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Editorial

Breath sounds

To most physicians "breath sounds" mean the respiratory noise heard through the stethoscope on the chest wall. The sound of breathing, heard with the ear close to the patient's mouth is seldom observed, because its clinical significance is not generally understood. Noisy breathing as a sign of disease was recognised by Laënnec (1819), who carefully distinguished it from wheezing and other adventitious sounds.

The breathing of a healthy person at rest is barely audible at the mouth, while in chronic bronchitis or asthma it can often be heard at a distance of several feet. This noise is intensified by bronchoconstriction and silenced by inhalation of a bronchodilator aerosol. Comparative sound measurements at identical flow rates confirmed that the intensity of the inspiratory sound at the mouth is closely correlated with the forced expiratory volume in one second, the peak expiratory flow rate, and other indices of airflow obstruction (Forgacs *et al*, 1971). A notable and clinically useful exception is primary emphysema, where the inspiratory sounds remain faint even when expiration is grossly obstructed.

It is not known whether the loud inspiratory noise comes from the larynx or the intrathoracic airways, and whether it is focally or diffusely generated. Adduction of the vocal cords in response to stimuli applied to the lung has been shown in animals (Stransky *et al,* 1973), and such a reflex, capable of regulating the width of the glottic chink in parallel with the calibre of the bronchi, may also exist in man. Focal narrowing of a lobar or segmental bronchus produces a hiss audible at a distance, but its timing differs from the noisy breathing of diffuse airflow obstruction, being out of phase with the respiratory cycle. The most plausible explanation is that the loud inspiratory sounds in chronic bronchitis and asthma are generated by intense turbulence in gas flowing at high velocity through narrowed lobar and segmental bronchi. Whatever the source of the noise, there is no doubt about the value of a clinical sign that often allows airflow obstruction to be recognised as soon as the patient enters the consulting room.

The respiratory sound heard at the mouth and over the trachea consists of oscillations whose amplitude is evenly distributed over a wide range of frequencies between 200 and 2000 Hz. Its loudness follows closely the variations in flow rate, remaining fairly constant throughout inspiration and fading in parallel with the steadily falling flow rate during expiration. Despite this expiratory decrescendo the breath sounds over the trachea remain audible to the end of expiration. By contrast the breath sounds heard through the chest contain a relatively narrow range of frequencies, with maximum amplitude at 200 Hz. Above this frequency the amplitude of oscillations decreases rapidly. Unlike the breath sounds over the trachea, they fade and become inaudible soon after the beginning of expiration. Laënnec called these sounds "vesicular" to mark the contrast with "bronchial" sounds heard over the trachea and transmitted to the neck and the interscapular area.

Controversy about the source of breath sounds heard through the chest wall continued throughout the nineteenth century. Some believed that they were the attenuated and filtered remains of sound generated in the upper air passages. Others attributed vesicular breathing to oscillations set up by the impact of the gas stream on the terminal bronchioles and alveoli. An interesting observation favouring a peripheral source, reported by Sahli in 1892, was that breath sounds could be heard over lung herniated through the sternum when the patient performed a Valsalva manoeuvre.

Attenuation and selective filtration account for some of the differences between the breath sounds heard over the trachea and through the chest wall. The lung and chest wall behave like a low-pass sound filter. The sounds transmitted are greatly attenuated; moreover they contain predominantly low frequencies to which the ear is less sensitive. As a result the expiratory breath sounds, which remain audible throughout expiration over the trachea, fall below the threshold of hearing early in expiration over the chest. An extreme example of attenuation is the complete silencing of breath sounds by reflection at the interface between the lung and air in pneumothorax, and between lung and fluid in pleural effusions. The unfiltered transmission of tracheal and bronchial sounds through solid lung has always been accepted as the correct explanation of bronchial breathing.

Other features of breath sounds are inconsistent with a simple theory of filtration. Laënnec was the first to draw attention to the fact that breath sounds may be abnormally loud at the mouth, yet normal or faint when heard through the chest. Indeed, this discrepancy goes even further. The inspiratory sound at the mouth gets louder as airflow obstruction increases, while over the chest the converse is true. This paradox cannot be explained by individual differences in sound conduction through the lung. It suggests that the sounds transmitted to the mouth and to the chest originate from different sources. Another clinical observation indicating that the breath sounds heard through the chest are peripherally generated is cogwheel breathing. In some subjects the inspiratory sound at the base of the left lung rises and falls synchronously with the heart beat. The rise, coinciding with ventricular systole, is due to a momentary acceleration of the regional inspiratory flow rate as a result of sudden expansion of the territory of the lung adjoining the left ventricle.

Additional evidence of a peripheral source of breath sounds was provided by Leblanc *et al* (1970). They showed that the intensity of the inspiratory sounds at the apex and base of the lung depends not only on the flow rate at the mouth but is also correlated with the regional flow rate. Over the apex the progressive fall of the inspiratory flow rate is accompanied by a gradual fading of the breath sounds, while at the base, where the inspiratory flow rate first increases then falls, there is a corresponding rise and fall in the intensity of the breath sounds. These measurements were later extended to a study of breath sounds in relation to regional ventilation, measured with xenon-133 (Ploy-Song-Sang *et al*, 1977). After correction for regional differences in sound transmission, the intensity of the breath sounds recorded through the chest was found to be closely correlated with the corresponding scintillation counts. These counts represent a combined measurement of the volume and ventilation of the underlying territory of the lung. The correlation is less close if regional differences in transmission of sound generated at the mouth are ignored. A simple comparison of the loudness of breath sounds at different points on the chest is therefore an inaccurate test of regional ventilation, or "air entry" as it is often called in clinical parlance. Weak breath sounds in these circumstances may mean either poor sound transmission or reduced regional ventilation.

All these observations point to the same conclusion, that breath sounds heard through the chest may include a component transmitted from the upper respiratory tract, trachea, and main bronchi but are weighted by sound originating in the underlying territory of the lung. The source of the locally generated sound is not known. On theoretical grounds it is unlikely to be in the terminal airways or alveoli, where gas flow is sluggish and laminar. There is certainly no respiratory noise superimposed on the heart sounds during breath holding, although the pulsations of the heart impart large movements to gas and the solid components of the lung immediately adjoining the left ventricle. When helium is added to inspired air the breath sounds become fainter. This indicates that the source of the sound is in gas in airways where flow is turbulent, or at any rate non-laminar.

Experiments on models of the bronchial tree showed that between turbulent flow in the central airways and laminar flow at the periphery of the bronchial tree there lies an intermediate zone extending from the segmental bronchi to about the tenth generation of the airways, where the flow pattern is irregular and contains vortices (Schroter and Sudlow, 1969). Discontinuities in gas flow and periodical variations of gas pressure in these bronchi are probably accompanied by oscillations at acoustic frequencies.

The breath sounds heard through the chest of a healthy person are more accurately described as "normal" rather than "vesicular." They contain a proportion of filtered and attenuated noise transmitted from the upper respiratory tract, but are dominated by sound generated by turbulent flow in the corresponding lobar bronchi and by irregular flow patterns in an uncertain and variable number of more peripheral branches. Selective transmission of these locally generated sounds to the corresponding area of the chest wall accounts for the correlation between the regional flow rate and the intensity of the breath sounds.

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