CRACKLE POLARITY IS INFLUENCED BY RESPIRATORY PHASE

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BACKGROUND

Crackles are intermittent explosive sounds that are associated with a number of pulmonary disorders including Interstitial Pulmonary Fibrosis (IPF), Congestive Heart Failure (CHF), and Pneumonia (Pn).

The mechanism underlying crackle generation is poorly understood. The working assumption is that sudden airway opening is responsible for inspiratory crackles and airway closing is responsible for expiratory crackles.

Fredberg and Holford postulated that crackles were due to a stress relaxation quadrupole associated with sudden airway opening and closing. Their model predicted that the polarity of expiratory crackles would be the reverse of inspiratory crackles.

PURPOSE

The goal of this research was to examine systematically the relationship between crackle polarity and respiratory phase to test the hypothesis of Fredberg and Holford.

METHODS

Patients with pneumonia, congestive heart failure, and interstitial fibrosis (n=165) were examined using a multichannel lung sound analyzer (Stethographics Model 1602).

Crackles were defined in accordance with accepted criteria[2,3].

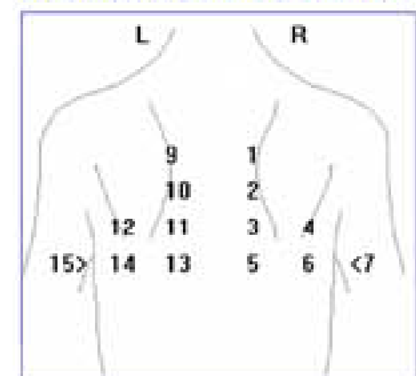
Inspiratory and expiratory crackles were counted separately.

To be accepted into the study either the inspiratory or the expiratory crackle count had to be greater than 2 crackles per breath.

Eighty five patients with Pn, 58 with CHF, and 22 with IPF were included in this study.

Crackle polarity was defined positive if the largest deflection was upward. Crackle polarity was defines negative if the largest deflection was downward. (See Figure 1.)

MICROPHONE LOCATION



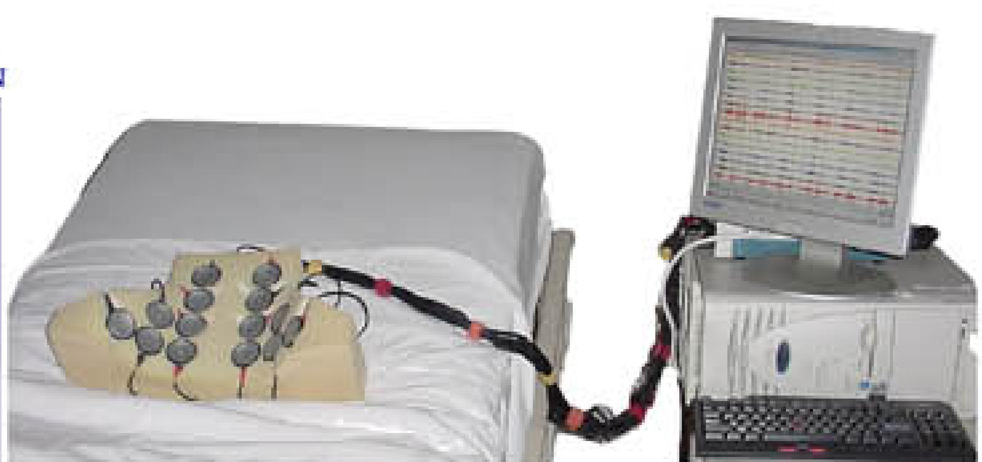


FIGURE 1.

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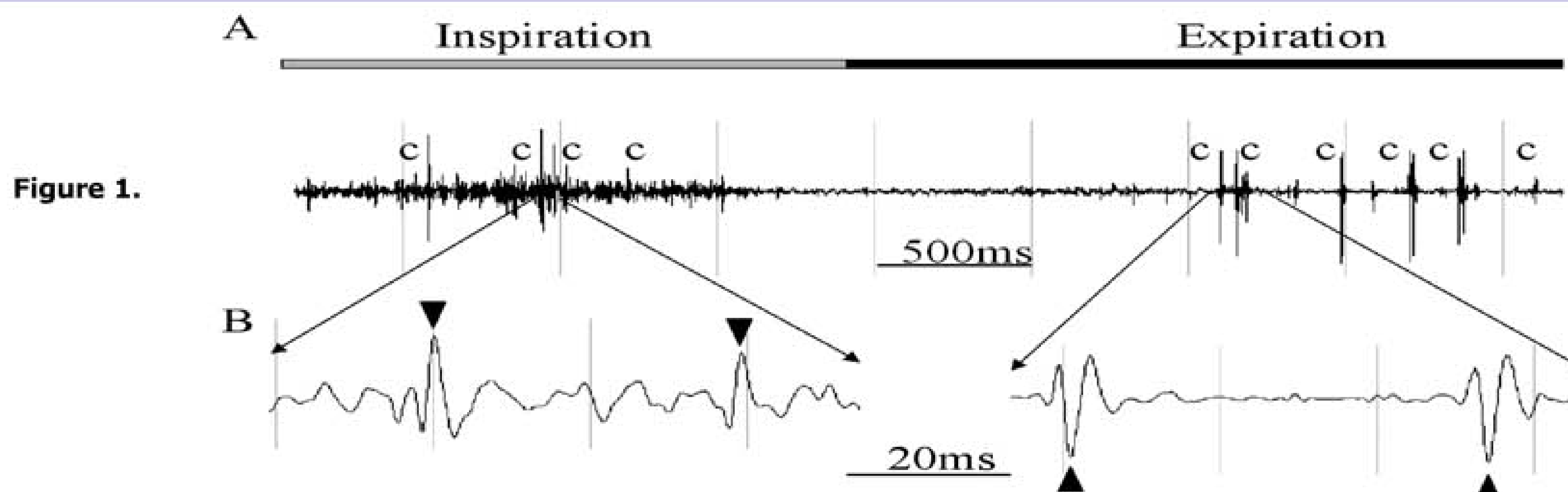

Fig. 1A shows a sound waveform recorded from a patient with pneumonia in the retrocardiac region. The acoustic sensor was located on the left posterior chest over the area of infiltration. The waveform shows one full breath. Crackles are marked by 'c'. Note that during inspiration crackles are superimposed on normal vesicular lung sounds.

Fig. 1B. In this figure, the sections between the long arrows are time-expanded to show the details of the crackle waveforms. The largest deflections in the inspiratory crackles are upward (triangles, Fig.1B left, positive polarity), while the largest defections in the expiratory crackles are downward (triangles, Fig.1B right, negative polarity). In this patient, all inspiratory crackles (total of 11 crackles or 2.8 inspiratory crackles per breath) had positive polarity, and all expiratory crackles (total of 55 crackles or 13.8 expiratory crackles per breath) had negative polarity.

RESULTS

<> The majority of patients had predominantly positive polarity of inspiratory crackles (88% of patients)

<> The majority of patients had predominantly negative polarity of expiratory crackles (83% of patients).

<> Seventy one percent of the 8,250 inspiratory crackles studied had positive polarity.

<> Seventy five percent of the 3,485 expiratory crackles studied had negative polarity.

<> Inspiratory crackle polarity was significantly different between CHF and IPF ($p<0.0008$). It was slightly different between Pn and IPF ($p<0.02$). It was not statistically different between PN and CHF. There were no significant differences in expiratory crackle polarity among the groups.

<> Eighty two patients had both inspiratory and expiratory crackle counts of over 2 crackles per breath, i.e. a total crackle count of over 4 crackles per breath. The following observations were made in these patients:

<> The crackle polarity reversed from predominantly positive during inspiration to predominantly negative during expiration in 78% of patients

<> The crackle polarity reversed from predominantly negative during inspiration to predominantly positive during expiration in just 2% of patients.

<> The frequency of inspiratory crackles tended to be higher than the frequency of expiratory crackles, but this difference was not statistically significant.

Table 1.
Crackle polarity as a function of respiratory phase

	Pneumonia	CHF	IPF	Total
Number of patients accepted into the study (with either over 2 inspiratory or over 2 expiratory crackles per breath)	85	58	22	165
Number of patients with over 2 inspiratory crackles per breath	81	55	22	158
Number of patients with over 2 expiratory crackles per breath	53	21	15	89
Percent patients with predominantly positive polarity of inspiratory crackles	88	84	100	88
Percent patients with predominantly negative polarity of expiratory crackles	85	76	87	83
Number of inspiratory crackles per breath (Mean ± STDev)	9±5	8±5	26±15	N/A
Number of expiratory crackles per breath (Mean ± STDev)	8±6	6±3	11±10	N/A
Total number of inspiratory crackles	3347	2154	2749	8250
Total number of expiratory crackles	1977	708	800	3485
Percent inspiratory crackles with positive polarity	71	64	77	71
Percent expiratory crackles with negative polarity	78	74	71	75
Number of patients with both over 2 inspiratory and 2 expiratory crackles per breath	49	18	15	82
Percent of these patient with crackle polarity reversed from predominantly positive during inspiration to predominantly negative during expiration	80	67	87	78
Percent of these patient with crackle polarity reversed from predominantly negative during inspiration to predominantly positive during expiration	4	0	0	2
In these patients frequency of inspiratory crackles (Mean ± STDev)	299±67	315±58	436±46	N/A
In these patients frequency of expiratory crackles (Mean ± STDev)	274±67	280±64	409±70	N/A

CONCLUSION

<> The reversal of crackle polarity from positive during inspiration to negative during expiration is consistent with the hypothesis that inspiratory crackles are caused by a mechanism opposite in direction to that of expiratory crackles.

<> Specifically it is consistent with the hypothesis that sudden airway opening is responsible for inspiratory crackles and airway closing is responsible for expiratory crackles.

<> We found that inspiratory crackle frequency had a tendency to be greater than expiratory crackle frequency. The difference was not statistically significant. This observation is consistent with the hypothesis that inspiratory crackles are generated by airways of similar or slightly smaller diameter than expiratory crackles.

<> While there are no immediate clinical benefits to knowing the polarity of a patient's crackles, a clearer understanding of the mechanism of production of lung sounds offers the promise of improving noninvasive diagnosis of lung disorders.

REFERENCES

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