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Vocal resonance: a narrative review

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Abstract

Physical examination is an important ritual of bedside medicine that establishes a strong bond between the patient and the physician. It provides practice to acquire important diagnostic skills. A poorly executed bedside examination may result in the wrong diagnosis and adverse outcomes. However, the ritual of obtaining a patient's history and performing a good clinical examination is declining globally. Even the quality of clinical examination skills is declining. One reason may be the short time spent by physicians at the bedside of patients. In addition, due to the substantial technological advancement, physicians often rely more on technology and consider clinical examinations less relevant. In resource-limited settings, thorough history-taking and physical examinations should always be prioritized. An important aspect of respiratory auscultation is the auscultation over the chest wall to detect abnormalities in the transmission of voice-generated sounds, which may provide an important diagnostic clue. Laënnec originally described in detail three types of voice-generated sounds and named them bronchophonism, pectoriloquism, and egophonism. Subsequently, they are known as bronchophony, whispering pectoriloquy, and egophony. A recent variant of egophony is "E-to-A" changes. We searched PubMed, EMBASE, and the CINAHL from inception to December 2023. We used the following search terms: vocal resonance, bronchophony, egophony, whispering pectoriloquy, auscultation, etc. All types of studies were chosen. This review will narrate the physics of sound waves, the types of vocal resonance, the mechanisms of vocal resonance, the methods to elicit them, and the accuracy of vocal resonance.

Key words: bronchophony, egophony, whispering pectoriloquy, vocal resonance.

Types and causes of vocal resonance

Vocal resonance is produced by the vibration of vocal folds. They are not generated in the lungs, unlike breath sounds and adventitious sounds. Vocal resonance is subsequently modulated by the filter function of the supralaryngeal airway [1]. Vocal resonance is classified as bronchophony, whispering pectoriloquy, and egophony. Normally, in a healthy person, the vocal resonance appears unintelligible, distant, and muffled. This is due to the filtering effect of air-filled lungs, resulting in the loss of higher frequencies [1]. However, in patients with respiratory diseases such as consolidation, upper border of pleural effusion, pulmonary cavitation, and pulmonary fibrosis, abnormal vocal resonance such as bronchophony, whispering pectoriloquy, and egophony may be heard. Whenever in doubt about the presence of bronchial breathing, it's very important to check for whispering pectoriloquy, as whispering pectoriloquy is always present along with bronchial breath sound [2]. The clinical usefulness of vocal resonance is much debated. Hla KS evaluated the frequency of performing vocal resonance and the general practitioner's perception of the importance of vocal resonance [3]. The study revealed that the majority of general practitioners (65.7%) rarely perform vocal fremitus/vocal resonance as a routine during a physical examination of the chest. About 53.7 % disagreed that routine use of vocal resonance on chest examinations was desirable. There are several strategies that can be adopted to improve bedside clinical skills. These include spending enough dedicated time in bedside clinical examination, regular training of clinicians and residents on dedicated bedside teaching, adoption of hypothesis-driven physical examination, and coupling of technology along with clinical examination.

Physics of sound waves

Different features of sound waves include pitch, frequency, loudness, timbre, and formants. Frequency is defined by the number of times a repeating event occurs during a specified time interval and is denoted by the unit "Hertz". The human ear is capable of detecting sound waves with frequencies ranging from approximately 20 Hz to 20,000 Hz. Pitch is the sensation of a frequency. A high-pitched and a low-pitched sound correspond to a high-frequency and a low-frequency sound wave, respectively. Amplitude depicts the height of a sound wave. It is measured in decibels (dB). The American National Standard (ANSI) defines timbre as that attribute that allows us to distinguish between sounds having the same perceptual duration, loudness, and pitch [4]. Formants are the peaks in the spectrum of a sound wave. The Acoustical Society of America (1994) defines formant thus: "of a complex sound, a range of frequencies in which there is an absolute or relative maximum in the sound spectrum" [5]. The highest frequency in the formant spectrum is called the "formant frequency." Vowels are distinguished from each other by formant frequencies. The lowest frequency component of a complex sound wave is called the fundamental frequency, or primary frequency. It is also known as F0 or first harmonics. Harmonics is the integral multiple of the fundamental frequency. If the frequency is greater than the fundamental frequency, it is called an overtone. Vocal resonance consists of a fundamental frequency and several overtones.

Methods of eliciting vocal resonance

Vocal resonance should always be elucidated in a sitting posture, and it is of utmost importance to ensure the tone and intensity are equally maintained as nearly as possible while examining the two sides. The clinician places the stethoscope over symmetric areas of the patient's chest wall and asks the patient to speak words such as "one-two-three" or "ninety-nine." For elicitation of vocal resonance, words with diphthongs are the most suitable. A diphthong is a sound made by combining two different vowels. Ninety-nine is a literal translation derived from the German word 'neunundneunzig' that has many diphthongs and is used by German physicians in their clinical practice. The word "ninety-nine" has fewer vowels and is less effective in evoking the phenomenon [6]. According to William Dock, this literal translation was a serious linguistic error [7]. In his 1973 publication in the Bulletin of the New York Academy of Medicine, he reported that the word "Ninety-nine" was inappropriate for physical examination as he showed that unlike 'neunundneunzig', the word "Ninety-nine" did not produce the necessary vibrations required for elicitation of vocal resonance. Vocal resonance will be better transmitted and become well-distinct in a condition where the air in the lungs is replaced with fluid or solid substances or the lungs undergo atelectasis. Vocal resonance is dominant in males and is feeble in woman and children. Woman and children have high-frequency voices whereas males have low-frequency voices. Our airway more closely resembles voices of low-frequencies [8].

Mechanism of vocal resonance

The healthy air-filled lungs and chest wall act as a low-pass filter and allow only sound waves of 100–300 Hz to pass through [9]. The vocal resonance are produced by the vibration of the vocal cords set in by exhaled air, whereas, the lung sounds are generated within the lungs [1]. The vocal resonance consist of a fundamental frequency and overtones that contain frequencies higher than the fundamental frequency. Normal lungs act as a low-pass filter, blocking the passage of high-frequency sound waves. Typically, lung sounds peak at frequencies lower than 100 Hz, and between 100 and 200 Hz, a sharp drop of sound energy occurs [10,11]. Due to the low-pass filtering effect, the formant frequencies, being a maximal frequency, are eliminated from the vowels. The formant frequencies help in distinguishing vowels from each other. Moreover, the recognition of vowels is essential for the comprehension of words [6]. These are the reasons that explain the muffled, low-pitched, and unintelligible character of the vocal resonance in a healthy person. However, clinical conditions that replace alveolar air with solids and liquids, such as consolidation, pulmonary edema, etc., will improve the transmission of higher frequencies and make vocal resonance louder, clearer, and more intelligible.

Subtypes of vocal resonance

Egophony is a voice-generated sound characterized by the high-pitched or nasal quality of the patient's voice. Egophony is characterized by a change in the timbre or quality of sound waves. The pitch or volume of the sound waves is not altered [12]. Etymology suggests that egophony is derived from the Greek word aigós (αἴξaix, aig-), which means "goat's," and phoné, which is "sound". This is due to the bleating quality of the sound [12,13]. Laënnec classically described this sound in his book "A Treatise on the Diseases of the Chest and Mediate Auscultation / by R.T.H. Laennec; translated from the French by John Forbes" described egophony as a trembling or bleating sound like the voice of a goat [14]. Laennec sought egophony by auscultating the patient with the cylinder applied strongly to the patient's chest. He initially described it in patients with moderate pleural effusions. Abnormally vocal resonance have been detected in areas where bronchial breath sounds are audible. Egophony is elicited by asking the patient to utter the word "E." It is normally heard on the chest wall as a muffled "E." but in consolidated lungs, "E" will be transformed into an "A" along with a nasal or bleating quality.

Shibley GS, who was practicing missionary medicine in China, reported the sign of vowel transformation in patients with consolidation or fluid-filled lungs in 1922 [15]. He observed that all the spoken vowels, such as A, E, I, O, and U, were heard as AH when auscultated over the pathological area. He discovered this sign accidentally while routinely examining the chests of the Chinese patients. As a customary practice, he asked the patients to utter the word ''one, two, three'' and the patients in Mandarin said ''i, er, san.'' In pathological areas, "I" was heard as "AH." He also reported that all the vowel sounds are altered towards the "AH" quality even in healthy lungs. However, the distinctive feature of egophony is the suddenness and intensity of the change with which it appears in areas of the chest where normal lungs are replaced by pathological lungs.

The E-to-A change is a paradox, as the E sound heard at the mouth is higher in pitch than the A does, and consolidated lungs favor higher-frequency sound to pass through the chest wall [6]. This paradox can be explained by the following facts; both E and A contain high-and low-frequency sound waves. The fundamental frequency and harmonics of sound E are about 130 Hz and 390 Hz, respectively, whereas the high-frequency components or overtones vary from 2,000 to 3,500 Hz. The vowel A has a fundamental frequency and harmonics of 120 Hz and 600 Hz, with the high-frequency component ranging from 1,500 to 3,000 Hz [16]. Although the consolidated lung can transmit higher frequencies than a normal lung, it cannot transmit frequencies as high as 2000–3500 Hz [1]. Therefore, high-frequency components of both E and A are not transmitted. However, consolidated lungs favor the low-frequency of A more than the low-frequency of E. since the low-frequency of A is higher than that of E, it explains the E-to-A change. The E-to-A change can also happen at the upper border of pleural effusion. In a patient with a large pleural effusion, there is an upward displacement and compression of the lung above the level of effusion, making it more solid than normal and a better transmitter of high-frequency sound [1].

Egophony is a pathological sign that has been detected in patients with consolidation, at the upper border of pleural effusion, lung cavity, and lung fibrosis. In a patient with pleural effusion, the fluid may displace and compress the lungs at the upper border of pleural effusion. Occasionally, effusion may cause circumferential compression of the lungs which may cause egophony being heard all over the area of the effusion [17]. In a case of consolidation, egophony is heard when the consolidated lungs extend from the chest wall to the tracheobronchial tree. Egophony may be heard in normal subjects over the anterior neck [12].

Whispering pectoriloquy is characterized by an abnormal increase in the clarity of whispered vocal sounds during auscultation, such as "one-two-three" or "ninety-nine" [18]. In a healthy individual, the words are heard faintly. However, in patients with consolidation, the whispered sounds are heard clearly and distinctly. Normally, the frequency of sound waves in speech lies below 300 Hz, and in the case of glottic hiss, it is up to 5000 Hz. However, whispered speech requires a speech frequency above 400 Hz. Therefore, they are audible in patients with consolidation and pleural effusion [19]. In bronchophony, there is an increase in the intensity and clarity of the patient's spoken voice, but the sounds are unintelligible. Durrant considered that bronchophony was due to either an enlarged caliber of the bronchial tubes or an abnormal density of the pulmonary tissues, which became better conductors of sound [20]. The accepted theory of bronchophony is the loss of air-containing lung tissues and its low-pass filtering effect. Although the hand is less sensitive than the ear in detecting sound waves, lower frequencies of 100 to 200 Hz are better appreciated by the hand [21]. However, pleural effusion impairs the transmission of lower frequencies. That is the reason why pleural effusion decreases tactile fremitus but increases vocal resonance.

Accuracy of vocal resonance

The accuracy of a clinical finding can be measured by likelihood ratios [20]. The positive likelihood ratio measures the probability of a disease being present when a clinical finding is present. The negative likelihood ratio measures the probability of the presence of a disease in the absence of a clinical finding. The positive likelihood ratios of egophony and bronchophony in pneumonia are 6.8 and 3.3, respectively [22]. Another statistical measure that can be used in clinical diagnosis is the interobserver agreement. It is defined by the degree to which two or more independent observers report the same observed values after measuring the same events. The inter-observer agreement is measured by the kappa statistic, or kappa coefficient, and a value of one indicates perfect agreement [23]. Wipf et al. reported kappa statistics for bronchophony and egophony of -0.14 to 0.22 and -0.10 to 0.18, respectively [24]. Spiteri et al. studied the agreement among 24 physicians on the presence or absence of respiratory signs and reported the kappa value of whispering pectoriloquy as 0.11 [25]. Therefore, whispering pectoriloquy has the lowest inter-observer agreement. Metlay et al. [26], in a review of several studies, found that the positive predictive value of egophony ranged between 20% to 56% for the diagnosis of pneumonia.

Besides conventional stethoscope, other methods to examine vocal resonance include computerized stethoscope, ultrasound, microphone arrays, and wavelength analysis and support vector machines. All these are based on same principles [27-29].

Other varieties of vocal resonance

Amphoric vocal resonance: Amphoric vocal resonance is characterized by the metallic character of the voice sounds and is typically heard over a large communicating lung cavity or open pneumothorax. It is similar to the sound produced by speaking into an empty or partially-filled pitcher [20].

Artificial vocal resonance: Artificial vocal resonance is elicited by percussing repeatedly or tapping the patient's thyroid cartilage in cases of deaf mutism, aphonia, and coma [30]. This method produces sounds similar to auscultation of the chest.

Conclusions

Bedside teaching is one of the important learning methods in medical education, and it involves teaching the students in the presence of their patients. Auscultation of the chest is one of the oldest bedside diagnostic techniques, and assessment of vocal resonance is an integral part of clinical examination of the respiratory system. Various auscultatory maneuvers, including vocal resonance, can help in predicting the likelihood of various respiratory diseases such as pneumonia, pleural effusion, etc. Respiratory examinations should be taught in medical schools and should be followed religiously by medical students and doctors. The technological advances should not be viewed as an alternative but as a supplement to bedside teaching.

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