TRANSMISSION OF CRACKLES IN PATIENTS WITH INTERSTITIAL PULMONARY FIBROSIS, CONGESTIVE HEART FAILURE, AND PNEUMONIA

Murphy, R., Paciej, R. Bezares, F., Vyshedskiy, A. - Brigham & Women's/Faulkner Hospitals, Faulkner Hospital, Boston, MA.

BACKGROUND

-- Patients with Interstitial pulmonary fibrosis (IPF) often have chest x-rays that are diffusely abnormal making it difficult to detect evidence of superimposed congestive heart failure (CHF) or pneumonia (PN).
-- The crackles of these patients are commonly mistaken for the crackles of CHF. As a result, they frequently are incorrectly diagnosed and prescribed diuretics inappropriately.

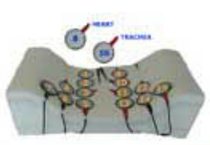
OBJECTIVE

The goal of this study was to determine whether the crackles of IPF differed in their transmission characteristics from those of CHF and PN in the hope of improving diagnosis and monitoring of these patients.

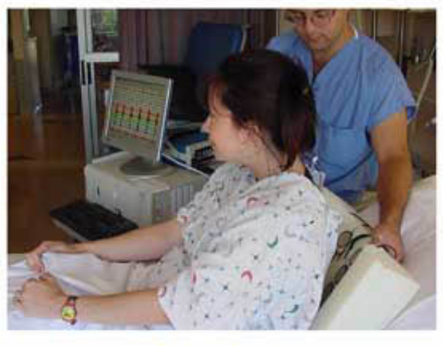
METHODS

-- A 16-channel lung sound analyzer (Stethographics Model STG1602) was used to collect 20 seconds samples of sound.
-- Patients with high number of crackles, i.e. over 20 inspiratory crackles in a 20 second recording, were chosen from a pool of over 500 patients.
-- These patients included 23 with Pneumonia, 17 with CHF, and 16 with IPF.
-- The diagnostic category of each of the patients was that of the clinicians caring for these patients. This was reviewed by the senior author to be sure they were consistent with established criteria.
-- This figure shows the soft foam backpad with microphones embedded in chestpieces (A) and method of application (B).

A.



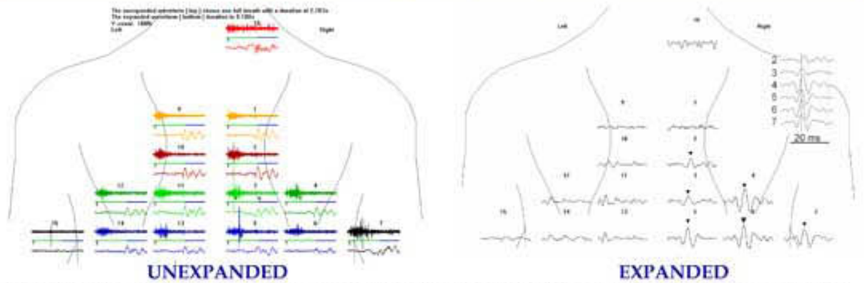
B.



RESULTS

Figure 1 shows time amplitude plots of a crackle as they appear at multiple sites in a subject with CHF. Twelve microphones are placed on the back; numbers 1 through 6 are on the right side, 9 through 14 are on the left. There is one on each lateral base - microphone numbers 7 and 15 respectively. There is one over the heart (not shown) and one over the trachea - number 16.
Waveforms are presented in the time-expanded mode.

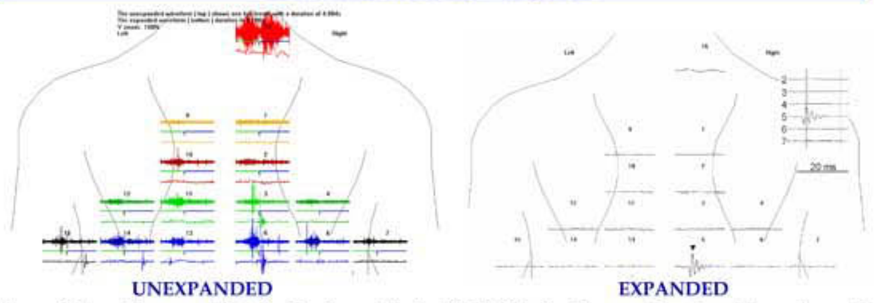
Congestive Heart Failure - Figure 1



UNEXPANDED EXPANDED

Figure 1 shows sound waveforms recorded from a CHF patient. The waveforms are superimposed on a body plot. Each waveform is positioned on a part of the body from where the sound was recorded. Note that the crackling sounds are transmitted throughout the right chest. A prominent crackle is seen on the tracing from channel 6 (indicated by a large triangle). Crackle waveforms that occur at approximately the same time are seen at channels 2, 3, 4, 5, and 7 (small triangles). We assume that crackles occurring within 5ms likely represent the same event of airways opening and call them a crackle family. The crackle with highest deflection (at channel 6) we call the mother crackle and the corresponding deflections at other channels we term daughter crackles. In this patient, the crackle was transmitted throughout a considerable area on the chest. As a rule of thumb crackles in patients with CHF and Pn are transmitted over an area about the size of the palm. We never observed significant crackle transmission to the contralateral lung.
The waveforms are shown in stacked mode to facilitate examination of arrival times at the various microphones. The crackle waveform seen in channel 6 begins earlier than the crackle waveforms in the other channels.

Interstitial Fibrosis - Figure 2



UNEXPANDED EXPANDED

Figure 2 shows the sound distribution in a patient with IPF. Notice the prominent crackle on channel 5 (indicated by a triangle). In contrast to the crackle shown in the patient with CHF, the crackle barely stands above the background noise at channels 3, 4, 5, or 7. In general crackles of IPF are transmitted over smaller area than crackles of CHF and Pn.

CRACKLE TRANSMISSION COEFFICIENT

-- To quantify the phenomena of the distance a crackling sound spreads or is transmitted, crackle waveforms occurring within the same 5 millisecond interval were considered to be coming from the same crackle source.
-- The signal containing the crackle with the highest amplitude (the mother crackle) was cross-correlated with the corresponding signals on other microphones (daughter crackles).
-- The ratio of the peak of the cross-correlation function to the peak of the mother crackle autocorrelation function was calculated.
-- This ratio characterizes the degree of sound transmission from the sound source to the corresponding microphone on the chest surface.
-- For every crackle family, the average of ratios over the chest characterizes the degree of sound transmission from the sound source to the chest.
-- The *crackle transmission coefficient* has a value of 0% in the absence of any transmission and 100% when there is equal transmission to all channels.

Results - continued

Average inspiratory crackle transmission coefficient and average crackle frequency were calculated for every patient in the study.

-- Inspiratory crackle CTC averaged 24±5% for Pneumonia, 25 ± 8% for CHF, and 14 ± 4% for IPF.
-- The difference in CTC between IPF and CHF and between IPF and Pn was statistically significant ($p<0.0001$).
-- Inspiratory crackle frequency was also different: the frequency averaged 302±47Hz for Pneumonia, 311 ± 62Hz for CHF, and 462 ± 50Hz for IPF.
-- The difference in frequency between IPF and CHF and between IPF and Pn was statistically significant ($p<0.0001$).

The crackles of IPF have higher frequency than those of either Pn or CHF, we wondered whether this frequency difference was a factor in the differences observed in transmission. To address this question we studied the relationship between CTC and crackle frequency.

Figure 3

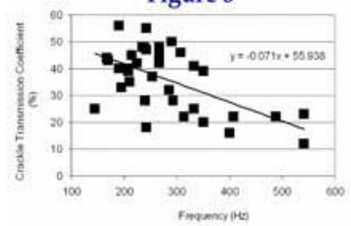
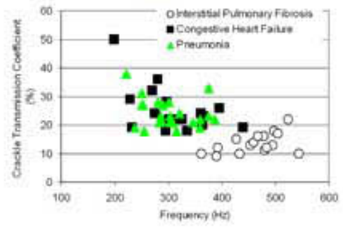


Figure 3 shows CTC as a function of crackle frequency from a patient with CHF. Note that CTC is decreased at higher frequency. The line fit on Fig. 3 has the slope of –0.07. This correspond to a 7% decrease in CTC for every 100Hz increase in frequency. This observation was noted in the majority of patients. CTC decreased with increased frequency in 91% of patients with Pn (slope=-0.03±0.02), in 88% of patients with CHF (slope=-0.03±0.02), and in 63% of patient with IPF (slope=-0.01±0.02). We conclude that crackles with higher frequency are usually transmitted over a smaller area of the chest.

We then calculated mean CTC and mean inspiratory crackle frequency for every patient. Consistent with our previous observations, CTC decreased at higher frequency. Comparison of IPF crackles to those of CHF and Pn yielded a new observation: at a given frequency the mean CTC was greater in patients with CHF and Pneumonia than in patients with IPF. This observation is consistent with the hypothesis that lungs of patients with CHF and Pn are better transmitters of sound. A possible explanation is that increased fluid content in the lungs of patient with CHF and Pn is responsible for improved sound transmission.

Figure 4



The mean crackle transmission coefficients as a function of mean frequency. There is a strong tendency for the data points of the CHF and Pn patients to be toward the upper left of the graph and IPF patients to be towards the lower right.

CONCLUSION

-- In this study we have described criteria that differentiate IPF patients from CHF and Pneumonia patients on the basis of crackle transmission and frequency.
-- The differences that characterize IPF patients from the other two conditions monitored in this study provide evidence that acoustical analysis could be a helpful guide in the management of these patients.