RECORDING OF BREATH SOUNDS

Auscultation of sounds generated from the thorax has been of immense value to the clinician since Laennec developed the monaural stethoscope. The present project was motivated by the resurgent interest in pulmonary disorders and the necessity for teaching physical examination and clinical chest disease to medical students. The current availability of suitable instrumentation permits a rapid and simple amplification of respiratory acoustic data and their recording and play-back with visual sequence as didactic devices. This approach permits a more objective definition of respiratory transients and is applicable for research, teaching purposes, or for bedside identification of specific disorders. The present preliminary report is concerned only with the instrumentation and clinical spectrum of lung sounds. Further discussions of the origins of respiratory sounds and the effect of pulmonary ventilation on sound intensity are available.[1-5]

The following system was adopted for accurate reproduction of breath sound frequencies up to 2,000 cycle per sec. When desired, actual stethoscopic conditions were simulated by the use of active filters. For transformation of the sound vibrations at the chest wall, it was found that a piezoelectric, crystal microphone with a predominant frequency response between 30 and 100 cycle per sec, and minor attenuation before sharp roll-off over 2,000 cycle per sec was optimal.[6] This unit has an aluminum bell, 60 mm in diameter, with a relatively airtight, rubber contact edge to minimize ambient and surface noise. Because such units are very sensitive, surface movement should be minimal, particularly if the unit is hand-held. This signal was preamplified (linear) and then fed with appropriate impedance matching and equalization to the low level input of a standard, four channel tape recorder. Excluding the tape deck, a flat frequency response between 20 and 20,000 cycle per sec (± 2 db), a signal to noise ratio better than 80 db and harmonic distortion typically less than 0.05 per cent at rated output ensured minimal signal distortion from pick-up to tape recording. With commercial low noise, high output recording tape (TDK-SD150) and a recording speed of 7.5 inch per sec, a final frequency response of 40 to 15,000 cycle per sec (± 2 db) and a theoretic signal to noise ratio of 55 db was thus projected. In actual practice, however, signal to noise ratios were of the order of 10 to 15 db for highly attenuated breath sounds.

Standardization of the actual recording intensity was achieved by a predetermined 2-mv, 400-cycle per sec signal fed directly to the recording tape with a play-back intensity of −20 db below 0 VU. Additionally, recording levels, body position, and isovolume conditions were controlled in a given patient. Simultaneous airflow and volume recording was also possible. A flow-dependent photoelectric impellar system was used that was linear from 0.2 liter per sec to 8.0 liter per sec and generated a square wave signal whose frequency was directly proportional to flow.[7] This obviated the frequency conversion necessary to record DC signals from pneumotachograph. The breath sound signal can be monitored before or during the actual recording by earphones or conventional speakers or both, or it can be displayed on a standard oscilloscope to ensure suitable recording levels. Similarly, this taped data can be retrieved for audio-visual inspection at any further time. In this study, a Tektronix-560 series, persistance cathode ray oscilloscope coupled with a Polaroid camera was used for the figures presented. Finally, a nose reduction unit based on the Dolby principle can be introduced to minimize tape noise, although in the present experience this provided only a modest improvement in the signal to noise ratio.

Visual examples of typical recorded data in normal subjects and patients with a variety of diseases are displayed in the figures. Calibrated temporal and intensity features were easily visualized in a continuous pattern, parallel to the playback of the original audio signal. In these preliminary observations, lung volume and flows were not necessarily controlled nor analyzed.

---

[1] McKusick, V. A., Jenkins, J. T., and Webb, T. N.: Amer. Rev. Tuberc., 1953, *72,* 12.

[2] LeBlanc, P., Macklem, P. T., and Ross, W. R. D.: Amer. Rev. Resp. Dis., 1970, *102,* 10.

[3] Forgacs, P.: Lancet, 1967, *2,* 203.

[4] Pottenger, F. M.: Ann. Intern. Med., 1949, *30,* 766.

[5] Fahr, G.: Arch. Intern. Med. (Chicago), 1927, *39,* 286.

[6] Model 213004, Cambridge Instruments, Brookline, Massachusetts.

[7] Impellaway®, Fibre Optics Industries, Inc., Milton, Massachusetts.

Fig. 1. Bronchial breathing (trachea). Expiration is louder, higher pitched (from audio recording), and longer than inspiration. In this and other figures intensity is displayed on the y-axis and time on the x-axis.

Fig. 2. Bronchovesicular sounds (middle lobe). Intensity of expiration is markedly reduced with a duration equal to inspiration.

Fig. 3. Vesicular sounds (base). Inspiration is louder, of greater duration, and higher pitched.

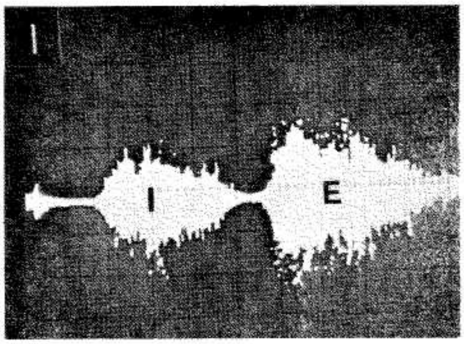
Fig. 4. Acute asthmatic attack (right base). Sounds are bronchial with prolonged, loud, expiratory wheezing. Note the reversal of the normal end-expiratory pause. Inspiration is held with only a minor pause after expiration. Wheezing was also present during inspiration.

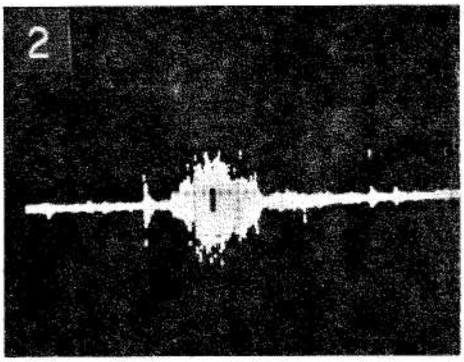
Fig. 5. Same patient as in figure 4, 30 minutes after bronchodilator. Inspiration and expiration are now sequenced in a more normal pattern with bronchovesicular tones. Inspiration is higher pitched and more prolonged whereas expiration is less intense but absolutely of greater duration than the acute attack.

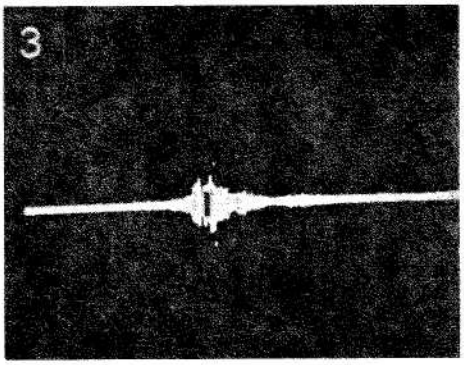
Fig. 6. Clinically asymptomatic asthmatic (middle lobe). Minor inspiratory wheezing and slight prolongation of expiration.

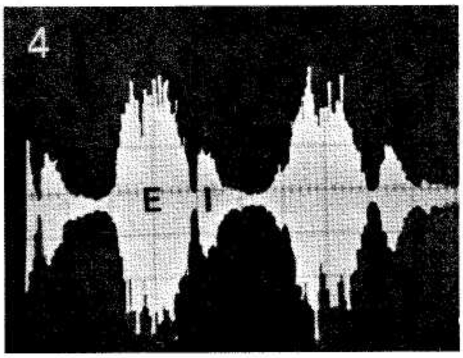
Fig. 7. Rhonchi in chronic bronchitis (lower lobe). Note the "outspikes," or deflections from the basic diamond-shape, breath sound configuration present in both inspiration and expiration. These are coarse and of variable intensity and duration. (Contrast with fibrotic rales.)

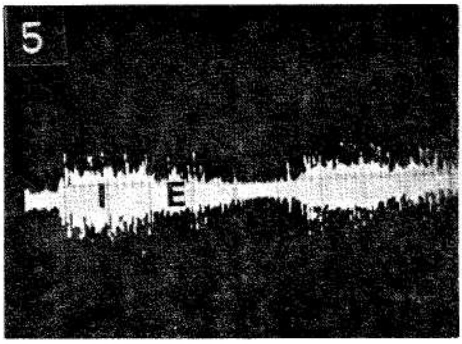
Fig. 8. Fibrotic rales (right base) (visual sequence magnified 10×). Ratio of inspiratory time to expiratory time is 1.0, with bronchovesicular characteristics. The "outspike" rales are fine, regular, and equally distributed throughout inspiration.

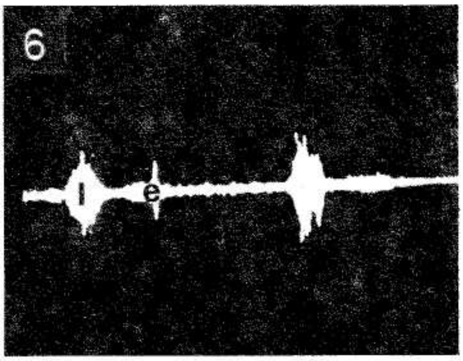

1
I
E

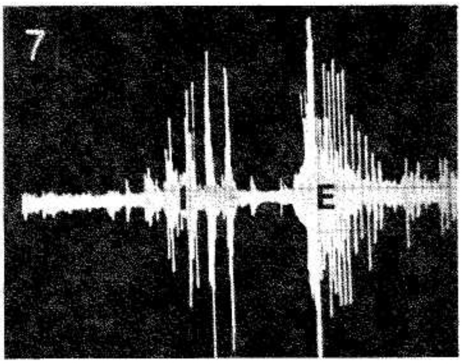

2
I

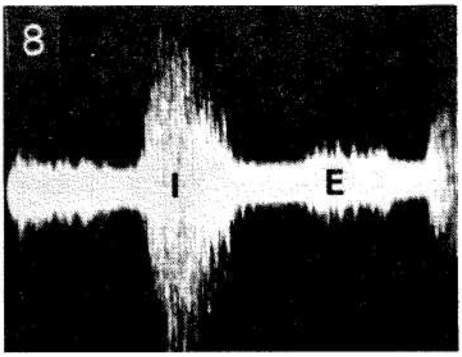

3
I

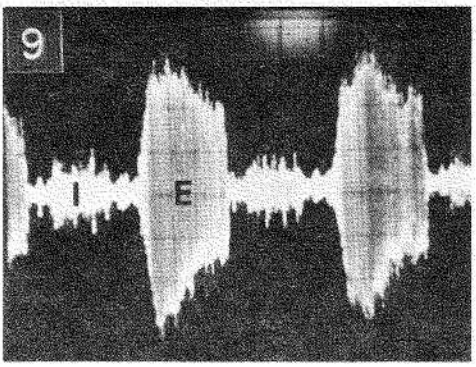

4
E
I

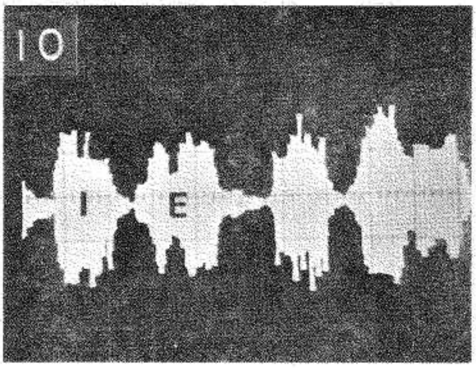

5
I
E

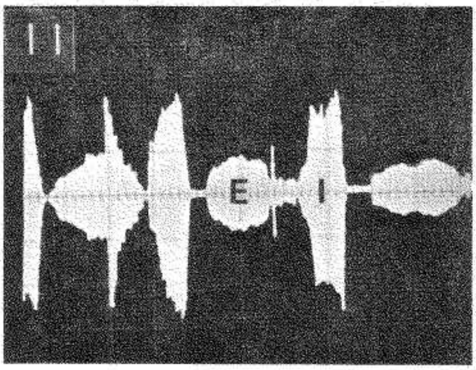

6
I
e

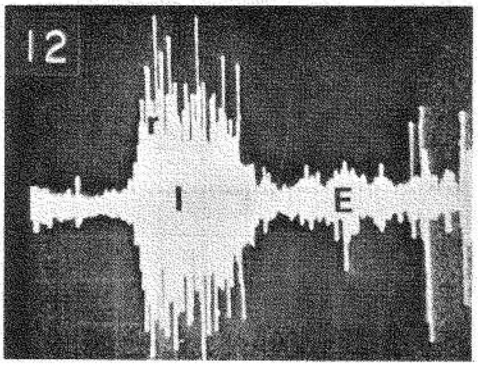

7
I
E

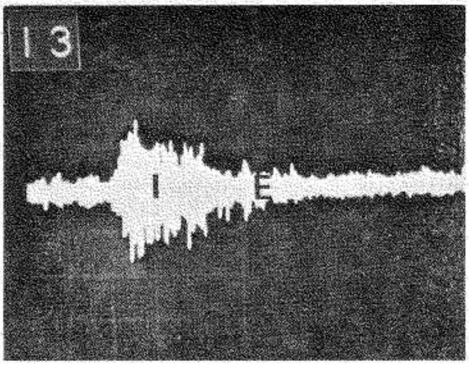

8
I
E

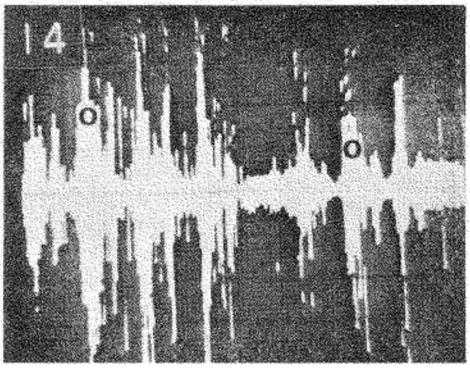

9
I
E

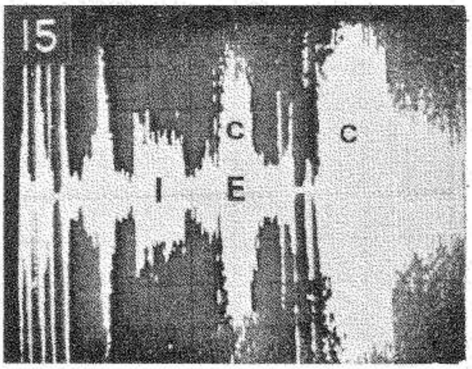

10
I
E


11
E
I


12
r
I
E


13
I
E


14
o
o


15
c
c
I
E

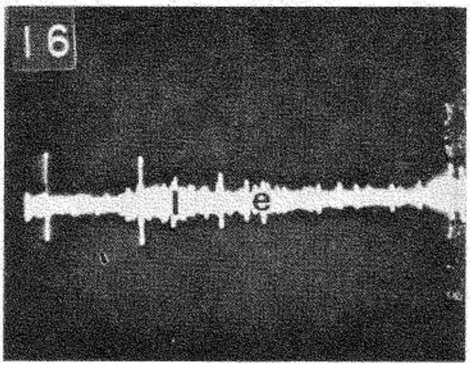

16
I
e

Fig. 9. Focal neoplastic obstruction (upper lobe bronchus). A high pitched, musical, expiratory wheeze was auscultated. Comparative tracings (not shown) at the base did not reveal this focal and diagnostic finding.

Fig. 10. Lymphangitic carcinomatosis (left base). Bronchial characteristics are presumably created by a reduced air to tissue ratio from the infiltrating tumor, paralleling the chest film and spirometric findings.

Fig. 11. Group in a tachypneic eight-month-old infant (posterior trachea). Note again the reversal of the normal postexpiratory pause (figure 4). Inspiration was short and twice the expiratory intensity. At the right base, expiration was significantly prolonged.

Fig. 12. Acute pulmonary edema rales (right base). The pattern is bronchovesicular with rales (r) limited largely to inspiration. These rales are neither as fine nor as regular as those associated with pulmonary fibrosis (figure 8).

Fig. 13. Positional effect on rales. Same patient as figure 12, ten minutes in the left lateral decubitus position recorded in the upright right base with isovolume ventilation and standard recording conditions. The breath sound intensity is reduced by approximately 0.5. Both on the recording and with the stethoscope the rales were markedly diminished.

Fig. 14. Subcutaneous emphysema complicating tracheostomy. Irregular "outspikes" created by manual compression over the tissues. A crisp, crunching sound was identical in the audio recording and the stethoscope.

Fig. 15. Coughing sequence in asthma. The pattern parallels the auscultory findings and is presented as an example of the recordable sound spectrum (C = cough).

Fig. 16. Pulmonary emphysema (right base). Inspiration and expiration are attenuated, the latter barely audible, with scattered, low intensity rhonchi in both cycles.

In summary: A system for the recording of respiratory acoustic data is described. The instrumentation is relatively simple to assemble and is essentially portable for bedside or classroom use. Acceptable signal to noise characteristics were generated and the audio and visual display were useful for analytic, clinical, or didactic programs.

EARLE B. WEISS
C. JEFFREY CARLSON
St. Vincent Hospital
Worcester, Massachusetts 01601
Lung Station (*Tufts*); and
Tufts Medical Services
Boston City Hospital
Boston, Massachusetts 02118

August 16, 1971