Thorax (1974), **29**, 223.

Inspiratory crackles—early and late

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Nath, A. R. and Capel, L. H. (1974). *Thorax,* **29,** 223–227. **Inspiratory crackles early and late.** Inspiratory crackles were recorded simultaneously with the inspiratory flow rate in patients with airways obstruction and in those with a restrictive defect. Early inspiratory crackles were associated with severe airways obstruction and late inspiratory crackles with a restrictive defect.

Crackles are non-musical lung sounds of short duration, in the past referred to variously as râles, moist sounds, and crepitations. They may occur at any time during inspiration or expiration. From a preliminary clinical study it was observed that crackles occurred early in some patients and late in others. Is the timing of inspiratory crackles of clinical and physiological significance? In an attempt to answer this question a recording of lung sounds in defined groups of patients was compared with the clinical, radiological, and functional findings in each case.

METHODS

The lung sounds were recorded using a crystal microphone in an aluminium cup with a suction chamber fixed on the posterior chest wall 5 cm above the costal margin. The output of the microphone was amplified and displayed on one channel of a UV recorder (S.E. Type 30006/DL). The sound amplifier incorporated a variable high pass filter which permitted low frequency cut-off up to 600 Hz. The frequency response of the microphone, amplifier, and the recording system was ±1dB from 200 to 2000 Hz. The inspiratory flow rate was simultaneously recorded at the mouth with a Fleisch pneumotachograph connected to a differential pressure manometer (Mercury Electronics Type M6) and the output was displayed on a second channel of the recorder. The flow rate signal at zero flow was superimposed on the sound signal. Thus the start and finish of inspiration was marked off by the flow signal as it crossed the sound signal (Fig. 1).

In all patients spirometric tests and radiological examination were carried out.

PATIENTS

Two groups of patients were studied. In the first group (Table I) were 56 patients selected because on clinical examination, confirmed by the phonopneumogram, they were found to have inspiratory crackles. These crackles were classified as early or late: *Early* inspiratory crackles appear shortly after the start of inspiration and do not continue beyond the first half of inspiration (Fig. 1). In contrast, *late* inspiratory

TABLE I

FEV_1/VC % IN PATIENTS WITH EARLY AND LATE INSPIRATORY CRACKLES
(56 patients selected because of inspiratory crackles)

Inspiratory Crackles	No. of Patients	FEV_1/VC Mean %	Range	SD
Early	24	31	19–39	5·6
Late	32	74	58–90	9·5

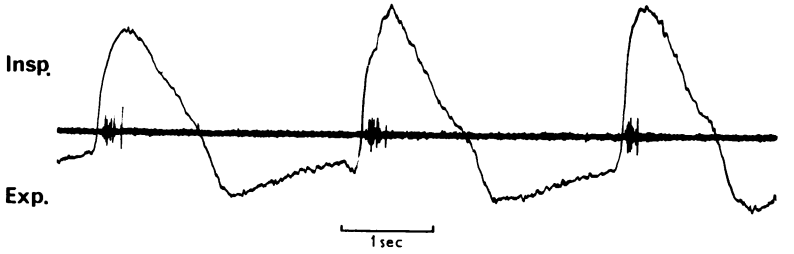

FIG. 1. *Phonopneumogram of early inspiratory crackles. This is a simultaneous recording of inspiratory crackles and airflow rate.*

crackles continue into the second half of inspiration but may start at any time during inspiration (Figs. 2–4).

In the second group were 44 patients selected for study because they showed spirometric evidence of airways obstruction (FEV_1/VC ratio less than 75%) and had a clear chest radiograph. These patients were then examined for the presence and timing of crackles (Table II).

RESULTS

In 24 of the 56 patients selected because they were found to have inspiratory crackles the crackles were heard early in inspiration, and in the remaining 32 patients the crackles were heard late in inspiration. In the 24 patients with early inspiratory crackles there was spirometric evidence of airways obstruction, with a mean

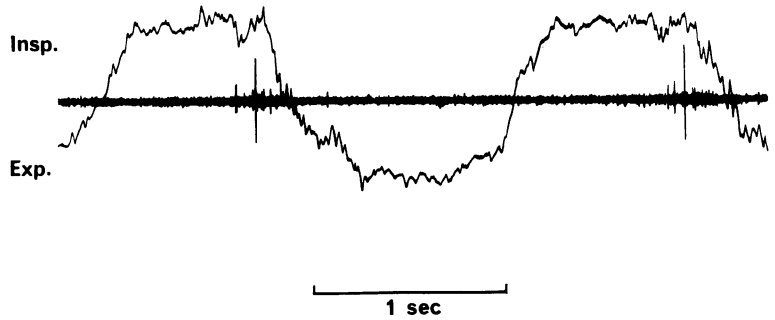

FIG. 2. *Phonopneumogram of late inspiratory crackles: inspiratory crackles are seen late in inspiration.*

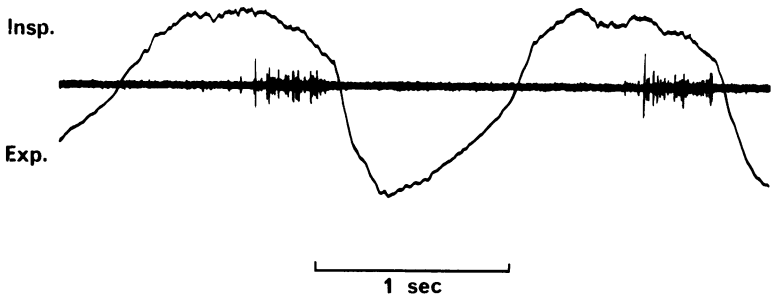

FIG. 3. *Phonopneumogram of late inspiratory crackles: inspiratory crackles are seen mid and late in inspiration.*

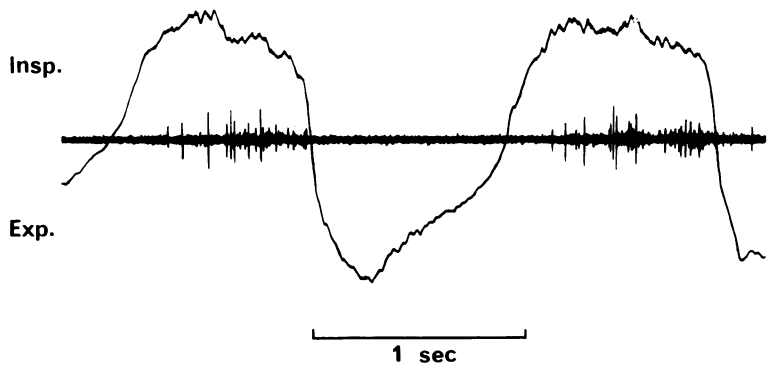

FIG. 4. *Phonopneumogram of late inspiratory crackles: inspiratory crackles are seen early, mid, and late in inspiration.*

TABLE II

SEVERITY OF AIRWAYS OBSTRUCTION AND OCCURRENCE OF EARLY INSPIRATORY CRACKLES
(44 patients, selected because of spirometric airways obstruction)

FEV_1/VC % (Range)	Early Inspiratory Crackles	
	Present	Absent
24–44 (Mean 34)	19	2
45–74 (Mean 53)	1	22

FEV_1/VC of 31%. Of the 32 patients with late inspiratory crackles, 25 showed no spirometric evidence of airways obstruction and in the remaining seven patients airways obstruction was mild (FEV_1/VC 58–69%).

The diagnosis in those found with early inspiratory crackles and in those found with late inspiratory crackles is shown in Table III. Those with early inspiratory crackles all showed the characteristic clinical and spirometric findings of obstructive lung disorder. Those with late inspiratory crackles all showed the characteristic clinical, radiological, and (except for the seven mentioned above) spirometric findings of restrictive lung disorder.

TABLE III

CLINICAL DIAGNOSIS AND TIMING OF INSPIRATORY CRACKLES

Early	Late
Chronic bronchitis	Fibrosing alveolitis
Asthma	Asbestosis
Emphysema	Pneumonia
	Pulmonary congestion of heart failure
	Pulmonary sarcoidosis
	Scleroderma
	Rheumatoid lung
	Pulmonary fibrosis unknown cause

In 20 of the 44 patients selected because of spirometric evidence of airways obstruction and a clear chest radiograph, early inspiratory crackles were heard and confirmed by phonopneumogram. In these 20 patients with early inspiratory crackles the FEV_1/VC ratio was less than 45% in all but one. In contrast, in the 24 patients without inspiratory crackles, the FEV_1/VC ratio was more than 45% in all but two (Table II).

Thus early inspiratory crackles were associated with a low FEV_1/VC ratio in two groups of patients, one selected by auscultation and the other by spirometry.

DISCUSSION

In the most important study of lung sounds since Laennec, Forgacs (1967) suggested that inspiratory crackles are produced by abrupt opening of closed airways in deflated regions of the lung. He pointed out that the time of opening will depend upon the development of tensions in surrounding lung tissue. Indeed the moment of occurrence of a crackle was found to be determined by the transpulmonary pressure during inspiration in experimental observations.

The difference in timing between the early crackles of patients with severe airways obstruction and the late crackles of those with restrictive lung disorder can be related to the site of airway closure.

A source in the proximal and larger airways may be suggested for early inspiratory crackles since they are frequently well transmitted to the mouth and few in number (Figs. 1 and 5). Hence the occurrence of early inspiratory crackles may mean that some of the larger airways remain closed at the end of preceding expiration. This would happen if bronchial compliance were increased or if the retractive pressures around the bronchi were low (Macklem, Fraser and Brown, 1965). In the subsequent inspiration a small transpulmonary pressure would then be required to pull these airways open.

A common feature of restrictive lung disorder due to fibrosis, infiltration or oedema is that the lung is partially deflated and this predisposes to the closure of peripheral airways. The distribution of airway closure is gravity dependent. The basal alveoli of a normal lung deflated to residual volume inflate late in inspiration, and these basal airways are first to close towards the end of expiration (Dolfuss, Milic-Emili, and Bates, 1967). Unlike the early inspiratory crackles of airways obstruction, the late inspiratory crackles are usually more profuse, gravity dependent, and only rarely transmitted to the mouth. We suggest that late inspiratory crackles originate in peripheral airways, each crackle representing abrupt opening of a single airway. The opening pressure developed later in inspiration is sufficient to produce showers of crackles.

In addition to timing of crackles in inspiration, further differentiating features between early and late inspiratory crackles can be readily elicited at the bedside (Table IV). Early inspiratory crackles are typically scanty but may be loud or faint. They are heard at one or both lung bases and are usually well transmitted to the mouth (Fig. 5). An important feature of these crackles is that they

TABLE IV

CLINICAL DISTINCTION BETWEEN EARLY AND LATE INSPIRATORY CRACKLES

Early	Late
Scanty	Profuse
Lower zones	Lower zones may extend to mid and upper zones
Gravity independent	Gravity dependent
Usually transmitted to mouth	Rarely transmitted to mouth
Associated with severe airways obstruction	Associated with restrictive lung disorder

are not silenced by cough or change of posture; this was true of all the 24 patients examined in the present study. Crackles associated with secretions in the larger airways, on the other hand, are modified or silenced by coughing, they are present in inspiration and expiration, and occur in random sequence from breath to breath. Early inspiratory crackles are associated with severe expiratory obstruction, although in some patients with emphysema they may not be heard on the chest wall.

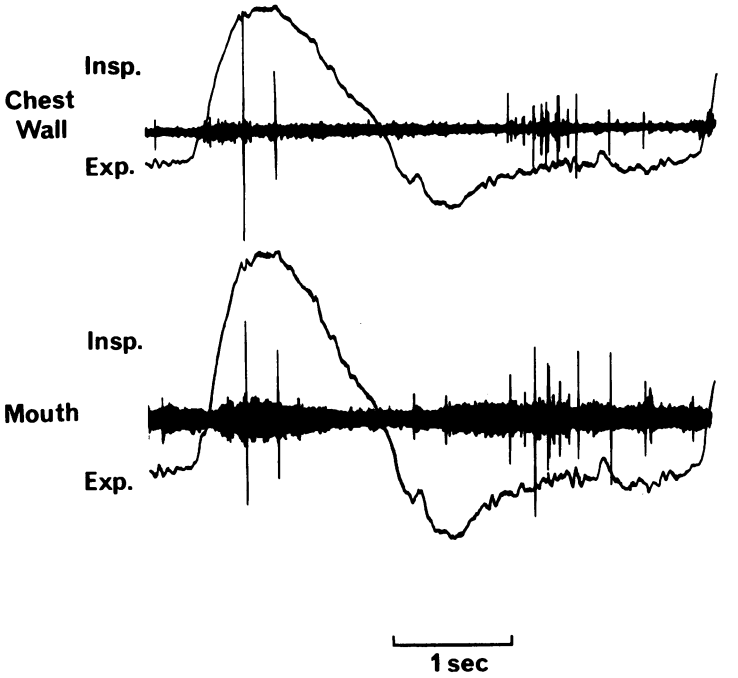

FIG. 5. *Simultaneous recording of early inspiratory crackles at the mouth and on the chest wall. A pair of crackles can be identified at these two sites. Note also the presence of expiratory crackles.*

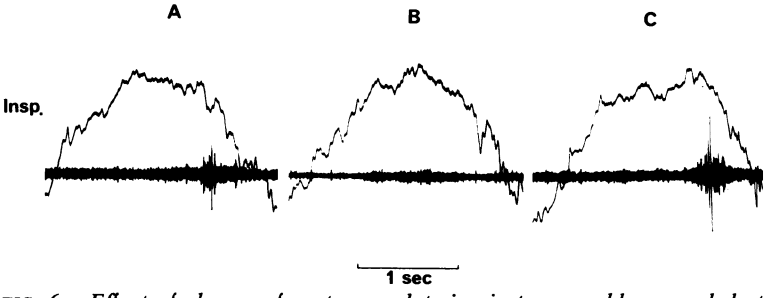

FIG. 6. *Effect of change of posture on late inspiratory crackles recorded at the right lung base. Late inspiratory crackles are present when standing* (A) *and silenced when the patient bends forwards* (B). *They reappear when the patient stands up again* (C).

In contrast, late inspiratory crackles are usually more profuse and may be associated with an end inspiratory wheeze. They are best heard over the lower zones and in advanced disease they may also be heard in the middle and upper zones but are rarely transmitted to the mouth. In the early stages of disease they are abolished or modified with change in posture (Fig. 6) but in later stages they are independent of posture.

The timing of inspiratory crackles is clinically helpful. Attention to their number, distribution, and transmission and to the effect of cough and change in posture provide useful information about the functional state of the lung.

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