest wall. The sound sources of normal subjects were found to be white noises. The transmission filter could be approximated by an all-pole filter which had a low-pass character of a roll-off of 6-9 db/octave beyond 50-80 Hz. The filters of the five subjects could be characterized by four partial correlation coefficients 1, 2, 3 and 4 and gains (G) as follows:

Subjects	$\alpha 1$	$\alpha 2$	$\alpha 3$	$\alpha 4$	G
1	-0.9452	0.6210	-0.0420	-0.0142	0.2277
2	-0.9046	0.6613	-0.0230	-0.0886	0.2681
3	-0.8775	0.4635	-0.0503	-0.0956	0.3795
4	-0.7827	0.4333	-0.0541	0.0586	0.4709
5	-0.8015	0.4219	-0.2869	-0.0431	0.6787

The ability to separate and quantify source and transmission filter characteristics should lead to better non-invasive diagnosis of pulmonary diseases using lung sounds because different diseases should affect the source and the filter differently both temporally and spatially.

SESSION D: MODERATORS G. CHARBONNEAU, S. KUDOH

1:00-1:15	BUSINESS MEETING	
1:15-1:35	PITCH PERCEPTION FOR BRIEF SOUND SIGNALS	R. LOUDON R. BAUGHMAN E. WEILER L. FORNER
1:35-1:55	SOUND ENERGY DISTRIBUTION OF CRACKLES ON THE CHEST WALL	F. DALMASSO G. BENEDETTO R. SPAGNOLO
1:55-2:15	PHONOPNEUMOGRAPHIC AND SPECTRAL CHARACTERISTICS OF FRICTION RUBS	H. UKITA Y. HOMMA H. OGASAWARA H. KUSAKA K. TANIMURA N. DENZUMI Y. KAWAKAMI
2:15-2:35	ACOUSTIC ANALYSIS OF CRACKLES ASSOCIATED WITH SQUAWKS	Y. KOYAMA N. SHIOYA N. NARITA A. SHIBUYA S. KUDOH R. MIKAMI
2:35-2:50	COFFEE BREAK	
2:50-3:10	ACOUSTIC CHARACTERISTICS OF EARLY AND LATE INSPIRATORY FINE CRACKLES IN EXCISED CANINE LUNG	N. DENZUMI Y. HOMMA K. TANIMURA H. KUSAKA H. OGASAWARA H. UKITA Y. KAWAKAMI
3:10-3:30	CRACKLE ACOUSTICAL ANALYSIS AND COMPUTED TOMOGRAPHY DENSITY IN INTERSTITIAL LUNG DISEASES	F. DALMASSO G. BENEDETTO M. GENOVESE M. SIRKKA R. SPAGNOLO R. VIOLANTE
3:30-3:50	AUSCULTARY FINDINGS CONSISTENT WITH INTERSTITIAL FIBROSIS (IF) IN PATIENTS WITH PRIMARY BILIARY CIRRHORIS (PBC)	E. Del BONO M. FINKLESTEIN M. KAPLAN R. MURPHY, Jr.
3:50-4:20	CRACKLEFEST	
4:20-4:50	SUMMARY	D. CUGELL

PITCH PERCEPTION FOR BRIEF SOUND SIGNALS

Robert G. Loudon
Robert P. Baughman
Ernest M. Weiler
Linda L. Forner

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Departments of Internal Medicine and Communication
Cincinnati, Ohio

At the 1st International Lung Sounds Conference, Forgacs demonstrated the loss of perceptible pitch which occurred when the duration of a pure tone sound signal was reduced below about 20 msecs. The pure tone suddenly became a click with no perceptible pitch. Consideration of brief squeaking sounds heard occasionally on chest auscultation led us to ask whether high-frequency tones of short duration might be recognized as having pitch but lower frequency tones of similar duration might not. Preliminary tests suggested that reduction in duration of a sine-wave sound signal led first to reduction in purity of the perceived tone, then subsequently with further reduction in signal duration to a loss of any perceptible pitch. Pure tones of several selected frequencies (200, 500, 1000, and 1500 Hz) were presented to subjects who controlled the duration of tone bursts between 1 and 60 msecs by rotating a knob. The sound pips were repeated at a rate of 10 per second. For each frequency in random order the subject was asked first to select the signal duration at which the purity of tone began to deteriorate, then the duration at which the signal lost any perceptible pitch, becoming a click rather than a tone. For each selection, the subject was encouraged to lengthen and shorten the duration until he was satisfied with his choice, which was measured without his being aware of the results.Reduction in pitch purity and loss of pitch perception both tended to occur at shorter durations with higher frequency tones. This corresponds to smaller proportional difference frequency limens reported for higher frequency short-duration tones (e.g. by Freyman and Nelson, J Acoust Soc Ann 1986; 79:1034). Pitch perception is possible, at least for some subjects, for 10 msec tones with frequency content above 500 Hz.

SOUND ENERGY DISTRIBUTION OF CRACKLES ON THE CHEST WALL

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It is known that already on auscultation the acoustical characteristics of adventitious sounds,and particularly of crackles, considerably change when changing the detection site. This paper reports some experimental results on crackle distribution on the chest wall. Three microphones are simultaneously used, arranged in three different subsequent configurations. The results refer to measurements on patients with the clinical features of interstitial lung disease and chronic obstructive lung disease.The details of the measurement method were already described by the authors. The sound signal was analyzed as a function of time,simultaneously with respiratory airflow.Similar and different features were determined among the acoustical signals detected at different sites. In some cases crackles occurring at the same time were identified, allowing some considerations on crackle generation mechanism. A better definition of the sound radiating areas can be achieved by means of the relative sound energy values, in dB, assuming as a reference value the sound energy emitted during inspiration at the site with higher acoustic radiation. The technique seems to be an efficient method to objectively describe the acoustical characteristics of crackles and in particular to locate the areas with higher sound radiation. This technique can also be usefully applied in following-up the disease evolution.

PHONOPNEUMOGRAPHIC AND SPECTRAL CHARACTERISTICS OF FRICTION RUBS

H. Ukita
Y. Homma
H. Ogasawara
H. Kusaka
K. Tanimura
N. Denzumi
Y. Kawakami

Pleural friction rubs are sometimes experienced at bedside, but have not fully been analyzed from the acoustic viewpoint. So we analyzed friction rubs from ten patients, which were differently audible from fine or coarse crackles on auscultation. Most of the patients were revealed to have pleural changes by chest x-ray examination.

The timing of the rubs in inspiratory and expiratory periods was examined in 5 respiratory cycles. Rubs occurred mainly in mid-inspiratory and early-expiratory periods. But the timing and number of these rubs occurred variably in 5 consecutive respiratory cycles of each patient.

DID (the direction of the initial deflection of the wave forms) distribution was investigated in 7 subjects. DID of each rub randomly distributed in upward and downward direction in contrast to those of fine or coarse crackles.

Spectral analyses were performed using the Fast Fourier transformation (FFT) algorithm. Peak frequency and maximal frequency (the frequency at 1/100 of peak power) of ten sounds from each patient were determined. Peak frequencies of friction rubs in inspiratory and expiratory periods were 239 ± 100 (mean$\pm$SD, n=100) and 252 ± 82 (n=40) Hz respectively, and maximal frequencies were 670 ± 197 (n=100) and 671 ± 220 (n=40 Hz) respectively. Average peak frequency was approximately same as that of coarse crackle, but average maximal frequency was between that of coarse and fine crackles.

From these results, those parameters such as timing, DID, and frequency may distinguish friction rubs from pulmonary crackles.

ACOUSTIC ANALYSIS OF CRACKLES ASSOCIATED WITH SQUAWKS

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2 - Research Institute for Polymers & Textiles, Yatabe, Ibaragi
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4 - National Sagamihara Hospital, Sagamihara, Kanagawa

Last year, we reported that squawks always were associated with crackles. In this study, we analyzed the acoustic characteristics of crackles associated with squawks for clarifying the mechanism of production of squawks. Squawks and crackles were recorded in seventeen patients with interstitital lung diseases (7 with asbestosis, 6 with collagen diseases, 2 with hypersensitivity pneumonia, and 2 with idiopathic interstitial pneumonia), and twelve with other lung diseases (4 with pulmonary tuberculosis, 4 with bronchiectasis, 3 with diffuse panbronchiolitis, and 1 with pneumonia). We analyzed crackles existing before and after squawks by time-expanded wave-form analysis and examined the acoustic characteristics of individual crackle. We also studied the relationship between the characteristics of crackle and the pitch of squawk. Results were as follows:

1) Crackles associated with squawks were distributed widely from "fine" to "coarse" crackles, and could not be divided into two groups.

2) There was no significant relationship between the acoustic characteristics of crackle and the pitch of squawk.

ACOUSTIC CHARACTERISTICS OF EARLY AND LATE INSPIRATORY FINE CRACKLES IN EXCISED CANINE LUNG

N. Denzumi
Y. Homma
K. Tanimura
H. Kusaka
H. Ogasawara
H. Ukita
Y. Kawakami

In our previous study using atelectatic lung lobes, we noted that fine crackles occurred not only in "late inspiratory" period but in relatively "early inspiratory" period, and that acoustic characteristics of these two kinds of sounds seemed to be different. So we analyzed both kinds of sounds from three mongrel dogs.

Recorded lung sounds were high-pass filtered above 50 Hz, and Tb, Tf and FFT analyses were done using our phonopneumograph and FFT analyzing system. In this experiment only late inspiratory crackles were heard at slight atelectasis (Group-1). Early inspiratory crackles were also heard in addition to the late inspiratory crackles as the severity of atelectasis increased. In the last case, the sounds were classified into two groups; Group-2: the sounds occurred in a first 30% of whole inspiratory period; Group-3: the sounds except for Group-2 sounds.

The results were obtained as follows:

	Group-1	Group-2	Group-3
N	42	24	58
PF (Hz)	795 ± 194*	554 ± 132	854 ± 254*
MF (Hz)	2514 ± 591*	1775 ± 577	2697 ± 622*
N	14	76	171
Tb (msec)	0.23 ± 0.07*	0.34 ± 0.12	0.29 ± 0.1*
N	2	20	59
Tf (msec)	2.1	3.7 ± 0.99	2.5 ± 0.69*

(mean±SD)

Scheffe's one way ANOVA test. All comparisons are referred to Group-2. * P<0.01.
PF: Peak frequency, MF: Maximal frequency (the frequency at 1/100 of peak power).
Tb: 1/4 cycle duration, Tf: 9/4 cycle duration.

We examined fine crackles from three IPF patients as well. From these results we supposed the difference of physiological backgrounds when early or late inspiratory crackles occur. We will discuss the results in detail.

CRACKLE ACOUSTICAL ANALYSIS AND COMPUTED TOMOGRAPHY DENSITY IN INTERSTITIAL LUNG DISEASES.

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** Istituto Elettrotecnico Nazionale Galileo Ferraris, Torino.

16 patients with Cryptogenic Interstitial Lung Disease (CILD) and 7 with Sarcoidosis were scanned by torax Computed Tomography (CT).The mean lung density (MLD), according to Rosemblum,and also the mean values of 3 areas for each base were measured. Two physicians performed auscultation of fine repetitive crackles and these were scored conventionally from 1-5. In all patients crackles were recorded with one electret microphone at the right base together with airflow at the mouth. In three CILD patients crackles were also recorded with three simultaneous microphones arranged in three different successive configurations. The signals are then computer analyzed for timing, waveform and frequency spectrum of crackles. To quantify the informative content of the crackles,time variation of the sound energy emitted over a whole inspiratory phase were represented as $E(t)=\int_0^t p^2(\tau)d\tau$ where p is the sound pressure. Linear regression analysis,r and Spearman coefficients were applied. There is, for CILD patients,close significant correlation of the mean density values for lateral and posterior-basal areas and crackle score at the same sites ($p<0.001$).We found none or inverse correlation for density and crackle score of 7 Sarcoidosis.Moreover we generally found a good agreement between ausculatation and objective crakle description and particularly between physicians' crakle score value and relative sound energy values at the bases.The data suggest that the recorded crackle map may be an objective, non invasive, repeatable tool for evaluating ILD.

AUSCULTATORY FINDINGS CONSISTENT WITH INTERSTITIAL FIBROSIS (IF) IN PATIENTS WITH PRIMARY BILIARY CIRRHOSIS (PBC)

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To determine whether patients with PBC had evidence of IF we examined x-ray findings, performed pulmonary function studies and studied the lung sounds in 23 patients with PBC. For comparison, similar studies were performed in 22 patients with cirrhosis from other causes (OC). Lung auscultation was performed at 50 chest sites on each patient. Sites positive for crackles (rales) were recorded and subjected to time expanded waveform analysis. Time intensity plots of sounds were made that allowed specific waveform characteristics of sounds to be measured and interpreted blindly (e.g. without knowledge as to the presence of PBC or OC). Spirometric patterns consistent with obstruction were similar in the two groups: 17.4% in PBC, 18.2% in OC. Patterns consistent with restriction alone, however, were read in 8.7% of the PBC patients and in 36.4% of the OC group. Restriction in the OC group was associated with ascites in 87.5% of cases; none of the patients with PBC and restriction had ascites. Evidence of irregular opacifications consistent with IF was found in 1 PBC patient and 2 OC patients. The number of patients with three or more sites positive for fine crackles was significantly greater with PBC than in patients with OC (65.2 vs 22.7). Although a control group without liver disease needs to be studied, our preliminary findings are consistent with the hypothesis that patients with PBC have evidence of mild degrees of IF not readily detectable by roentgenogram or spirometric analysis.

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