CHEST Original Research
PHYSICAL EXAMINATION

Mechanism of Inspiratory and Expiratory Crackles*

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Objective: **Although crackles are frequently heard on auscultation of the chest of patients with common cardiopulmonary disorders, the mechanism of production of these sounds is inadequately understood. The goal of this research was to gain insights into the mechanism of crackle generation by systematic examination of the relationship between inspiratory and expiratory crackle characteristics.**

Methods: **Patients with a significant number of both inspiratory and expiratory crackles were examined using a multichannel lung sound analyzer. These patients included 37 with pneumonia, 5 with heart failure, and 13 with interstitial fibrosis. Multiple crackle characteristics were calculated for each crackle, including frequency, amplitude, crackle transmission coefficient, and crackle polarity.**

Results: **Spectral, temporal, and spatial characteristics of expiratory and inspiratory crackles in these patients were found to be similar, but two characteristics were strikingly different: crackle numbers and crackle polarities. Inspiratory crackles were almost twice as numerous as expiratory crackles (n = 3,308 vs 1,841) and had predominately negative polarity (76% of inspiratory crackles vs 31% of expiratory crackles).**

Conclusion: **These observations are quantitatively consistent with the so-called _stress-relaxation quadrupole hypothesis_ of crackle generation. This hypothesis holds that expiratory crackles are caused by sudden airway closure events that are similar in mechanism but opposite in sign and far less energetic than the explosive opening events that generate inspiratory crackles. We conclude that the most likely mechanism of crackle generation is sudden airway closing during expiration and sudden airway reopening during inspiration.** **_(CHEST 2009; 135:156–164)_**

Key words: acoustics; breath sounds; crackle mechanism; crackles; lung mechanics; lung sounds; rales; respiratory sounds

Abbreviations: CHF = congestive heart failure; CTC = crackle transmission coefficient; IPF = interstitial pulmonary fibrosis; T1 = half period to the left of the highest peak; T2 = half period to the right of the highest peak; T2/T1 = ratio of the second half period to the first half period

Crackles are intermittent short-lived sounds that emanate from the lung and are associated with pulmonary disorders including interstitial pulmonary fibrosis (IPF), congestive heart failure (CHF), and pneumonia.[1] The mechanism underlying crackle generation is not well understood, however, and the spectral, temporal, and spatial characteristics of crackles have not been well quantified. In this article, we characterize crackles in patients with IPF, CHF, and pneumonia who had a significant number of both inspiratory and expiratory crackles. We quantified these events using multiple microphones placed on the chest surface, and we focused in particular on differences between crackles generated during inspiration vs expiration.

These data were then used to address a particular hypothesis of crackle generation that was suggested many years ago, the *stress-relaxation quadrupole*

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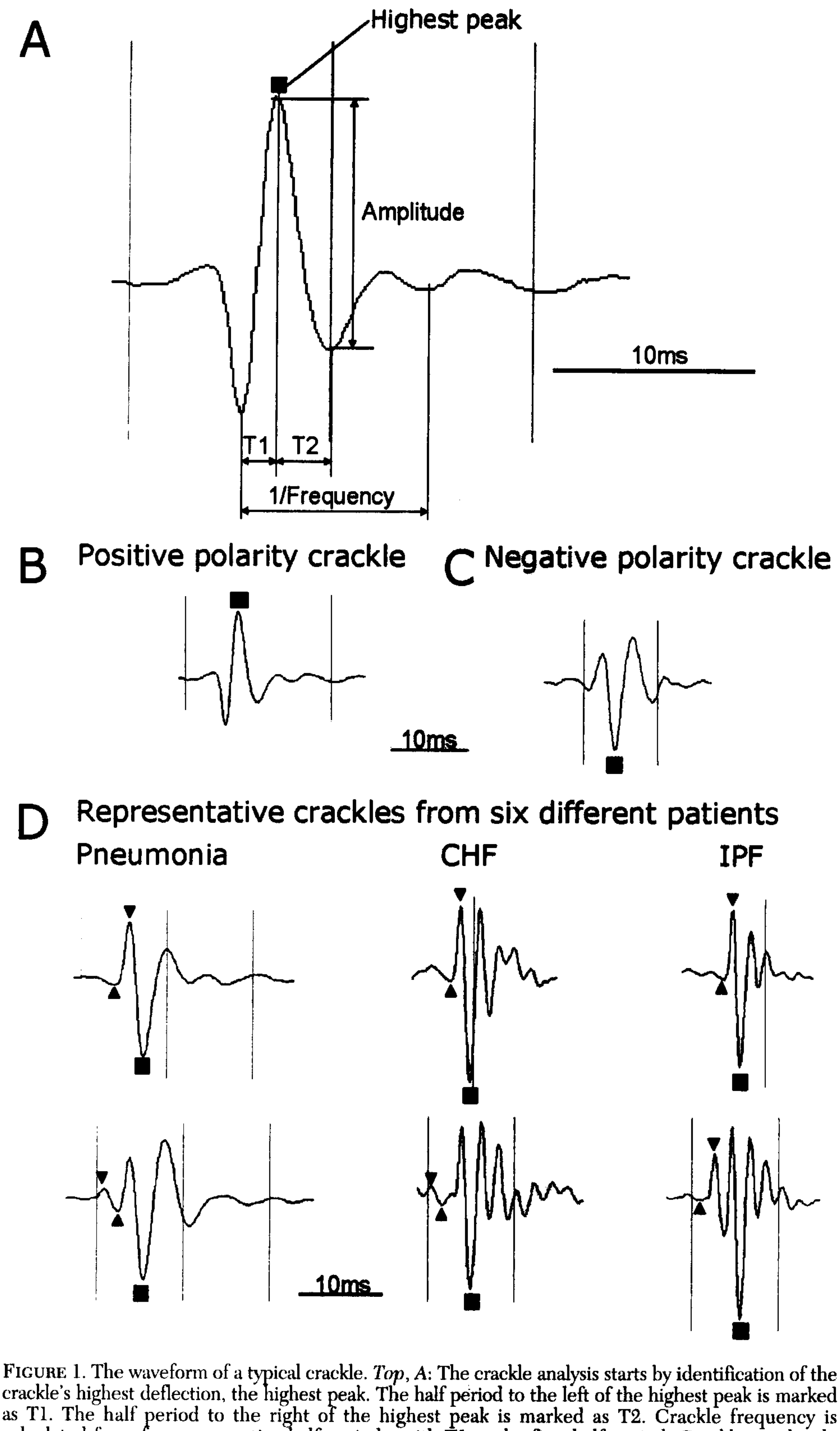

FIGURE 1. The waveform of a typical crackle. *Top*, *A*: The crackle analysis starts by identification of the crackle's highest deflection, the highest peak. The half period to the left of the highest peak is marked as T1. The half period to the right of the highest peak is marked as T2. Crackle frequency is calculated from four consecutive half periods, with T1 as the first half period. Crackle amplitude is marked "amplitude." *Center*, *left*, *B*: Crackle polarity is defined as positive if the highest peak is upward. *Center*, *right*, *C*: Crackle polarity is defined as negative if the highest peak is downward. *Bottom*, *D*: Six representative crackles recorded from six different patients. Squares mark the highest deflection. Triangles mark the candidates for initial deflection. The definition of the highest deflection is unambiguous. The definition of the initial deflection is highly subjective because it might be very small and comparable to the noise floor.