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SERIES 'CHEST PHYSICAL EXAMINATION'
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Chest percussion

J.C. Yernault*, A.B. Bohadana**

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ABSTRACT: The direct method of chest percussion, first described by Auenbrugger but disseminated by Corvisart, has rapidly been replaced by the indirect or digitodigital method.

Chest percussion has not been evaluated by modern acoustic means, so that our present knowledge of the method does not consistently differ from the 19th century approach. Auscultatory percussion is not superior to conventional percussion.
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*Service de Pneumologie, Cliniques Universitaires de Bruxelles, Hôpital Erasme, Brussels. **Service de Pneumologie, Centre Hospitalier Universitaire de Nancy-Brabois et Institut National de la Santé et de la Recherche Médicale, INSERM - Unité 115, Santé au Travail et Santé Publique, Vandoeuvre-les-Nancy, France.

Correspondence: J.C. Yernault, Service de Pneumologie, Cliniques Universitaires de Bruxelles, Hôpital Erasme, Route de Lennik, B–1070 Bruxelles

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Historical background

Although percussion of the abdomen seems to date back to antiquity [1], chest percussion was first described in 1761 [2] by Leopold Auenbrugger, who was born in 1722 in Graz (Austria) in the inn called "Zum schwarzen Mohren" [3]. It was there that Auenbrugger saw his father striking barrels in order to determine the level of liquid inside. This observation induced him to start percussing the chest when he was working in the Vienna Spanish military hospital, with the aim of tapping and draining pleural effusions. Relying on anatomoclinical confrontations, he developed the method of direct or immediate percussion for 7 years before his first publication. Striking the clothed chest with the tips of all the fingers held together firmly (or using a leather glove to strike the bare skin), he made the basic observation that, when percussed, a healthy man's thorax is resonant: "*Thorax sani homini sonat si percutitur*". Auenbrugger recognized three categories of sounds: a "*sonus altior*" (tympanic), a "*sonus carnis*" (dull) and a "*sonus obscurior*" of indistinct quality.

Although a first French translation of Auenbrugger's work was published in 1770 by Rozière de la Chassagne from Montpellier, percussion was not immediately accepted as a valuable tool. In 1782, Tissot [4] wrote: "According to a German physician, if the chest covered with a simple shirt is struck with the hand, it gives back a dull sound on the side where vomica is, as if one was striking a flesh piece, whereas if the chest opposite side is struck, it gives back a resonant sound, as if one was striking a drum. However, I still doubt that this observation is generally correct".

Although Auenbrugger found a supporter in Maximilian Stoll, who was professor of the medical clinic in Vienna from 1778 to 1787, percussion did not meet with great success until it was propagated by Corvisart [5] working in Paris. He used the palmar surface of the extended and approximated fingers to percuss the chest. Convinced that "sense organs, education and exercise are mandatory for physicians to become commendable at the patient's bedside", Corvisart employed percussion as the main method to discover the nature and the localization of several diseases. Extending and further evaluating Auenbrugger's initial observations, he communicated his enthusiasm to his students, including René Théophile Hyacinthe Laënnec. That Laënnec, before his discovery of mediate auscultation, was regularly percussing his patients is testified by Grandville [6], who wrote: "It was Laënnec's habit, when examining a newly admitted patient, laboring under pectoral disorder, to percute him in every part of the chest, both in front and at the back, as well as on either side. After which he would apply the ear to any part which resounded badly or imperfectly". Acknowledging that percussion was unquestionably one of the main discoveries in medicine, Laennec [7] realized, however, that it was not a sensitive tool in pulmonary phthisis. He insisted on the value of adding percussion to auscultation with the cylinder for the diagnosis of emphysema, pneumothorax and pleural effusion. It was a book by Forbes [8] which introduced the techniques of percussion and auscultation into the English literature.

Piorry [9] developed the indirect or mediate percussion: "mediate percussion consists in an impulse given to a resonant and solid body, applied on an organ or a cavity, in order to obtain a sound related to the physical state of these parts". Piorry described several circumstances in which direct percussion was inadequate or not feasible [10]: 1) it can be painful in cases of inflammation of the pleura; 2) a thick subcutaneous tissue hinders the useful auditory sensations obtained; and 3) sounds obtained with the palm of the hand set a large area into vibration, and may miss small circumscribed lesions.

The solid body, called a plessimeter, was struck with the tip of the right index finger, sometimes together with the middle finger. The ideal plessimeter was found to be a circular ivory sheet, 5 cm in diameter and 2.5 mm in thickness, that could be screwed onto the end of a Laënnec stethoscope. Some physicians replaced the striking finger by a percussion hammer, whereas others, such as William Stokes and James Hope, who assisted in Piorry's lessons, tried to further simplify the method by using their left middle finger as a plessimeter [11]. Although Piorry disliked this simplification, it was adopted by well-known clinicians, such as SKODA [12] who became the advocate of percussion in Europe.

Skoda attempted to replace the imprecise flowery terms used by his French predecessors, by describing four types of percussion notes [13]: 1) full-empty; 2) clear-dull; 3) tympanic-nontympanic; and 4) high-low.

According to BARTH and ROGER [14], in 1855 Woilliez also described three fundamental characteristics of percussion notes: 1) the intensity, which can be normal, low or high; 2) the tone, which can be normal, low or high; and 3) the thoracic elasticity, which is perceived by the percussing finger.

One of the reasons for BARTH and ROGER [14] to prefer digitodigital percussion over the original plessimeter method was that "the finger is always available to the physician, who might be embarrassed by the loss of his plessimeter"!! They described the technique of digitodigital percussion as follows: "the whole left hand, applied on the region whose sonority has to be known, is kept fixed; then the middle finger is isolated from the other fingers. Movements of the right hand which is striking must originate neither from the shoulder nor from the elbow, but exclusively from the wrist". The number of striking fingers (from one to three) will vary according to the force of the impulse which is needed; this force must initially remain gentle, and can then increase progressively. In pathological cases, the percussion notes may vary from tympanic (like the note which is perceived over the stomach gas bubble) to flat (like the note perceived over the liver). Hyperresonant or tympanic notes are heard in cases of emphysema, pneumothorax or large superficial cavities; whereas, dull or flat notes are produced over zones of collapsed or condensed lung, or of accumulation of fluid in the pleural cavity. In cases of massive pleural effusion, compressing the underlying lower part of the lung and even reducing the volume of its upper part, SKODA [12] unexpectedly found a hyperresonant note when striking the upper part of the anterior chest under the clavicle. The so-called "Skoda's resonance" was born, for which no satisfactory explanation has yet been given. OSLER [15] wrote: "In a pleural effusion the percussion signs are very suggestive. In the subclavicular region the attention is often aroused at once by a tympanitic note, the so-called Skoda's resonance... it shades insensibly into a flat note in the lower regions. Skoda's resonance may be obtained also behind, just above the limit of effusion". He further stated "the dullness has a peculiarly resistant, wooden quality, differing from that of pneumonia and readily recognized by skilled fingers", so insisting on the role of the tactile sense in percussion. However, the role of the tactile sense in percussion was not confirmed by other authors, like SERGENT [16], because resistance to the finger usually follows the dullness.

According to LETULLE [17], in 1876 Noël Guéneau de Mussy started studying the transonance of the lung apex by striking the clavicle whilst simultaneously auscultating the corresponding supraspinous fossa. Also used by NAESSENS [18] in order to detect enlarged hilar nodes, the combination of auscultation and percussion was given a second youth by GUARINO [19] under the name "auscultatory percussion".

The physics of percussion

The physics of chest percussion is dominated by the transmission properties of the respiratory system, a matter previously discussed by RICE [20]. From a physical standpoint, the respiratory system can be considered as a coupled system, composed of the chest wall and the lung placed in series. Under the influence of an external shock, the chest wall tends to vibrate and "ring", as a resonant cavity partially damped by the thoracic contents.

In normal conditions, the vibrations of percussion are underdamped, as a consequence of the large acoustic mismatch observed between the chest wall and the underlying lung parenchyma. Such mismatch is due to the fact that the acoustic impedance of the semi-rigid chest wall is quite dissimilar to that of the lung parenchyma, a structure that behaves like homogeneous mixture of gas and tissue. (The acoustic impedance (Z) of a medium, is the product of the density of the medium by the sound velocity in the medium. The proportion of sound energy transmitted across a boundary between two acoustic media (T) is a function of the acoustic impedances ($Z1$ and $Z2$) of the two media; $T=4Z1Z2/(Z1+Z2)^2$). Therefore, a large proportion of the vibratory energy of percussion is reflected at the gas-tissue interface, yielding a clear, long-lasting sound described as resonant.

If the underlying lung parenchyma is replaced by air, as in pneumothorax, the acoustic mismatch is maximal so that underdamping is even more pronounced. The result is a sound of greater amplitude and duration, which has a frankly musical quality described as tympanic.

Finally, in situations where the alveolar air is replaced by exudate and/or solid tissue, the acoustic mismatch between the chest wall and the underlying tissue is minimal, because the acoustic impedances of these two structures are similar to one another. Consequently, percussing vibrations are overdamped; they propagate away from the surface very rapidly and vanish quickly, resulting in a sound of low amplitude and short duration described as dull.

To the best of our knowledge, the physical characteristics of lung percussion have never been documented using modern technology. Incidentally, the most recent study on this matter was published by McKusick *et al.* [21] almost 40 years ago. Using a sound spectrograph, these authors described the acoustic parameters of percussion notes in a small number of selected subjects. Their main observations can be summarized as follows: 1) the three percussion notes - tympanic, resonant, and dull - have in common a central core, originated from the sound of impact of the percussing finger on the plessimeter finger; 2) the resonant note is, to great extent, composed by additional vibrations which are maximal in the range of the natural frequency of the thorax (the natural frequency (f) depends on the tendency of an elastic structure when deformed from its position of rest to return to that position; f is directly proportional to density and inversely proportional to volume); 3) in the case of a dull note, such additional vibrations are absent because the impulsive force is not able to set the structures under the percussing finger into vibration to any significant extent. Compared to the resonant sound, the dull sound was found to be of higher pitch, a finding explained not only because vibrations of higher frequency have been excited (as, for instance, in consolidated lung tissue [22]) but mainly because the average pitch of the dull note is not weighted by the low-frequency vibrations of the thorax; and finally, 4) compared to the other sounds, the tympanic sound (recorded over the stomach bubble) showed a discernible musical quality reflected by the presence of clearly defined harmonics.

Chest percussion in health and disease

A full description of the acoustic characteristics of chest percussion assessed by subjective means is available in excellent textbooks [23, 24], and will not be attempted here. However, a clinically relevant aspect should be stressed: in healthy, nonobese individuals, the sonority of chest percussion may not be uniform, varying somewhat according to the zone considered. In general, the posterior lung zones are less sonorous than the anterior ones, because of the combined effect of muscle layer, interposition of scapula and the lesser elasticity of ribs at that level.

On the other hand, the percussion of the axillary zone usually yields a more resonant sound, which may, occasionally, become frankly tympanic. Finally, in case of extreme obesity, the method of lung percussion may be of limited value as the percussing sound is generally muffled or even inaudible.

In pathological conditions, the sound of percussion may be altered in many ways. The most typical example is the presence of dullness in diseases associated with pleural effusion and/or alveolar filling by exudate or consolidated tissue. In general, the degree of dullness correlates well with the extent of the effusion (or consolidation) and with the distance of the lesion from the chest wall, assessed radiographically. However, on occasion, the presence of dullness may antedate the radiographic abnormalities by a period of time, ranging from hours to days [25].

An exaggeratedly resonant (but not tympanic) sound is a usual finding in patients with bronchial asthma or, more typically, severe emphysema. Nevertheless, this hyperresonant note is not pathognomonic of these two conditions, being merely a manifestation of increased thoracic gas volume. Finally, a clearly tympanic sound generally indicates the presence of air in the pleural space.

Conventional percussion (CP) *versus* auscultatory percussion (AP)

It is well-known that lung lesions too small - less than 2–3 cm in diameter - or too deeply situated in the lung parenchyma - about 5–7 cm away from the chest wall - are beyond the reach of conventional percussion [23, 24]. In order to circumvent this limitation, Guarino [19] further developed the auscultatory percussion. Briefly, it consists of tapping lightly over the manubrium sterni with the distal phalanx of one finger, whilst listening with a stethoscope over the chest wall posteriorly; a decrease in sound amplitude is usually ascribed to lung abnormality. Using this technique, Guarino [19] claimed to be able to detect intrapulmonary lesions in 28 patients, all of whom had an abnormal chest roentgenogram and a normal or equivocal examination by conventional percussion; in three cases the diameters of the lesions were less than 2 cm.

Subsequently, some attempts have been made to reassess the validity of the two methods of percussion using the chest roentgenogram as gold standard, but the results are rather conflicting. In one study [26], 281 random patients were examined by two physicians independently, in a blind fashion. Roentgenographic abnormalities were found in 96 patients. The best results showed CP to be only 9% sensitive but 99% specific in detecting roentgenographic abnormalities; whereas, AP was 15% sensitive and 88% specific. Three years later, Bourke *et al.* [27] performed similar experiments: 50 patients were examined by two physicians alternating between AP and CP. Twenty six percent of 100 lungs had radiographic abnormalities. CP was found to be 15% sensitive and 97% specific, and AP to be 19% sensitive and 85% specific.

Hansen *et al.* [28] reported more favourable results: 53 patients with either normal (n=21) or abnormal (n=32) chest roentgenograms were examined in a blind manner by means of the two methods of percussion. In contrast to the two studies previously mentioned, AP was found to be 86% sensitive and 84% specific, whereas CP was 76% sensitive and 100% specific.

Discrepancies on the performance characteristics of the two methods of percussion were somewhat clarified by two further studies. In the first, Bohadana and Kraman [29] examined the effect of lung volume and respired gas composition on the transmission of sternal percussion-generated sound. They observed that, in a group of healthy individuals, the amplitude of the transmitted sound recorded over the posterior wall tended to be greater over the upper chest than the mid and lower chest, especially at total lung capacity and residual volume. In the second study by the same team [30], sound produced by sternal percussion was recorded at 63 evenly spaced points over the posterior chest wall of three healthy subjects and four patients with large, discrete intrathoracic lesions in the right upper lobe (two patients), left lower lobe (one patient), and left upper lobe (one patient). Three dimensional contour maps of the indices of sound amplitude and frequency were constructed in order to view graphically the pattern of the sound distribution. Areas of increased amplitude were found in the zones of projection of some osseous structures, especially the scapulae, both in the healthy subjects and in the patients. Moreover, no disturbances in the pattern reflecting the presence of mediastinal structures or intrathoracic lesions were found, despite the existence of deeply situated lung masses as large as 10 cm in diameter. The findings of these two studies support the argument that the sound of sternal percussion travels to the posterior chest predominantly through chest wall structures and not along a straight path through the lung parenchyma.

The above interpretation helps in understanding the good results reported by Hansen *et al.* [28]. In fact, it is apparent from their paper that their patients had a high prevalence of lesions in close contact with the chest wall (*e.g.* pneumonia, hydrothorax, pulmonary infarction). Since the acoustic impedance of fluid and consolidated lung tissue is similar to that of the chest wall, the sound travelling through the chest cage would be diverted away and dissipated. This mechanism, which would also explain the similarity of sensitivity of AP and CP observed by Hansen *et al.* [28], is in agreement with the previous observation that AP and CP are equally effective in detecting large pleural effusions [26].

Interesting results on the usefulness of auscultatory percussion have recently been published by Nelson *et al.* [31]. These authors compared the performance characteristics of the two methods of percussion (and auscultation) in patients with human immunodeficiency virus (HIV) infection, using chest roentgenograms as the gold standard. Sixty three patients were examined by one to three examiners. Radiographic abnormalities were found in 70 out of 126 lungs (56%) The best results were observed for AP, with sensitivity and specificity for detecting radiographic abnormalities ranging 51–69% and 75–94%, respectively. For CP, the figures observed were compatible with those previously reported in the literature: sensitivity ranging 8–27% and specificity ranging 93–96%. Interestingly, AP was the most sensitive method to detect radiographic abnormalities in patients with *Pneumocystis carinii* pneumonia confirmed by positive silver stain of either induced sputum or bronchial washings.

However, as pointed out by Nelson *et al.* [31] themselves, the results obtained in a highly selected group of subjects with a high prevalence of radiographic abnormalities, heavily weighted toward diffuse interstitial lung disease, cannot be extrapolated to usual clinical settings, where a high rate of false positive results have been observed (unpublished personal observations).

Percussion of the heart

A common problem in differential diagnosis is to separate respiratory from cardiac causes of dyspnoea. Percussion can help in the bedside diagnosis by demonstrating cardiomegaly. Providing that patients with chronic obstructive pulmonary disease (COPD) and chest deformities were excluded, Heckerling *et al.* [32] found in a series of 100 patients complaining chiefly of dyspnoea, a high correlation coefficient ($r=0.65$; $p<0.00001$) between the cardiothoracic ratio (which was above 0.5 in 36 cases) and the breadth of the "percussion distance" measured at the level of the fifth left intercostal space between the midsternal line and the left heart border (the point where the dullness is replaced by a resonant sound). In this population, a percussion dullness more than 10.5 cm had a sensitivity of 94% to detect an increased cardiothoracic ratio, but a specificity of only 67%; for a percussion dullness of more than 11 cm, the specificity increased to 91%, but, of course, at the expense of a lower sensitivity (89%).

In conclusion, in contrast to lung auscultation, chest percussion has not recently been studied with modern acoustic methods, and its clinical value is not well established. The proposals by Laënnec that it should complement auscultation in the differential diagnosis of emphysema, pneumothorax and pleural effusion seems to remain valid today. It is also of interest for the diagnosis of pneumonia in geriatric patients unable to breathe deeply on command and in whom crackles are frequently lacking [33]. There is no solid evidence that auscultatory percussion should replace the conventional digitodigital percussion.

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