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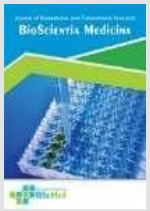

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The Art of Diagnosis from Breath Sound: A Literature Review

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A B S T R A C T

Breath sounds provide relevant information related to lung abnormalities. It is often difficult to differentiate between breath sounds, this is due to the different characteristics of each breath sound. Differentiating the types of breath sounds is crucial in making an accurate diagnosis. Breath sounds are divided into normal breath sounds and abnormal (additional) breath sounds. Normal breath sounds are sounds that originate from the chest wall, such as tracheal, bronchial, bronchovesicular and vesicular breath sounds. Meanwhile, abnormal (additional) breath sounds are breath sounds that indicate an abnormal condition in the respiratory system. Normal and abnormal breath sounds have different characteristics such as intensity, duration, frequency, quality of air flow, air flow pattern, air distribution, body position, location of sound production, changes in pressure and vibration of dense tissue in the lungs.

1. Introduction

Breath sounds are an important indicator in assessing abnormalities in the respiratory system.[1] The mechanism of breath sounds helps with physical examination, especially with regard to lung auscultation. Knowing the physiology and pathophysiology of breath sounds is very helpful in examining breath sounds. Even though many advanced technologies have been used to identify breath sounds, a basic physical examination is still needed to study them further.[2] Breath sounds provide relevant information related to lung abnormalities.[3] It is often difficult to differentiate between breath sounds due to the different characteristics of each breath sound.[5] Differentiating the types of breath sounds is crucial in making an accurate diagnosis.[6] Breath sounds are divided into normal breath sounds and abnormal (additional) breath sounds. Normal breath sounds are sounds that originate from the chest wall, such as tracheal, bronchial, bronchovesicular, and vesicular breath sounds. Meanwhile, abnormal (additional) breath sounds are breath sounds that indicate an abnormal condition in the respiratory system. Normal and abnormal breath sounds have different characteristics, such as intensity, duration, frequency, quality of air flow, air flow patterns, air distribution, body position, location of sound production, pressure changes, and vibrations of dense tissue in the lungs.[4,6,7] Research conducted by Kiyokawa and Pasterkamp on variations in the location of breath sounds stated that abnormal (additional) breath sounds provide important clinical information. This information is related to air flow movements, changes in lung tissue and changes in

morphology and secretions. Accurate interpretation is influenced by the clinician's experience, his ability to hear well, his knowledge of the variations in breath sounds, and remember individual patterns.[8] According to the European Respiratory Society Sub Division of Breath Sounds, there have been several changes and statements in the nomenclature of breath sounds from year to year. Among the most basic normal breath sounds are vesicular, the term "crepitation" changed to "fine crackles" or wet crackles and "rales" changed to "ronchi".[9] This study aims to explore the mechanisms of normal and abnormal breath sounds that are found every day.

Physiology of breath sounds

The condition for breath sounds to occur is air flowing in the respiratory tract. Airway stability is highly dependent on the properties of lung tissue, intrapulmonary airways, and the pressure exerted by the airways (both internal and external). During the respiratory cycle, there is a pressure difference between the air in the atmosphere and the air in the lungs. Changes in pressure that occur during the inspiratory and expiratory phases cause air to flow in and out of the airways. This movement of airflow then causes breathing sounds to appear. Airflow patterns are influenced by airway branching, variations in airway diameter, and the shape of the airway wall surface in the tracheobronchial pathway.[4,10]

There are three types of airflow patterns, namely turbulent airflow, transitional airflow (vortex/vortex), and laminar airflow. Turbulent and transitional air flow (vortices/vortex) is a flow of air that can produce breathing sounds.[2] Turbulent airflow is airflow that is fast and moves turbulently. Air molecules move randomly and collide with each other's airway walls. This movement can be against the airflow. Colliding air molecules produce rapid pressure changes in the airways, resulting in sound. Turbulent airflow occurs in the trachea, main bronchi, and other large airways.[1,4,10]

Transitional airflow is airflow that is forced to change direction suddenly in the bifurcation of the airways. The airflow separates into layers and moves at different speeds. Transitional airflow (vortex/vortex) is an airflow in the form of a vortex, which occurs in the bronchial tree.[1,4,10] Meanwhile, laminar airflow occurs in the small airways, terminal airways, and respiratory bronchioles. Laminar airflow is slower and nonturbulent. In this flow, there is no change in pressure, flow pattern, or airway walls, resulting in inaudible breathing sounds. An explanation of the three air flows described above can be seen in Figure 1.[1,4,10,11]

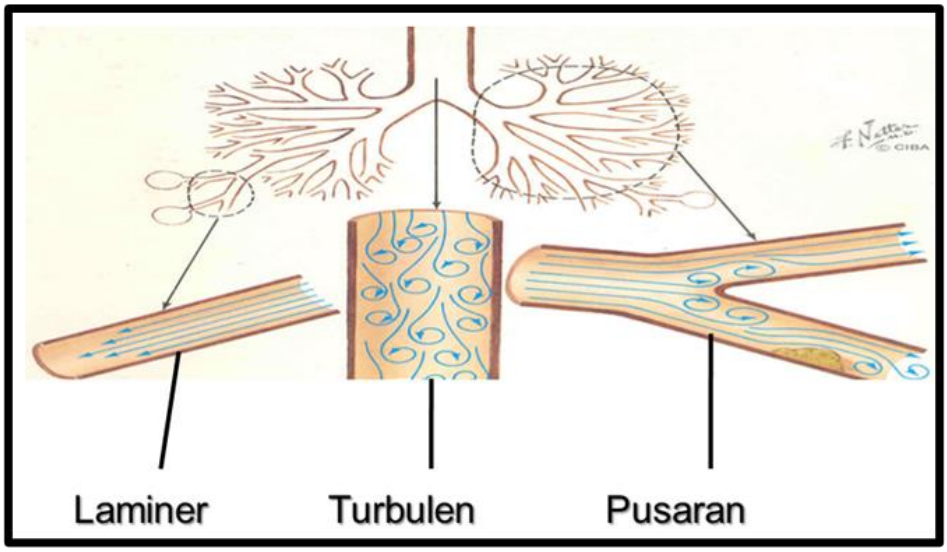

Figure 1. Airflow patterns in the airways.

The disease process affects the movement of airflow, resulting in abnormal (additional) breath sounds. This is due to changes in vibration and movement of airflow due to changes in airway tissue. Areas of consolidation may promote better transmission of breath sounds to the chest wall. This condition is caused by consolidated substances or solid substances having a denser molecular density than other air media.[4] Sound transmission can be influenced by intrapulmonary and extrapulmonary factors. Some examples of extrapulmonary factors include obesity, chest deformity (kyposcoliosis), and abdominal distension due to ascites. Intrapulmonary factors can be caused by damage to the lung parenchyma and conduction media between the stethoscope and the location of breath sounds (for example, pleural effusion and pneumothorax).[12,13]

Normal breath sounds

Normal breath sounds are divided into several variations, namely tracheal, bronchial, bronchovesicular, and vesicular breath sounds. Each type of normal breath sound has different characteristics. Several things that can be assessed when listening to normal breath sounds are the duration of the sound, the intensity of the expiratory sound, the tone during exhalation, and the location of auscultation, as in Table 1, as an example of the difference in normal breath sounds, namely the duration of the breath sound. Vesicular breath sounds tend to be more prolonged during inspiration, whereas bronchial breath sounds tend to be longer during expiration.[9-15] The different locations of normal breath sounds can be seen in Figure 2.[4]

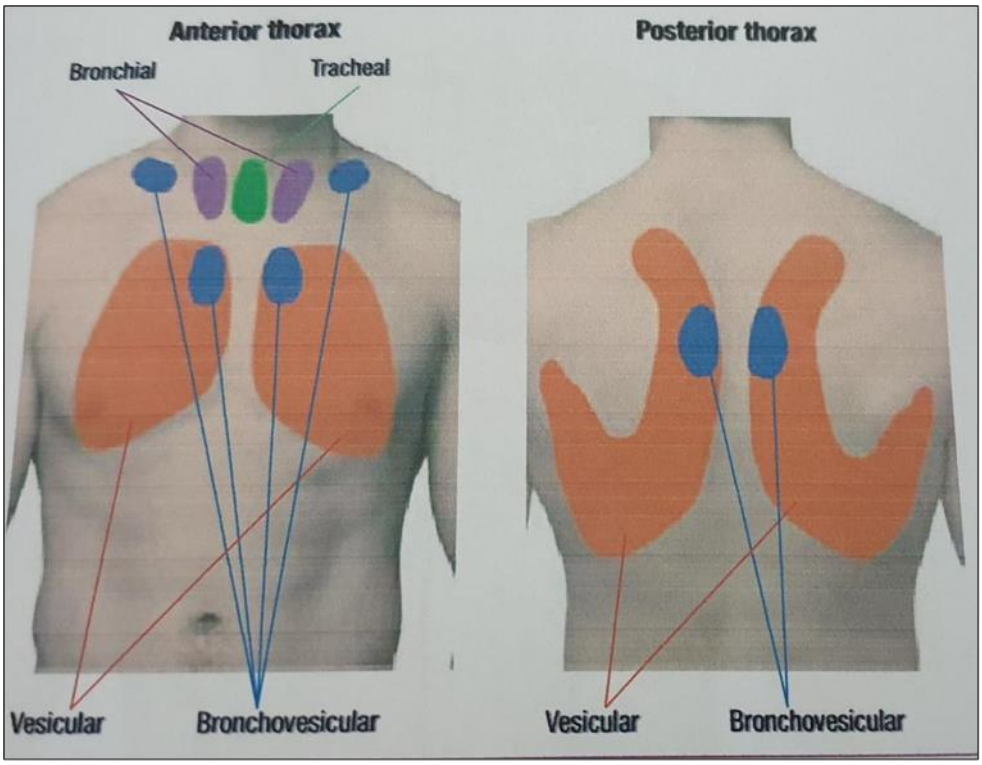

Figure 2. Location of normal breath sounds.

Tracheal

Tracheal breath sounds are characterized by being loud and high-pitched and can be heard above the trachea. When tracheal breath sounds are auscultated, you will hear a short pause between inspiration and expiration, and expiration tends to be the same as inspiration.[4] The inspiratory-expiratory ratio is 1:1, and the frequency of breath sounds is

around 200-2000 Hz. The highest frequency of breath sounds is in the trachea.[4,5] This sound is generally not checked routinely on auscultation. It is more similar to bronchial sounds, and these breath sounds are easy to hear because the distance from the sound source is relatively short, and there is no filter from the lung tissue.[5,16] These sounds can also be useful in analyzing the monitoring of sleeping patients with apnea-hypopnea syndrome.[10,12,17]

Bronchial

Bronchial breath sounds are quite strong/loud with a high pitch, similar to the sound of air being blown through a hollow pipe. When examined, it turns out there is a distance between the two phases. There is no sound between the end of inspiration and the beginning of expiration. The expiratory phase is harder and longer than inspiration, with a ratio of 1:3. Bronchial breath sounds can be heard in the area close to the manubrium sterni. Bronchial breath sounds have a higher frequency than vesicular sounds. These breath sounds are located in the large airways.[4,16] Bronchial breath sounds can be said to be abnormal in several conditions. The presence of bronchial breath sounds in the peripheral parts of the lungs is interpreted as an abnormal sound transmission process due to compressed lung tissue. This condition can be caused by consolidation, atelectasis, and fibrosis. When a process of increasing lung density occurs between the central airways and the chest wall, sound transmission from the larger airways will increase.[1,4,14,16]

Amphoric sounds are high-pitched breathing sounds that resemble the sound produced when blowing air into the wide, empty mouth of a bottle. Occurs when there is a large superficial cavity (5-6 cm) with a patent bronchus. A fungus ball or fluid in the cavity can eliminate this amphoric sound.[10,16] Cavernous sounds are low-pitched breath sounds heard in a superficial cavity connected to a patent bronchus. The cavity size must be > 2 cm. Tubular sounds are high-pitched breathing sounds that occur due to the flow of vibrations produced in the small bronchi directly toward the chest wall through the lung tissue. Often heard in consolidation, pleural effusion, pulmonary fibrosis, distal lung collapse, and mediastinal tumors in the main bronchi.[10]

Bronchovesicular

Bronchovesicular breath sounds can be heard in the anterior area and in the posterior area, namely around the large airways. Their pitch and duration are intermediate between vesicular breath sounds and bronchial breath sounds. The ratio of inspiration and expiration is the same, namely 1:1. Bronchovesicular breath sounds have a low pitch that can be heard using a diaphragm or the bell of a stethoscope. These sounds are softer and tend to be less harsh than bronchial breath sounds. It can be heard between the scapulae posteriorly and in the center of the chest anteriorly.[4,6,10]

Vesicular

Vesicular breath sounds are transmitted through the lung tissue and chest wall, which arise due to changes in airflow patterns. These breath sounds are smaller and softer than tracheal and bronchial breath sounds. During inspiration, the sound of breathing can be heard clearly. The inspiratory to expiratory ratio is 3:1 or 4:1, and the frequency ranges from 200-600 Hz.[4,13,16] Previously, these breath sounds were thought to arise due to air in the alveoli, but later it was proven that these sounds were caused by turbulent flow in the lobar and segmental bronchi, not in the alveoli.[10,16]

Vesicular breath sounds have various variations, namely excessive vesicular breath sounds, diminished vesicular breath sounds, and vesicular breath sounds with prolonged expiration.[10] Excessive vesicular breath sounds are vesicular breath sounds that are often found in children and thin individuals. This breathing sound can also be heard in conditions when one lung is damaged, so the other lung will work extra. Areas of the lung that work extra will produce excessive variations in vesicular breath sounds (exaggerated vesicular breath sounds). Disappearing

vesicular breath sounds are caused by reduced sound intensity due to several things, such as weak sound formation or sound transmission problems. Some of the conditions that cause it are bullae, lung hyperinflation, pneumothorax, pleural effusion, and obesity. Vesicular breath sounds with prolonged expiration are breath sounds that occur in conditions of airway obstruction, for example, asthma and chronic bronchitis.[6,10,17]

Abnormal breath sounds (Additional)

In 1957, Robertson and Coope classified abnormal (additional) breath sounds into continuous and discontinuous. Then, in 1976International Lung Sounds Association, These breath sounds were divided into discontinuous, namely fine wet crackles and rough wet crackles, then continuously divided into wheezing, stridor, and dry crackles. Abnormal (additional) breath sounds have different characteristics from each other and have different meanings in assessing abnormalities that occur in lung tissue. As with wheezing, the appearance of which is interpreted as narrowing or constriction of the airways.[10]

Stridor

Stridor is a continuous, monophonic, high-pitched breath sound that can be heard without a stethoscope. This is caused by narrowing or partial obstruction of the extrathoracic airway (larynx and trachea), resulting in turbulence in the upper airway.[5,10,13] Narrowing of the diameter of the upper airway can be caused by mucosal edema/epiglottitis due to acute infection, inflammation after extubation, narrowing due to laryngeal tumors, and others.[16-18] Stridor occurs through the same mechanism as wheezing, but stridor occurs in the upper airway.[13] Stridor can occur during inspiration, expiration, or both phases. Inspiratory stridor is often caused by acute obstruction, foreign bodies, trauma, vocal cord paralysis, and tracheal-laryngeal malacia. Expiration can be caused by intrinsic airway obstruction, external compression, and tracheobronchomalacia. Meanwhile, both phases of respiration can be caused by laryngeal mass, bilateral paralysis of the vocal cords, vocal cord dysfunction, and post-extubation.[5,7,12]

Wheezing

Wheezing is synonymous with bronchospasm, thickening of the airways caused by swelling of the mucosa or muscle hypertrophy, inhalation of foreign objects, tumors, and secretions. Wheezing occurs due to the narrowing of the airway walls when air passes at high speed. The tone of wheezing does not depend on the length of the narrowed airway but depends on the degree of narrowing of the airway. The more severe the degree of constriction, the higher the pitch of the wheeze and the louder the intensity, and it can involve two breathing cycles. When wheezing is identified, it is also necessary to identify its tone, intensity, and respiratory cycle involved (inspiration or expiration).[1,2,4,18]

Wheezing has musical characteristics, relatively high pitched and continuous, with a frequency of ≥ 400 Hz and a duration of ≥ 250 milliseconds. The frequency of wheezing depends on the mass and elasticity of the airway walls and the speed of airflow. Wheezing can be heard on inspiration and expiration and can be diffuse, episodic, or chronic.[4] Wheezing can be monophonic or polyphonic. Polyphonic indicates multiple narrowed airways (obstruction), for example, in asthma, chronic bronchitis, COPD, and congestive heart failure (cardiac asthma). In monophonic, the narrowed airways can be single or multiple. A single monophonic example is obstruction of one airway due to a bronchial tumor.[5,13,16,19] Severe chronic obstructive pulmonary disease or status asthmaticus causes the patient to no longer be able to breathe in sufficient amounts of air. This situation causes this to happen in the silent chest (the absence of audible breath sounds), which should immediately receive more attention from the clinician and should not be mistaken for an improvement. The appearance of wheezing after a silent chest is a good prognosis.[10,12,17]

Dry crackles

Dry crackles are musical, continuous breath sounds that tend to be low-pitched, originating from the large airways. It can be heard during inspiration and expiration, or both.[1,5,14,16] The mechanism of formation is almost similar to wheezing. Therefore, it is often said to be another variant of low-pitched wheezing. Dry crackles are associated with discharge and narrowing of the large airways. The vibration of the secretory layer as air passes produces breathing sounds. These breath sounds may disappear after coughing or after airway clearance is performed.[6,7]

Wet crackles

Wet crackles are discontinuous, intermittent, explosive, and non-musical, which are heard in inspiration and sometimes during expiration. There are two types of wet crackles in the breath sound, namely fine wet crackles and rough wet crackles. This is based on the duration, frequency, pitch, and timing of the breathing cycle.[4,10] Fine wet rales are known for their characteristics as soft, short, high-pitched sounds. The intensity is lower, the duration is relatively short, and it tends to be inspiratory.[4] The sound will become more characteristic after coughing, which indicates an abnormality or disease in the alveoli.[5,6,10,12,20] Coarse wet crackles have the characteristics of being louder, high intensity, low pitched, and slightly longer than fine wet crackles. These breath sounds occur during the beginning of inspiration and during expiration.[4,5,16]

There are two main explanations for the occurrence of rough wet rales, namely Theory Forgacs, which suggested the theory of sudden and explosive opening of the airways. This condition occurs in the small airways that collapse during the expiration process. As a result, the acceleration of airspeed increases during inspiration, causing the sudden opening of the small airways. This mechanism is also called the theory stress relaxation quadrupole hypothesis by Fredberg and Holford. The second mechanism is breath sounds, which occur due to air bubbles flowing through secretions and slightly closed airways during respiration. This mechanism creates sound air bubble.[1,10,17,21]

Wet crackle breath sounds in pneumonia depend on the degree of pneumonia. In acute pneumonia, wet crackles are heard in mid-inspiration and tend to be rough, wet crackles. The reopening of airways that were closed by edema and inflammatory infiltrates causes the appearance of coarse, wet crackles. In the healing period, these breath sounds are at the end of inspiration and are short in duration and softer.[4,6,20] In COPD (chronic obstructive pulmonary disease), breath sounds can be heard in the mouth and are associated with severe airway obstruction. This is also related to secretions in the airways, especially the large airways. This breath sound can be heard in both phases of breathing, both inspiration and expiration. This condition is caused by the opening and closing of the airways in the proximal bronchi due to narrowing due to inflammation.[10,12,22]

In bronchiectasis, the sound of wet rales is loud. These breath sounds appear at the beginning of the inspiration, continue until the middle of the inspiration, and disappear at the end of the inspiration. There are two reasons why the duration of wet crackles is longer in bronchiectasis. The first thing is that it takes time to open the bronchiectasis segment. The second thing is persistent secretions due to the collapse of the airway. So that during inspiration, the airway opens, and air bubbles appear in the secretions. Wet crackles in heart failure conditions appear when the airway is opened, which is narrowed due to peribronchial edema. This condition occurs during the inspiratory and expiratory phases and is high-pitched. Wet crackles will disappear as heart failure resolves. The wet crackle breath sounds in this condition are of the posterior basal type in patients who sleep on their backs. Pulmonary edema in heart failure can cause wet crackles during inspiration.[4,10,23]

Mixed (Squawk)

This breath sound is a breath sound that has a high musical tone at the end of inspiration and a short

wheezing sound. It has a duration of less than 200 milliseconds, with a base frequency between 200 and 300 Hz. This type of breathing sound is often found in sufferers of hypersensitivity pneumonitis.[5,10,12,17] Until now, the mechanism underlying these breath sounds is still unknown. According to Forgacs, these breathing sounds occur due to movement of the surface of the walls of the small airways and due to collapsed lung tissue. When air flows into the airway, the collapsed lung tissue opens. This breathing sound is a mixture of wet rales and wheezing.[5,6,7,10]

Pleural friction rub

When the visceral and parietal pleura are damaged by fibrin deposits, inflammation and neoplastic cells, the ability to rub together properly is lost. Movement will become difficult, and periods of lull may occur. This movement gives rise to a sound called pleural friction rub (pleural friction sound).[13,14,16] The sound is often difficult to differentiate from rough wet rales and does not change with coughing. This sound will appear during inspiration and expiration in the respiratory cycle and can be heard in the lower lungs. These breath sounds disappear when there is fluid between the pleural cavities. Pleural friction noise is associated with sharp pleuritic pain during inspiration. This causes the patient to spontaneously minimize muscle movement and chest expansion, as well as create a fast and shallow breathing pattern.[4,5,1,17]

Abnormal vocal resonance sound

Vocal sounds are produced by vibrations of the vocal cords when air from the lungs passes through the vocal cords. When vocal sounds pass through normally inflated lungs filled with air, high-frequency vocal sounds will be filtered and faded. In areas of consolidated lung tissue or atelectasis, less filtering occurs, thereby improving sound transmission and making sounds clearer.[4,24] This sound is produced by the larynx, and vowel sounds have a high pitch and a low frequency. In healthy individuals, these sounds are transmitted equally to the chest cavity. On the other hand, if the lungs are filled with fluid, and there is consolidation or atelectasis, the vocal sound will be transmitted into a different form.[10,25]

Bronchophony

In bronchophony, the transmitted sound sounds clearer and louder. This is because the sound is transmitted through dense lung tissue and without air. So it can transmit vocal sounds with higher frequencies and more easily. Bronchophony can be heard anywhere on the upper anterior, lateral, and posterior chest walls. The anterior area is located between the clavicular space and the second intercostal space from the midclavicular line to the left of the midclavicular line. The posterior region is located between the first and third intercostal spaces from the vertebral line towards the left midline. The patient is asked to repeat the word "ninety-nine" or "seventy-seven" several times. Then, listen with a stethoscope on the surface of the chest wall. In consolidated lung tissue, sounds will be heard louder and clearer.[4,10,16,20]

Egophony

Egophony has nasal or nasal characteristics when heard over the chest wall. It is produced in areas of consolidation and atelectasis, causing increased transmission of breath sounds in these areas. Egophony can be heard anywhere over the surface of the anterior, posterior, or lateral chest wall in areas of consolidation or atelectasis. In patients with right lower lobe pneumonia, egophony is heard over the surface of the lateral chest wall. The patient is asked to pronounce the letters "It is" several times. In areas where there is consolidation, it sounds like the letters “a” and has a high pitch with a nasal quality.[4,10,11,20]

Pectoriloquy

A pectoriloquy is a louder and clearer whisper sound, which is heard through lung tissue that contains little air, such as consolidation and atelectasis. In patients with consolidation or atelectasis, these vocal sounds are transmitted to the

surface of the chest wall without much high-frequency filtering and can be heard clearly with a stethoscope. Pectoriloquy can be heard anywhere over the surface of the anterior or posterior chest wall. The patient is asked to whisper words such as "one, two, three" several times. In healthy lung tissue, the words cannot be understood, while in areas of atelectasis, the whispering sound is very clear.[4,12,20]

2. Conclusion

Breath sounds are a guide in lung auscultation. Breath sounds are caused by air turbulence in the airways. Breath sounds can be divided into two, namely, normal breath sounds and abnormal breath sounds. Normal breath sounds include tracheal, bronchial, bronchovesicular, and vesicular breath sounds. Abnormal (additional) breath sounds include wheezing, dry crackles, fine wet crackles, rough wet crackles, stridor, pleural friction, and mixed. Transmitted vocal breath sounds include bronchophony, egophony, and pectoriloquy. Understanding the mechanisms of breath sounds can help diagnose lung disease.

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