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Chicago

THIRTEENTH INTERNATIONAL CONFERENCE
ON LUNG SOUNDS

第13回国際肺音学会

SEPTEMBER 14-16, 1988

HOLIDAY INN CHICAGO CITY CENTER
CHICAGO, ILLINOIS

PRESENTED BY
INTERNATIONAL LUNG SOUNDS ASSOCIATION

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13th International Conference on Lung Sounds

Chicago, Illinois

Program

Thursday, September 15, 1988

Registration	8:30 AM
Welcome - Dr. David Cugell	9:00 AM
Keynote Address - Dr. Hans Pasterkamp	9:15 AM
Session A - Dr. Riichiro Mikami and Dr. Sadamu Ishikawa, Chairmen	9:30-11:45 AM
Lunch	11:45-1:00 PM
Session B - Dr. Will Waring, Chairman	1:00-4:20 PM

Friday, September 16, 1988

Session C - Dr. Masashi Mori and Dr. David Cugell, Chairmen	9:00-11:20 AM
Debate	11:20-12:00 N
Lunch	12:00- 1:15 PM
Session D - Dr. Robert Loudon and Dr. Filiberto Dalmasso, Co-Chairmen	1:15 - 4:30 PM
Cracklefest	3:00 - 3:15 PM
Business Meeting	3:15 - 4:00 PM
Summary - Dr. Wilmot Ball	4:00 - 4:30 PM

Session A

Dr. Riichiro Mikami and Dr. Sadamu Ishikawa
Co-Chairmen

9:30 - 9:50	Global analyses of crackles using digital filters	M. Ono K. Arakawa M. Igucih T. Nagata T. Horiuchi T. Hisada H. Kino M. Mori T. Sugimoto H. Harashima
9:50 -10:10	An advanced system for computer analysis of lung sounds	A. Sovijarvi S. Haltsonen T. Kaisla T. Katila P. Piirila M. Raivio T. Rosqvist
10:10-10:30	Description of adventitious lung sounds by respiratory care practitioners	R. Wilkins J. Dexter M. Smith A. Marshak
10:30-10:45	Coffee Break	
10:45-11:05	Interpreting the subjective evaluation of crackles as "fine" and "coarse"	G. Benedetto F. Dalmasso R. Piazza R. Spagnolo
11:05-11:25	Dynamic phenomenon of the flow between parallel plates	Y. Ploysongsang P. Siribothi
11:25-11:45	The natural frequency of the tracheal model	P. Siribothi Y. Ploysongsang
11:45- 1:00	Lunch	

GLOBAL ANALYSES OF CRACKLES USING DIGITAL FILTERS

Mariko Ono(1), Kaoru Arakawa(2), Mari Iguchi(1)
Taiji Nagata(1), Tadashi Horiuchi(1), Tetsuya Hisada(1)
Hiroyoshi Kino(3), Masashi Mori(3), Tsuneaki Sugimoto(1)
Hiroshi Harashima(2)

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(3) Pulmonary Center, Mitsui Memorial Hospital.

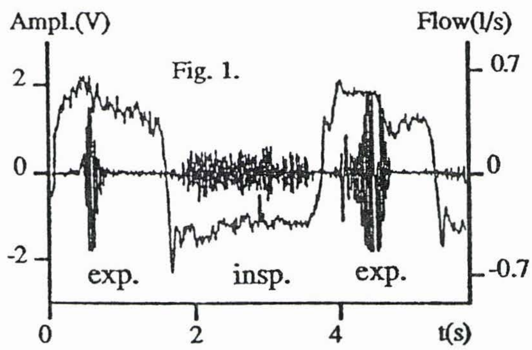
We have been using a nonlinear filter, stationary-nonstationary separating filter, for the separation of crackles from vesicular sounds. This time we applied this filter to the ·lobal analyses of crackles, which include counting the numbers, detecting the timing of their occurrences and estimating the distribution of IDWs; all of them being known to be useful in the classification of crackles. Lung sounds containing crackles were recorded from 14 patients, passed through the stationary-nonstationary separating filter, and then processed using digital filters suitable for these purposes. The results were compared with the findings of auscultaion and visual time expanded wave form analysis.

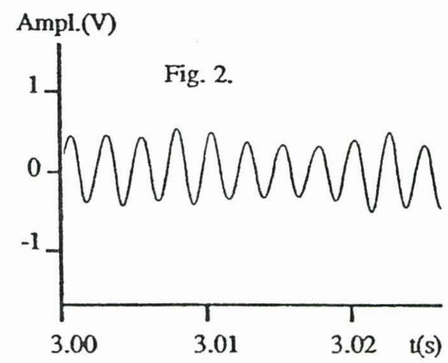
AN ADVANCED SYSTEM FOR COMPUTER ANALYSIS OF LUNG SOUNDS

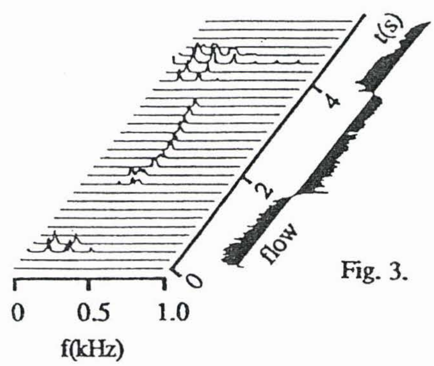
A. Sovijärvi[1], S. Haltsonen[2,3], T. Kaisla[2], T. Katila[2], P.Piirilä[1], M. Raivio[2], and T. Rosqvist[2]

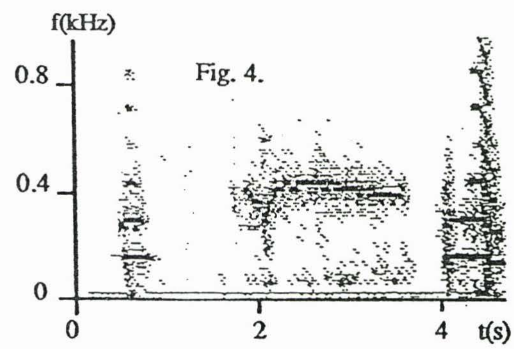
[1]Helsinki University Central Hospital, Pulmonary Function Lab., 00290 Helsinki
[2]Helsinki University of Technology, Departm. of Technical Physics, 02150 Espoo
[3]Espoo-Vantaa Institute of Technology, 02600 Espoo, Finland

We describe a system for recording lung sounds and analyzing them in time and frequency domains. Measurements are made with two microphones and a pneumotachograph in an acoustically shielded room. Lung sound and flow signals are filtered, amplified and recorded on magnetic tape. The data is then transferred via an A/D converter to an HP 9000/330C UNIX workstation. The analysis software is menu-driven and mouse-controlled. Unprocessed sound and flow signals can be displayed (Figs. 1 and 2; the data are from a patient with paresis of vocal cords). Relevant parameters, such as sound and flow amplitudes, can be measured with a cursor. The time development of the frequency spectrum is visualized by means of 30 consecutive FFTs displayed one above the other (Fig. 3). Sequential spectra can be averaged. Finally, a sonagram display with user-definable frequency resolution is available (Fig. 4). We are presently developing software for more automated analysis of lung sounds.









DESCRIPTION OF ADVENTITIOUS LUNG SOUNDS BY RESPIRATORY CARE PRACTITIONERS

Wilkins, R.L., Dexter, J.R., Smith, M.P., and Marshak A.B.

Communication between health care professionals would be facilitated by precise and uniform descriptions of adventitious lung sounds (ALS). The International Lung Sounds Association and the American College of Chest Physicians (ACCP)/ American Thoracic Society (ATS) Ad Hoc Committee on Pulmonary Nomenclature have made recommendations toward this goal. At the 1987 American Association of Respiratory Care convention, 156 respiratory care practitioners (RCPs) and 13 physicians were surveyed for biographical data and asked to describe 5 examples of ALS heard through earphones of an audiocassette tape player. Examples included: 1) crackles typical of pulmonary fibrosis; 2) crackles typical of airway secretions; 3) wheeze typical of asthma; 4) low-pitched wheeze typical of partial large bronchus obstruction; 5) high-pitched wheeze typical of partial upper airway obstruction. Results of the RCP responses:

Term	Ex.1	Ex.2	Ex.3	Ex.4	Ex.5
Rales	49%	22%	3%	4%	1%
Crackles	27%	10%	0%	1%	0%
Rhonchi	5%	39%	8%	30%	3%
Wheeze	0%	0%	76%	15%	29%
Stridor	0%	0%	2%	6%	55%

Qualifying adjectives were used to describe the ALS by approximately 30% of RCPs for examples 1-4 and by 10% of RCPs for example 5. A large variety of qualifying adjectives were used for each example. West Coast RCPs described example 1 with the term "crackles" more commonly than East Coast RCPs (p=.015). Conclusions: 1) terms "rales" and "crackles" are used interchangeably and almost exclusively for discontinuous ALS with "rales" being used almost twice as frequently as "crackles"; 2) the term "rhonchi" which was used for both continuous ALS and discontinuous ALS is imprecise and should be abandoned; 3) polyphonic wheezes (ex. 3) were more uniformly described than monophonic wheezes (ex. 3 & 4); 4) qualifying adjectives are infrequently and imprecisely used; 5) west coast RCPs follow ACCP/ATS recommendations more frequently than East Coast RCPs in describing discontinuous ALS; 6) comparison of RCP responses with the physicians demonstrates physician use of terminology similar to that of west coast RCPs.

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INTERPRETING THE SUBJECTIVE EVALUATION OF CRACKLES AS "FINE" AND "COARSE"

G. Benedetto, F. Dalmasso*, R. Piazza**, R. Spagnolo

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* Servizio di Pneumologia, Ospedale Mauriziano Umberto I, Torino
** Istituto di Fisiologia e Chimica Biologica dell'Universita', Torino

One point in the classification of crackles which is still debated is the relation between objective parameters of the sound signal and subjective pitch evaluation. More exactly, according to some authors the different pitch is connected to a different duration of the half-periods of crackle waveforms while other authors assert that the signal should be considered on the whole, as crackles of a certain duration separated by periods of "silence", in a more or less regular sequence. The research in progress has the purpose to detect a method to objectively characterize the crackling sound signal, which simulates the hearing behaviour. As a first phase 97 inspiratory crackles were considered from 5 patients with fibrosing alveolitis and 71 inspiratory crackles from 6 patients with chronic obstructive lung disease. The crackles were selected among the ones most identifiable, repetitive and with larger amplitude in successive respiratory cycles. It is well known that a tone should last a minimum number of cycles in order to be perceived as having a definite tonal quality. In the case of crackles, whose spectrum has a maximum at frequencies in the range 200 - 400 Hz, about 3 or 4 waves are required. Crackle waveforms usually do not last for such a number of waves. As to the period of "silence" between different crackles, the impulses are considered as separated by hearing only if this period is longer than 50 ms. In a more general approach one should take into account that the auditory apparatus behaves like an integrating circuit, with a time constant approximately equal to the impulse duration (the standardized values of 35 ms, which we used previously, seems therefore too large). A further step of this research will concern subjective tests, in which computer generated impulsive noises (with a waveform similar to crackle's) will be presented to normally-hearing subjects, alternatively to tones with adjustable frequency and normalized duration, long enough to give a stable tonal quality. So, it will be possible to change continuously the signal parameters (rise time, duration, amplitude, period of "silence") and to verify their influence on the subjective judgement.

DYNAMIC PHENOMENON OF THE FLOW BETWEEN PARALLEL PLATES

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Pongvit Siribothi

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The dynamic behaviour of thin-wall plates conveying fluid is studied with an emphasis on the effects of the flow which distributes its pressure along the wall. The physical and mathematical models are developed by setting two parallel plates supported by four simple fixed pin joints. The fluid is assumed to be a two-dimensional ideal fluid. Its properties are governed by the Continuity equation (Conservation of mass equation) and Bernoulli's equation. The plate displacement is expressed by a plate bending equation. The Galerkin method is used to solve these Couple partial differential equations. The solution of the critical velocity (the minimal velocity required to set a structure into vibration) of only two significant vibration conditions: in-phase and 180°-out of phase conditions, is carried out. The results, using the selected material : trachea, wall thickness .05 cm., length 15 cm., Young's modulus of plate 5 x 10^3 Pa, Poison ratio 0.5, density of plate 1121 Kg/m^3, and density of fluid 1.206 Kg/m^3 (air at 20° c, 1.013 bar), show that if the in-phase condition is considered, the critical velocity increases without limitation as the plates come very close together. On the other hand, for the 180°-out of phase condition, the critical velocity occurs at very low values. Thus, it is expected that the plates will collapse or flap in the 180°-out of phase condition, rather than in-phase condition. The 180°-out of phase condition critical velocity is found to be .12 cm/sec - .17 cm/sec. Using the normal tidal flow rate of 0-1 l/sec., the Weibel's total cross section area of the 22nd generation airway (5,880 cm^2), and this critical velocity, we predict that oscillation of the bronchial wall is possible along the whole tracheobronchial tree. If breath sounds are produced by airway's wall vibration, this result suggests that breath sounds can be generated in airways as peripheral as the 22nd generation.

THE NATURAL FREQUENCY OF THE TRACHEAL MODEL

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The natural frequency is a frequency at which a system will vibrate with an infinite amplitude when excited at this frequency. This violent response will lead to a definite destruction of the system. This study is designed to determine the natural frequency of an airway model.The natural frequency of thin-walled plates conveying fluid is mathematically modeled by an inviscid, incompressible fluid flowing through a finite, two-dimensional, flexible channel. The fluid properties are governed by the Continuity equation (Conservation of mass equation) and the Bernoulli's equation. The fluid pressures are determined by using the Potential Flow theory. The plate displacement is expressed by a plate bending equation. The Galerkin method is used to solve these Couple partial differential equations. Only first two vibration modes with two conditions : in-phase and 180°-out of phase, are examined. The results, using the selected material : trachea, wall thickness .05 cm., length 15 cm., Young's modulus of plate 5×10^3 Pa, Poison ratio 0.5, density of plate 1121 Kg/m^3 , and density of fluid 1.206 Kg/m^3 (air at 20°c, 1.013 bar), show that when the plates are in phase, the natural frequencies of the plate decrease as the mass of the fluid between them reduces. On the other hand, when the plates are out of phase, its natural frequencies increase ,when the mass of the fluid between them decreases. These natural frequencies are very low (2-7 Hz) when compared with the frequencies of free vibrations of the tracheobronchial tree (400-1700 Hz) as determined by Martini and Mueller (Deutsches Arch. f. klin. Med. 143:159,1923). This suggests that the human airway is very safe from self-destruction when it vibrates during breathing.

Session B

Dr. Will Waring, Chairman

1:00 - 1:20	The prevalence and characteristics of acquired clubbing	R. Baughman E. Lower E. Fara
1:20 - 1:40	Experimental demonstration of pleural crackling sounds in canine	H. Ukita Y. Ohtsuka K. Tanimura H. Kusaka N. Denzumi Y. Masaki M. Munakata Y. Homma Y. Kawakami
1:40 - 2:00	Time-expanded wave-form and spectral characteristics of snores in a dog model of upper airway obstruction	R. Beck N. Gavriely
2:00 - 2:20	Reproducibility and validity of measurements of crackles	J. Hoevers R. Loudon
2:20 - 2:40	Coffee break	
2:40 - 3:00	Contour maps of auscultatory percussion in healthy subjects and patients with large intra-pulmonary lesions	A. Bohadana R. Patel S. Kraman
3:00 - 3:20	Monitoring respiration in intubated patients	M. Mori M. Ono M. Iguchi S. Kudoh H. Kino T. Nagata T. Tooda T. Sugimoto H. Matsuki
3:20 - 3:40	The amplitude modulation stethoscope - Tuning in to low frequency lung sounds	H. Pasterkamp D. Daien
3:40 - 4:00	Normal breath sounds in childhood	H. Hidalgo M. Wegmann W. Waring
4:00 - 4:20	Lung sounds of healthy premature and term newborns	E. Slawinski D. McMillan

THE PREVALENCE AND CHARACTERISTICS OF ACQUIRED CLUBBING.

Baughman RP, Lower, EE, Fara EF. University of Cincinnati Medical Center, Cincinnati, Ohio.

Previous estimates of the prevalence of clubbing in patients with lung cancer are of questionable accuracy due to subjective techniques used to establish the presence of clubbing. We objectively examined the digits of subjects with lung cancer and compared these values to normal subjects. A method of quantifying clubbing has been described in which the thickness of the finger at the base of the nail (DPD) and the thickness of the finger at the distal interphalyngeal joint (IPD) are measured with calipers (Waring et al, Am Rev Respir Dis 1971; 104:166). A DPD/IPD ratio of greater than one is found in clubbed individuals. The DPD/IPD ratio is independent of age, sex, and race. We determined the ratio in 25 unselected normal subjects; only one had a ratio of more than 1. Of the 50 patients with lung cancer studied, 16 (32%) had a ratio more than 1. In 42 patients, a particular cell type for the lung cancer was identified. The percentage of clubbed individuals was similar in all three groups (SQUAMOUS CELL: 3 of 13 were clubbed; ADENOCARCINOMA: 5 of 15 were clubbed; SMALL CELL: 4 of 14 were clubbed). In order to better understand the mechanism of acquired clubbing, we performed capillaroscopy on the fingers of two lung cancer patients with clubbing, 7 patients with acquired clubbing due to other causes, and 9 control subjects. Examination of the capillary nail bed showed marked differences between the clubbed and normal subjects. The clubbed individuals had a marked increase in the number and the distance from the nail bed of the capillary loops. The individual capillary could have many branches, rather than one loop (arborization). The loops could also be splayed. Photomicrographs of the capillaroscopy examinations of each finger were read and scored standardly with respect to the extent of plexus formation, presence of arborized loops, and the presence of splayed loops. Comparison of the extent of plexus, presence of arborized loops, and presence of splayed loops were significantly different between the clubbed and non-clubbed groups ($p<0.001$ in all three analysis). We conclude that acquired clubbing is a relatively frequent finding in all forms of lung cancer, regardless of cell type, and that acquired clubbing due to cancer or other processes appears to be due to increased number and flow of capillary loops of the nail bed, which can easily be quantitated by capillaroscopy.

EXPERIMENTAL DEMONSTRATION OF PLEURAL CRACKLING SOUNDS IN CANINE:

HIDEAKI UKITA, YOSHINORI OHTSUKA, KAZUNORI TANIMURA, HIROTAKA KUSAKA, NAOMI DENZUMI, YOSHITAKA MASAKI, MITSURU MUNAKATA, YUKIHIKO HOMMA, YOSHIKAZU KAWAKAMI 1st. Dep. Int. Med. School of Medicine, Hokkaido University. 060 Sapporo, Japan.

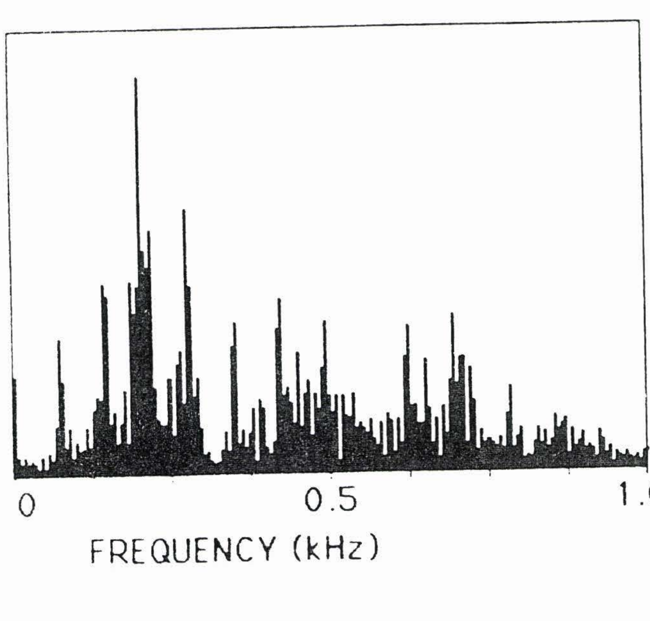
Last year, we reported that crackling sounds were detected in patients with pleural lesions. Phonopneumographic and spectral characteristics of these crackling sounds were quite similar to those of pulmonary crackles. Although roentgenological abnormalities of the lung adjacent to pleural lesions in these patients were not prominent, there was a possibility that these sounds were produced not by pleural lesions but by lung parenchyma. So, whether simple pleural lesions can produce crackling sounds similar to pulmonary crackles is still an open question. In this study, we made artificial pleural lesions only in the limited area of parietal pleura of the dog. Sounds were detected from the surface of the chest wall after surgical procedures under the closed chest condition. At the end of experiment, sounds were also recorded directly from the surface of the lungs located just beneath the artificial pleural lesion.

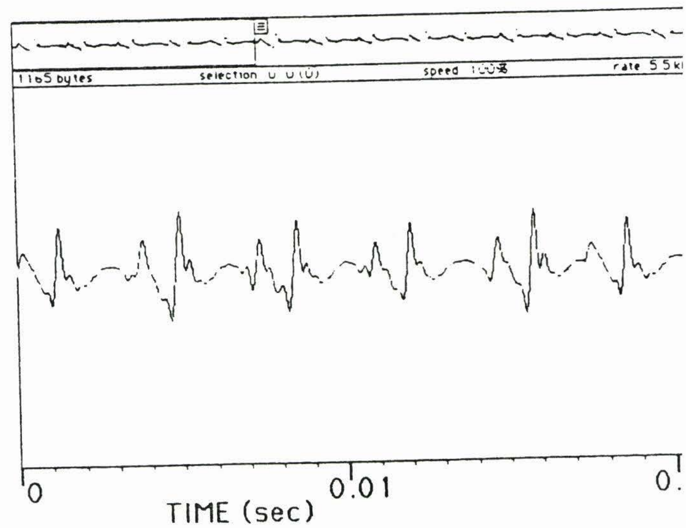
Crackling sounds (with or without leathery sounds) were detected during late inspiratory and early expiratory phases over a small area of the chest wall just above the pleural lesion. In the fast Fourier transformation (FFT) analysis, the peak frequencies of the pleural crackling sounds in inspiratory and expiratory phases were 302 ± 81 Hz (mean$\pm$SD) and 269 ± 66 Hz, respectively, and maximal frequencies (frequencies at 1/100 of the peak power) were 800 ± 194 Hz and 732 ± 88 Hz, respectively. No crackling sounds was detected directly from the surface of the lung.

From these results we concluded that crackling sounds can be produced from simple pleural lesions and their spectral characteristics are similar to those of crackles. Clinically, more precise understanding and detection of these sounds may be important in diagnosis and interpretation of pathophysiology of the patients with pulmonary diseases.

TIME-EXPANDED WAVE-FORM AND SPECTRAL CHARACTERISTICS OF SNORES IN A DOG MODEL OF UPPER AIRWAY OBSTRUCTION. Raphael Beck, MD (1) and Noam Gavriely, MD, D.Sc. (2).
(1) The University of Calgary, Department of Pediatrics, Alberta Children's Hospital, 1820 Richmond Road SW, Calgary, Alberta, Canada.
(2) Technion-Israel Institute of Technology, Department of Physiology and Biophysics, Faculty of Medicine, The Rappaport Institute for Research in the Medical Sciences, P.O.B. 9677, Haifa, Israel.

Snoring is considered an important sign of upper airway obstruction during sleep and many studies have shown its close association with obstructive sleep apnea (OSA). The coarse inspiratory sound is thought to be generated by flapping and oscillation of the soft tissues above the glottis. Five dogs had an upper airway obstruction created by implantation of a soft rubber balloon under the mucosa of the hypopharynx just above the glottis. Varying degrees of obstruction were created by inflating the balloon with increasing amounts of air. We measured tracheal air flow, transpulmonary pressure, EMG of pharyngeal muscles and blood pressure. Respiratory sounds were recorded over the trachea, 2-3 cm below the larynx, via a HP 21050A contact sensor. The sound was amplified (x10), high-pass (50Hz) and low-pass (2000Hz) filtered, digitized (8 bit A/D converter, sampling rate 5.5 kHz), and stored in a computer. Analysis was performed off-line with a MacIntosh SE computer (SoundCap/TM and SoundWave/TM software). Snoring sounds were identified by playback, isolated, and studied in time and frequency domains. We found the main feature of snores to be repetitive complex wave-forms, consisting of 3-5 waves and spikes. The shape of these wave-forms differed from dog to dog and also changed with varying obstructions. They were, however, distinctive and constant during each run of snores. Spectral analysis showed all these different wave-forms to exhibit a similar pattern, consisting of multiple, close set, comb-like spikes. The spikes spread over a frequency range starting at 50-100Hz and up to 400-600Hz. We compared this data to snores recorded in the sleep lab from a patient with OSA and to simulated snores produced by one of the investigators. Similar wave-forms were found with identical spectral characteristics. More work is needed to relate these acoustic findings to flow pattern and tissue motion in the upper airways during OSA.



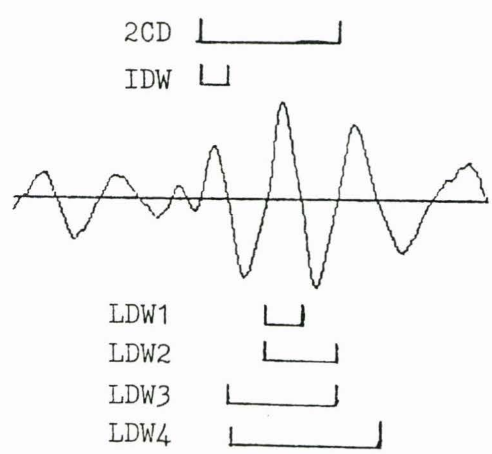


REPRODUCIBILITY AND VALIDITY OF MEASUREMENTS OF CRACKLES

J. M. Hoevers
R. G. Loudon

Departments of Medicine, University of Leiden and University of Cincinnati

The measurements most commonly reported for individual crackles are the Initial Deflection Width (IDW) and the Two Cycle Duration (2CD). Both measurements are based on decisions about the point at which the crackle wave-form starts. Suspecting that the initial deflection of a crackle is less easily and less reproducibly identifiable than the largest deflection, both by human observers of wave-forms and by electronic devices, we compared measures based on the IDW and those based on the Largest Deflection Width (LDW). Sixty-four coarse and 64 fine crackles from a teaching tape were selected for analysis, digitized at 10,000 samples per second, and stored in computer memory. They were then presented in random order as time-expanded wave-forms on a computer screen to the observer, who used a cursor to select the initial deflection. Placing the cursor before the initial deflection and pressing a soft key caused the measurement of the next twelve zero crossing intervals and peak (or trough) voltages, and their storage in memory. The largest of the twelve voltages (in absolute value) was used to define the LDW, and the zero crossing intervals for 1,2,3, and 4 half-cycles adjacent to the LDW were measured and stored, as LDW1, LDW2, LDW3, and LDW4. IDW and 2CD were also measured and recorded for each crackle. Six measures were compared for reproducibility (inter-and intra-observer) and ability to distinguish coarse from fine crackles.



The four measurements related to largest deflection width were very similar to one another in reproducibility and in discriminating power, so LDW1 was used, renamed LDW, and the other three measurements (LDW2, LDW3, and LDW4) were not considered further. As expected, LDW was more reproducible than either IDW or 2CD. The greater capacity of LDW to classify crackles correctly as fine or coarse was unexpected; of 512 measurements, LDW correctly classified the crackles in 440 cases (86%), IDW in 298 cases (58%), and 2CD in 417 cases (81%).

CONTOUR MAPS OF AUSCULTATORY PERCUSSION IN HEALTHY SUBJECTS AND PATIENTS WITH LARGE INTRA-PULMONARY LESIONS.

Abraham B. Bohadana, R. Patel and Steve S. Kraman

V. A. Medical Center and Department of Medicine, University of Kentucky, Lexington, Kentucky.

Auscultatory percussion of the chest is a clinical examination method purported to detect intra-pulmonary masses by their effect on the transmission of the percussion note to the posterior chest. Recent findings from this laboratory have suggested to us that the sound of sternal percussion may actually travel through the chest cage more than the lung parenchyma. In order to investigate this possibility, we recorded the sound of sternal percussion at 63 evenly spaced points over the posterior chest wall of three healthy subjects and four patients with large, discrete intrathoracic lesions situated in the right upper lobe (two patients), left lower lobe and left upper lobe (one patient each). We constructed tri-dimensional contour maps of indices of sound amplitude and frequency to graphically view the pattern of distribution of the sound. Examination of the maps revealed areas of increased amplitude in the zones of projection of osseous structures, especially the scapulae, both in the healthy subjects and in the patients. No disturbances in the pattern reflecting the presence of mediastinal structures or intrathoracic lesions were found despite the existence of lung masses as large as 10 cm diameter. Our findings suggest that the sound of sternal percussion predominantly travels to the posterior chest wall through osseous structures and not through the lung.

MONITORING RESPIRATION IN INTUBATED PATIENTS

M. Mori, M. Ono, M. Iguchi, S. Kudoh
H. Kino, T. Nagata, T. Tooda, T. Sugimoto, H. Matsuki

In intubated patients it is important to keep the airway clear by suctioning whenever sputum accumulates. However, for the nurses and doctors it is not always easy to decide how often or when to suction because they have to take care of other patients who also need close attention. The purpose of this study is to monitor the state of respiration in intubated patients who are on respirators without the use of a stethoscope at the bedside.

A small wireless microphone (3.3 mm x 8 mm, RION) was attached to the intubated endoctracheal tube firmly by adhesive tape. The output from the microphone was received at the nurses station where the sound from the speaker was monitored and recorded on a tape recorder when necessary. Though the number of patients studied to date is still small it was possible, even for less experienced nurses to decide when to suction. It is expected that our method may become a routine method of monitoring respiratory status in critically ill patients.

THE AMPLITUDE MODULATION STETHOSCOPE*

Tuning in to low frequency lung sounds

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A significant proportion of lung sounds is contained in the frequency range below 100 Hz. The human ear is limited in its ability to perceive sounds this low, particularly when they are of low intensity. We therefore developed a system which transposes low frequency lung sounds to a higher frequency range in order to increase their audibility. Breath sounds are first low pass filtered at 100 Hz, using a six-pole low pass filter with a 36 dB per octave attenuation in the stop band. The filtered breath sounds are then amplitude modulated at 300 Hz with carrier level suppression. The carrier frequency is empirically chosen to present the frequency shifted sounds close to the commonly perceived range of lung sounds (200 to 400 Hz). The carrier is suppressed so that the 300 Hz tone is not constantly heard and to ensure that no noise is perceived in the absence of breath sounds. Preliminary observations in normal subjects indicate that respiration related sounds below 100 Hz are clearly audible with this stethoscope both over the lung (right lower lobe posteriorly) and trachea (suprasternal notch). Over the lung, frequency shifted respiratory sounds were significantly louder during inspiration than during expiration, whereas this distinction was not as clear over the trachea. We will present additional data on the application of this new stethoscope to patients with respiratory diseases.

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

NORMAL BREATH SOUNDS IN CHILDHOOD. H.A. Hidalgo, M.J. Wegmann, and W.W. Waring, Department of Pediatrics, Tulane University Medical School, 1430 Tulane Avenue, New Orleans, LA 70112

We have recorded the breath sounds of 33 normal children (ages 0.1-12.9 years) during tidal breathing. Breath sounds were recorded from the right lower lobe while the subjects were erect and quiet in a sound insulated room. Thoracic impedance was recorded simultaneously to determine the phase of the ventilatory cycle. Breath sound signals were pass-filtered between 100-2000 Hz, and those free of acoustic artifacts were selected to be analyzed further. The sound and impedance signals were digitized and 10 inspiratory segments of up to 1 second were transformed from the time to the frequency domain. The individual frequency spectra were displayed and averaged.

We have shown that this technique of measuring breath sound frequency spectra is reproducible and have used it to measure the range of inspiratory spectra of childhood breath sounds. We calculated the frequencies F25, F50, F75, and F95 that define the limits of 25, 50, 75, and 95% of the amplitude in the amplitude-frequency spectra, respectively, and found that from 0.1 to 12.9 years of age there is a gradual linear decrease in all these frequency parameters. These data are useful because they define the frequencies of normal inspiratory breath sounds in childhood.

LUNG SOUNDS OF HEALTHY PREMATURE AND TERM NEWBORNS

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Our subjects were two groups of infants: ten premature infants of gestational age 29 to 32 weeks and ten term infants of gestational age in a range of 36 to 40 weeks. Recordings were taken from left side of neck, left upper posterior chest and left lower posterior chest. The respiratory sounds were digitized using an analog to digital convertor on VAX 11/730 computer. Three cycles of respiration were analyzed for each recording location and for each child. While analyzing, breath sounds were observed in time and frequency domain, with regard to changes of spectra over time.

The respiratory sounds of healthy preterm and term infants recorded from either location of the chest show a higher overall intensity at inspiration than at expiration, and this is why the differences between preterm and term babies are more easily discerned upon inspirations.

Infants born at term have different identifying inspiratory sounds spectra at the level of upper and lower lobe. Spectra of inspiratory sounds recorded at upper lobe exhibit dominant frequencies at the 250 Hz - 900 Hz range, while those recorded at the lower lobe are characterized only by one peak around 300 Hz.

Size (shorter distances) and structural differences of the lung parenchyma (smaller number of alveoli) of preterm infants cause sounds originated at various locations to be almost not attenuated, and respiratory sounds have many common features (bimodal spectra with peaks at 300 Hz and 1100 Hz) while being detected at different locations.

Session C

Dr. Masashi Mori and Dr. David Cugell
Co-Chairmen

9:00 - 9:20	Is expiration prolonged in asthma	H. Pasterkamp D. Daien
9:20 - 9:40	The provocative concentration of methacholine to produce wheezing (PCw) - a new test to study lung disease in young children	A. Avital N. Noviski E. Bar-Yishay S. Godfrey
9:40 -10:00	When is a snore a wheeze?	E. Lens G. Postiaux T. Tran
10:00-10:20	Lung sound abnormalities in cocaine users	E. Del Bono K. O'Brien R. Murphy
10:20-10:40	Coffee Break	
10:40-11:00	Auscultation in asbestos workers: relationship of lung sounds to radiological findings and pulmonary function	S. Choh Y. Koyama N. Shioya H. Kasuga N. Narita M. Hatakeyama H. Uchida A. Shibuya S. Kudoh R. Mikami
11:00-11:20	Expiratory crackles in patients with fibrosing alveolitis	J. Earis M. Walshaw M. Nisar P. Calverley M. Pearson
11:20-12:00	Debate: Wheezes are more important than crackles Pro: Robert G. Loudon Con: Raymond L.H. Murphy	
12:00- 1:15	Lunch	

IS EXPIRATION PROLONGED IN ASTHMA

Observations on patterns of airflow and respiratory sounds during acute bronchospasm*

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Wheezing and a prolonged expiration are considered to be clinical hallmarks of asthma. However, our first impressions of respiratory patterns in subjects before and during acute bronchospasm did not suggest significant changes of the inspiration:expiration (I:E) ratio. To test the hypothesis that expiratory prolongation may be an acoustical rather than an actual airflow phenomenon, with longer and louder expiratory sounds during acute bronchospasm, we analyzed tape recorded lung sounds (right upper lobe), tracheal sounds and airflow (mouth) from 6 asthmatic subjects before and at 5, 10 and 20 min after exercise. Baseline lung sounds during tidal breathing were of low intensity and close to background noise level. The following table summarizes our findings (means ± SD):

	Baseline	5 min	10 min	20 min
FEV_1 (% fall)	*****	38 ± 14	32 ± 14	22 ± 14
TGV (% rise)	*****	49 ± 25	39 ± 20	23 ± 15
RR (breath/m)	18 ± 6	24 ± 6	20 ± 7	18 ± 2
V_i (l/s)	.49 ± .30	.67 ± .34	.53 ± .24	.48 ± .25
V_e (l/s)	.48 ± .37	.63 ± .26	.46 ± .20	.40 ± .11
I:E (sec/sec)	.75 ± .10	.75 ± .14	.77 ± .23	.72 ± .21
$Smax_i$ (dB)	13 ± 4	17 ± 4	15 ± 6	13 ± 3
$Smax_e$ (dB)	13 ± 4	17 ± 3	15 ± 5	11 ± 3
WH_L (% T_i)	2 ± 4	3 ± 6	10 ± 19	5 ± 7
WH_L (% T_e)	1 ± 3	4 ± 5	10 ± 11	3 ± 4
WH_T (% T_i)	1 ± 2	18 ± 19	33 ± 21	8 ± 12
WH_T (% T_e)	1 ± 1	8 ± 9	25 ± 23	6 ± 10

where V_i and V_e = maximum inspiratory and expiratory airflows, $Smax_i$ and $Smax_e$ = maximum sound level during in- and expiration, and WH_L/WH_T = wheezing over lung/trachea as proportion of inspiratory (T_i) and expiratory (T_e) time. Thus, despite significant airflow obstruction and hyperinflation following exercise, I:E changed little. Contrary to our predictions, however, expiratory sounds did not become disproportionally louder. Also, wheezing occurred both in inspiration and expiration. Respirosonography suggests that the relation of inspiratory sound duration and total respiratory time may lead to the perception of expiratory prolongation. Respiratory flow patterns, changes in inspiratory versus expiratory sounds and comparison of wheezing over trachea and lung may help to identify the predominant site of airway obstruction in asthma. We hope to present additional information on airflow and sound changes during acute spontaneous asthma.

* supported by the Children's Hospital of Winnipeg Research Foundation
** Scholar of the Manitoba Health Research Council

THE PROVOCATIVE CONCENTRATION OF METHACHOLINE TO PRODUCE WHEEZING (PC_W) - A NEW TEST TO STUDY LUNG DISEASE IN YOUNG CHILDREN

A. Avital, N. Noviski, E. Bar-Yishay, S. Godfrey
Hadassah Mt. Scopus, Jerusalem, ISRAEL

Airway reactivity was evaluated by tracheal auscultation during methacholine provocation test in 150 children, ages 1 to 7 years. Methacholine inhalation concentrations were doubled up to a concentration of 8 mg/ml or until tachypnea, persistent coughing, or wheezing over the trachea appeared. Children were divided into 7 clinical groups. Those with clinical asthma were classified according to their minimal therapeutic requirements for optimal symptomatic control. The different groups included patients without asthma, investigated for breathlessness, recurrent laryngitis or cough; patients with suspected clinical asthma (positive history for exercise induced bronchospasm, right middle lobe syndrome); patients with mild, moderate and severe asthma; patients with cystic fibrosis; and patients with pediatric chronic obstructive pulmonary disease (bronchiolitis obliterans, Swyer-James syndrome, bronchiectasis). Those with suspected asthma had a mean PC_W of 1.45 mg/ml, almost identical to that of mild asthmatics (mean 1.48 mg/ml). Cystic fibrosis patients had a mean PC_W of 1.8 mg/ml. Children with COPD were closer in their mean PC_W (0.56 mg/ml) to those with moderate asthma (0.29 mg/ml). Patients with severe asthma had a mean PC_W of 0.12 mg/ml. Auscultatory assessment of young patients undergoing methacholine provocation is an easy and useful tool in the clinical evaluation of these children.

WHEN IS A SNORE A WHEEZE ?

E. LENS (1), G. POSTIAUX (1), T. TRAN (2)

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We performed a thirty nocturnal on-line monitoring studies of wheezing patients with the system described last year at this conference (Paris) During auditory validation of the wheezing score we observed that some "snores" were considered as wheezing by the computerized algorithm. Indeed, snoring is known to be very common in asthma.
Thus, we tried to overcome what we thought to be drawbacks because some of these "wheezing-snores" introduced discrepancies between the wheezing % of the computerized numerical display and our auditory control. To differentiate these "wheezing-snores" from habitual heavy snoring we analyzed several spectral parameters of examples of snoring recorded from a variety of different illnesses with habitual snoring and desaturation (Sa 02 $<$ 4 %) : C.O.P.D., obesity, nasal septal deviation, excessive length of the soft palate, etc.
So, we obtained an algorithm of snoring allowing a better comparison between the habitual heavy snoring and the wheezing-snore which we call "RONSIB" (telescoping of French words Ronflement with sibilance). We hypothesize that the two components of the wheeze-snores (Ronsib) correspond at variable areas in upper airways and different flow levels. The semiologic question remains wether these inspiratory or expiratory wheezing-snores may be taken into account as a sign as classical wheezing ?
Examples of snoring and wheezing-snores (Ronsib) characterisation will be presented and discussed at the conference.

LUNG SOUND ABNORMALITIES IN COCAINE USERS

Elizabeth A. Del Bono, M.P.H.*
Kevin O'Brien, M.D.**
Raymond L.H. Murphy, Jr., M.D.*

We noted that a number of the patients admitted to the Treatment Unit of our hospital as a result of freebasing and nasal insufflation of cocaine complained of cough and phlegm production although their chest x-rays were within normal limits. We systematically mapped and made time expanded waveforms of lung sounds in six individuals admitted to this Service within twenty-four hours of their admission (Day 1). To study persistence or consistency of the findings, we also examined them five days after ceasing cocaine use (Day 5). All six of the individuals had abnormal sounds at a minimum of 3 of 20 mapped sites on the day of admission. The number of sites positive for abnormal sounds decreased considerably by Day 5 but were still present in 4 of the 6 subjects. The abnormalities we noted to be present were over the large airways and in particular between the scapulae. There were no chest x-ray abnormalities noted in the four patients on whom chest roentgenograms were available and the spirometric studies were within normal limits. These objectively demonstrated findings suggest that a bronchial and/or pulmonary inflammation is caused by this form of substance abuse and that its presence can be documented.

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AUSCULTATION IN ASBESTOS WORKERS: RELATIONSHIP OF LUNG SOUNDS TO RADIOLOGICAL FINDINGS AND PULMONARY FUNCTION

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We reported that chest auscultation using vital capacity (VC) maneuver was of value in detecting early stage of asbestosis, in 1981. The purpose of this study is to find out relationships of lung sounds to radiological findings and pulmonary function. Auscultation was performed on ninety-four asbestos workers (80 males, 14 females, age: 49.2 ± 11.1 (mean ± S.D.) years old, duration of asbestos exposure: 25.0 ± 9.7year) using VC maneuver. Auscultatory findings were classified into 4 groups.:

Group 0 : Normal vesicular sounds
Group I : Late inspiratory crackles
Group II : Prolonged inspiratory crackles
or inspiratory-expiratory crackles
Group III : Crackles associated with squawks

Chest radiographs were interpretted according to the ILO/UC(1971) classification. Computed tomographic scannings were also performed in 22 cases. Pulmonary function tests (%VC, $FEV_{1.0}$%) were also examined.

Results were as follows:

1) Crackles were heard in 33% of ILO category 0/0, and in 74% of ILO category 0/1.
2) The auscultatory findings were significantly correlated to stages in radiological findings .
3) There was significant correlation between the decreasing tendency of %VC and the extent of auscultatory findings (Group 0 through III).

We conclude that chest auscultation in asbestos workers is of value in monitoring the extension of asbestosis.

EXPIRATORY CRACKLES IN PATIENTS WITH FIBROSING ALVEOLITIS

EARIS J.E., WALSHAW M.J., NISAR M., CALVERLEY P.M.A., PEARSON M.G.

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Late inspiratory crackles are a constant and diagnostic feature of fibrosing alveolitis, but the prevalence of expiratory crackles has not been described. To investigate this , lung sounds were recorded in 13 patients (mean age 67 years) with fibrosing alveolitis (10 cryptogenic, three autoimmune). All had restricted spirometry (mean FVC 63%) and a low TLCO(mean 48%) and none produced sputum. Recordings were made at the right lung base with a crystal microphone and airflow was measured with a pneumotachograph. Signals were stored on a FM tape recorder and reproduced on a chart recorder. All patients had late inspiratory crackles in every breath. Expiratory crackles occurred in 12 patients and 84% took place in the last two thirds of inspiration. No patient had more than five crackles in any one expiration and 70% contained at least one crackle. Varying the pattern of respiration (deep breathing, breathing to residual volume, measurement after breath holding) did not alter the prevalence or distribution of the crackles. The proportion of expirations containing crackles was inversely related to the TLCO ($p<0,05$). When comparing inspiratory and expiratory crackle waveforms in the same patient the initial pen deflection was always in opposite directions. This raises questions about the current theories of how crackles are generated.

Session D

Dr. Robert Loudon and Dr. Filiberto Dalmasso
Co-Chairmen

1:15 - 2:00	Guest Speaker - Dr. Alfred Soffer Exec.Director, American College of Chest Physicians Editor, Chest	
2:00 - 2:20	Airflow-generated sound in a hollow canine airway cast	S. Kraman P. Wang
2:20 - 2:40	Mapping of transmitted lung sounds	D. Rice
2:40 - 3:00	The effect of stethoscope size on recorded crackles	F. Davidson E. Del Bono R. Murphy
3:00 - 3:15	Cracklefest	
3:15 - 4:00	Business meeting	
4:00 - 4:30	Summary	

AIRFLOW-GENERATED SOUND IN A HOLLOW CANINE AIRWAY CAST.

Steve S. Kraman and P. M. Wang

V.A. Medical Center and Department of Medicine, University of Kentucky Lexington, Kentucky

We examined the spatial distribution of airflow-generated sound within a Silastic model of canine airways representing the airways from trachea to those of 1 mm diameter. Sounds were picked up by an electret condenser microphone adapted to a glass conical probe, 0.5 mm diameter at the tip. The tip was introduced through a puncture hole in the wall of the model, just deep enough to enter the lumen. We acquired 341 measurements in airways of 2.0, 2.5, 3.0, 3.5, 4.0, 5.0, 6.0, 7.0, 8.0, 10.0, 14.0, 15.0, 16.0, and 19.0 mm diameter. Sounds were recorded during no airflow and at 0.5, 1.0, 1.5, 2.0 and 2.5 l/s in the inspiratory and expiratory directions (from muffled compressed air and vacuum sources). We found that, in the expiratory direction, the sound amplitude was approximately linearly related to airway cross-sectional area, the greatest amplitude occurring in the trachea. In the inspiratory direction, the greatest amplitude occurred in airways of about 8 mm diameter with a second, weaker amplitude peak within airways of approximately 5 mm diameter. Amplitude as a function of airflow appeared to be curvi-linear, suggestive of an exponential function. We found that a linear function best fit the amplitude data when it was plotted against the square of the airflow.

Our findings suggest that the expiratory component of the vesicular lung sound is produced in large airways as a simple function of airway cross-sectional area but that the inspiratory component is a more complex function distinguished by prominent sound generation within medium sized airways corresponding to locations (in the human adult lung) within the range of lobar to sub-segmental airways.

Mapping of Transmitted Lung Sounds

David A. Rice

In order to characterize the sound transfer properties of normal lung, we recorded signals transmitted from the mouth to the chest surface using an array of 16 microphones. A 200 microsecond square pulse applied to a horn driver generated the input to a mouth cannula. A system designed to analyze evoked potentials in the EEG displayed the recorded data. The system converted sound pressure at a specified instant into color values that are displayed on a two dimensional map that represents the microphone positions. A sequence of these maps covering a series of time steps presents information about amplitude and relative timing of the sound with respect to position on the chest. Observing this sequence permits the observer to identify relationships that otherwise may be hidden in the mass of waveform data. Right-left comparisons can be made directly or by mapping the difference between contralateral positions.

Statistical analysis of the data tests the validity of the patterns observed. Preliminary data indicate that the first sound to reach the surface appears over the spine and sternum, points of mediastinal attachment. On the back, the delay times increase as the microphone position moves caudally ($p<0.01$) and laterally ($p<0.01$). The difference between the right and left side is relatively small. Amplitudes vary from position to position. The amplitude pattern appears to vary more between subjects than with changes in lung volume in a single subject. Arrival times increase as lung volume decreases from TLC to RV ($p<0.01$).

Mapping transmitted lung sounds provides a means for standardized presentation, hard copy for permanent records, and a display for spatial and temporal pattern recognition. This approach should be especially effective for finding localized lung lesions.

My thanks go to H. Hidalgo and W. Waring for their assistance in data collection.

THE EFFECT OF STETHOSCOPE SIZE ON RECORDED CRACKLES

Frank Davidson, M.D.
Elizabeth A. Del Bono, M.P.H.
Raymond L.H. Murphy, Jr., M.D.

In certain diseases, the number of crackles relates to the severity of disease. This study examines the effect of stethoscope size on crackles recorded over a given area. We used a small custom-made recording stethoscope (ID = 2 cm), a Littman stethoscope bell (ID = 2.75 cm) and diaphragm (ID = 4.2 cm) as well as a large "fetal" scope (ID = 7 cm) with the same microphone and recording system in each. In one patient recordings were centered over a point on the chest where crackles were numerous and constant by clinical auscultation. Additional recordings were then made with the smaller stethoscopes at four other sites within the area covered by the largest stethoscope.

Results show that with the 2, 2.75 and 4.2 cm diameter scopes the number of crackles counted increased linearly with stethoscope area. Crackles per unit area, however, decreased with increasing stethoscope size. This effect appeared to be independent of stethoscope volume. This relationship did not hold for the large fetal stethoscope where counts were much lower than expected for the large area. Counting of crackles from the lungs depends on stethoscope size which should be specified when reporting counts of crackles in disease.

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