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Review Article

Radio Imaging of Pneumonia: A Comprehensive Review

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A B S T R A C T

Pneumonia, a major leading problem existing since centuries, is considered a respiratory infection including all the parts of the respiratory tract. In the case of medical health, it can be classified into two major categories; CAP (Community-acquired pneumonia), and HAP (Hospital-acquired pneumonia). This infection cause is defined by the existence of various bacteria, fungi, parasites, and viruses inside the body causing sepsis and other difficulties related to the upper respiratory tract. The survival rate from pneumonia is very low when it is diagnosed much later. Pneumonia highly affects the children of the age group of 0-5 years and the elderly aged more than 50 years or in their 60s. The risk of getting infected primarily depends on the immune response of the host and the species of pneumonia. Traditional radiography should always be the first step in any imaging assessment. When normal radiography results are inconclusive, computed tomography is required. The optimum approach to pulmonary infectious processes is a combination of pattern recognition and clinical expertise. However, nowadays it's easy to detect the infection by means of radiological and clinical investigations. As pneumonia is much more manifested in the case of COVID infection, so research is still going on in this field. This article explains the different elements of pneumonia, including definition, risk factors, aetiological agents, diagnosis, treatment, and prevention, with a focus on current developments.

Keywords: Pneumonia, Medical Imaging, Upper Respiratory Disease, Radiography

Introduction

Pneumonia is broadly defined as a severe infection of the lower respiratory system that involves the alveoli and the bronchiole tree of the human lungs. Here, lungs are the major organs involved which are a crucial part of the respiratory system required for inspiration (breathing in) and expiration (breathing out). The lungs consist of the bronchi, bronchioles, and air sacs called the alveoli. Majorly, the alveoli are filled with unwanted liquids like pus and fluids in the case of pneumonia which leads the patients causing dyspnoea (Difficulty in breathing).[1] Pneumonia can be caused due to bacteria, viruses, or fungi. The commonly seen agents include Streptococcus pneumoniae, which causes bacterial pneumonia in children, Haemophilus Influenza (HIB), and respiratory syncytial virus, which is the

general cause of viral pneumonia. HIV positivity increases the risk of this disease.

Pneumonia also includes another term called consolidations. The consolidation usually occurs when the pneumatic lung or the inflamed lungs alveoli are completely filled with excretory substances like pus making it opaque. The passage of air is null in these areas as they are not able to fill the oxygen.[2]

Figure 1.Consolidationin Right Lobe of Lungs of the Female Patient (Brown et al., 1991)

In Figure 1, the chest X-ray image is taken in the posteroanterior projection which showed pneumonia with the presence of consolidation over the right side of the lungs which is seen as white due to the presence of pus and other fluids rather than air.

According to the sources, pneumonia is considered the second largest infectious disease with an increasing mortality rate worldwide.[3] It has been common in children and elderly people. About 14% of children aged 5 years died due to pneumonia in 2019. The death rate is high in South Asia and sub-Saharan Africa.

History, Types and Morphology

Firstly, around 460 BC, pneumonia was carrying symptoms in human individuals and was noted by a Greek physician named Hippocrates. However, this symptom was not confirmed as pneumonia as it had different names in the late centuries.[4] Until 1875, the bacteria that causes pneumonia could be seen under a microscope, which has helped modern medicine determine its cure. The treatment or preventive measures of this illness were discovered in the 1930s by the formulation of the antibiotic treatment.

Even though the treatment of this infection was developed quite early, still the mortality rates due to this disease are increasing daily. The cost for treating CAP (Community Acquired Pneumonia) was around 17$ globally.

Categories of Pneumonia

According to Anatomy

- Bronchopneumonia: This type of pneumonia affects the bronchus of the lungs
- Lobar pneumonia: This infection affects a portion of the lungs; only the lobes are involved
- Interstitial pneumonia: This involves the infection of the interstitial (space between the alveoli and the surrounding structure)

According to Clinical types

- Wuired pneumonia (CAP)
- Hospital-acquired Pneumonia (HAP)
- Ventilator-acquired Pneumonia (VAP)
- Aspiration Pneumonia
- Healthcare-associated Pneumonia (HCAP)

Community-acquired Pneumonia (CAP): Community-acquired pneumonia is described as pneumonia observed in an individual who has not been hospitalised. The causative agents for CAP involve both bacteria (Streptococcus pneumoniae, Haemophilus influenza, Myoplasm pneumoniae, etc) as well as respiratory viruses.[5] CAP includes mild, moderate, and acute cases. A mild case is treated on an outpatient basis, moderate in a hospital ward and an acute case in an intensive care unit (ICU), along with ventilators.

Hospital-acquired Pneumonia (HAP): This includes Ventilator-acquired Pneumonia. HAP is elucidated as pneumonia obtained only after 2 days of being admitted to hospitals without any signs of incubation of bacteria. This type is seen only after some days of admission and the responsible microorganisms include Staphylococcus aureus (MSSA: methicillin-susceptible S. aureus, MRSA: methicillin-resistant S. aureus), Acinetobacter spp.[6]

HAP and CAP both are seen in patients having relatively high or low immunity. VAP is noticed after the intubation (endotracheal) usually 48 hours after the oxygen supply.

Aspiration Pneumonia: The term aspiration is defined as difficulty in breathing like choking or blockage of airways. Aspiration pneumonia occurs when any kind of foreign body is inhaled into the lungs obscuring the passage of the airway. It counts both as CAP and HAP.[7]

Healthcare-associated Pneumonia (HCAP): This pneumonia is acquired in in-hospital care units like normal medical institutions. Here, the causative bacteria can be the same as that in HAP.

The different types of pneumonia as per the anatomical classification and the various microorganisms causing them have been shown in Figures 2 and 3.

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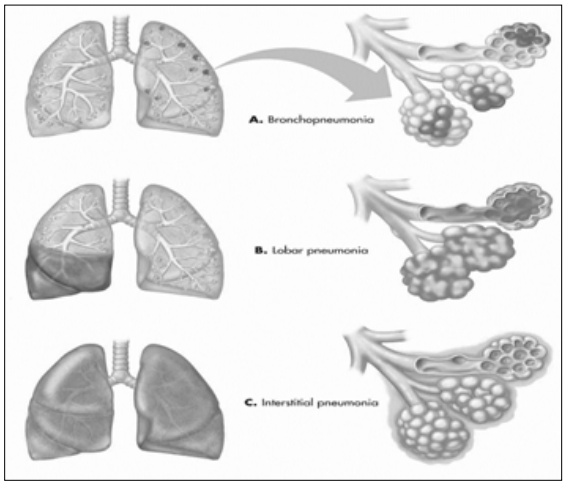

Figure 2.Types of Pneumonia Listed according to Anatomical Classification

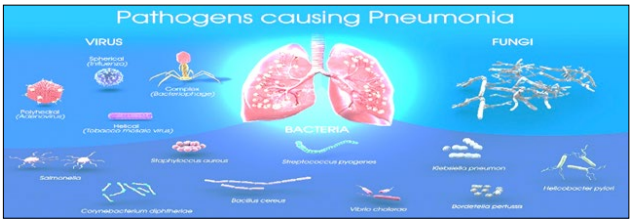

Figure 3.Different Microorganisms causing Various Types of Pneumonia

Pneumonia Correlated with COVID Infection

The COVID-19 epidemiology was observed in December 2019. It first originated in Wuhan city of China. To date, it is still difficult to finalise the cause and useful treatment of this virus. It appeared as a mild form with common symptoms like common cold (cough, headache, runny nose, sinus, high fever and so on). Then, it took a severe form causing pneumonia as well. According to the survey, taken in the previous year 2020, a COVID CT scan showed pneumonia along with consolidation, Ground Glass Opacities (GGO), and some cases of pneumothorax.[8]

There was a study carried out by Zhou et al. in 2020 on the difference between pneumonia caused by COVID-19 and other types of pneumonia by the use of a chest CT scan. COVID-19 pneumonia was verified in 154 people starting from February of the year 2020. 100 patients were diagnosed with other pathological pneumonia (April 2011-December 2020). HRCT chest was performed on these patients to ascertain the normal origin, distribution, type of lesion, lobe involvement, total number of lesions, and pleural effusions. The result indicated a 13.04-fold risk of COVID pneumonia along with peripheral dispersion. The three range lesions were compared to another with a maximum lesion range of > 5 cm dispersed throughout all 5 lobes, which was associated with a 9.75-fold risk of coronavirus pneumonia. Comparatively, there was no pleural effusion in the 3.58 risk of COVID pneumonia. Meanwhile, in the case of a 2.79-fold risk of COVID pneumonia, there was a presence of Hilar and Mediastinal lymph node extension.[9]

Therefore, this study concluded that COVID-19 pneumonia showed the lesion having peripheral coverage with a size of more than 10 cm present in five lobes of the lungs, especially in the Hilar and mediastinal region with enlargement. Significantly, there was an absence of pleural effusion.

Table 1.(CT Findings) The three range lesions were compared to another with a maximum lesion range of > 5cm dispersed throughout all 5 lobes, which was associated with a 9.75-fold risk of coronavirus pneumonia. Comparatively, there was no pleural effusion in the 3.58 risk of COVID pneumoniaof the Viruses in the COVID-19 Pneumonia Cases

Virus	CT Findings
Adenovirus pneumonia	Multifocal consolidation and ground-glass opacities
Rhinovirus pneumonia	Multifocal ground-glass opacities with or without consolidation
Other coronavirus	Multifocal consolidation and ground-glass opacities with a peripheral predominance
Influenza virus-pneumonia	Multifocal consolidation with or without ground glass opacities
Respiratory syncytial virus pneumonia	Multifocal consolidation and centrilobular nodules with an airway-centric pattern
Cytomegalovirus pneumonia	Diffused ground glass opacities with or without multiple ill-defined tiny nodules
Human metapneumovirus pneumonia	Centrilobular nodules with bronchitis pattern

As shown in Table 1, the CT scan findings associated with different viruses are similar to one another with some variations. Most of the viruses carrying COVID pneumonia show the appearance of ground glass opacities along with some consolidations.

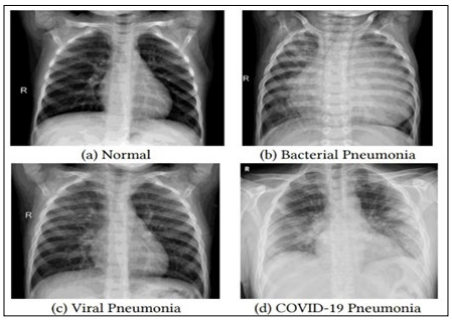

Figure 4.Chest AP(Anteroposterior) view Showing different Pneumonia

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The normal condition of the lung as seen in Figure 4(a) shows a good quality radiograph with proper contrast and the full lung field involved. Figure 4(b) shows a chest X-ray of a patient with bacterial pneumonia that exhibits fading lungs and bacteria infection in the left lung lobe. Figure 4(c) shows viral pneumonia affecting the bronchus of lungs giving a patchy white appearance. Figure 4(d) clearly shows COVID pneumonia with the lobes of the lungs filled with infection, and consolidation giving the soft grey appearance.

Risk Factors

There are varieties of risk factors for various types of pneumonia. The factors that influence the cause of CAP in children involve prematurity, malnutrition, pollution of household air, suboptimal breastfeeding, etc., while in the case of adults, respiratory diseases like Chronic Obstructive Pulmonary Disease, diseases related to the heart, and liver infections like liver cirrhosis, etc. can be the cause for risk factors. Because of the difference in morphology, males tend to have a higher susceptibility to CAP than females. According to the survey conducted by the US, among more than 18000 patients who were hospitalised, around 3,419 patients had pneumonia. A patient with reduced immunity has an increased risk of CAP compared to the general public. Some other studies also indicated that the increase in risk factors of CAP can involve the lifestyles and daily behaviour of the individual.[10] The habit of smoking tobacco and drinking alcohol can lead to pneumonia too. This condition is also influenced by a large family environment, which includes frequent interactions with youngsters, and the family's unhealthy diet. During the process of smoking, the settlement of bacteria into the lungs causes a rise in infection in the lungs causing irritation due to bacteria (S. pneumoniae). A study conducted among 345 patients hospitalised with CAP and 494 without the symptoms of pneumonia revealed the exposure of up to 1-2 years to poisonous gases like nitrogen dioxide and particulate matter (2.5 micrometre's) resulting in a longer hospitalisation as compared to other individuals.[11]

The elements that include risk for pneumonia can be divided into either related to the patient or related to the hospital. The HAP risk factors comprise bacterial colonisation of the oropharynx. This oropharyngeal colonisation is needed to be placed in Intensive Care Units because of the severity. A study conducted in Japan on the oral colonisation of patients admitted in hospitals for a long term showed that around 38% of the patients were colonised with antibiotic-resistant bacteria (Acinetobacter spp., Enterobacter spp., Pseudomonas spp.). Also, the patients having assisted ventilation showed the entry of bacteria in the oropharynx and the stomach first which followed the lower respiratory tract, finally reaching the endotracheal tube. This proves that the bacteria in the tube because of poor hygiene can transfer to the lungs causing HAP.[12] When gas contents enter the lungs and interfere with the lungs' normal function, aspiration pneumonia occurs. The risk factors include impaired swallowing, cough reflexes, etc.

Pneumonia Severity Index (PSI)

The pneumonia severity index is the measurement tool used to indicate the severity and acuteness of pneumonia and determine the admission status. In the case of a patient with community-acquired pneumonia, PSI will help to identify the need for the patient to be hospitalised (Table 2).[13] The use of PSI is distinguished into different classes including:

- Class 1 and class 2 pneumonia patients are less severe and can be sent home after some medications (oral antibiotics)
- Class 3 patients after considering the conditions and follow up either can be sent home or can stay in hospital for a short time with antibiotics therapy
- Class 4 patients are those who need hospitalisation

Table 2.PneumoniaSeverity Index along with the Line Graph which have the High-risk factor of Pneumonia in case of Inpatient which is above 130 in a majority

Age (Years)	Risk	Disposition
< 50	Low risk class-I	Outpatient
< 70	Low risk class-II	Outpatient
70-90	Low risk class-III	Outpatient
91-130	Moderate risk class-IV	Inpatient
> 130	High risk class-V	Inpatient

A historic study done during the years 2013-2015 included around 1,434 adult patients having community-acquired pneumonia of age above 18 years admitted in the emergency unit. The patient recognised with non-community acquired were listed in the control group (N = 1173). There were 2 different forms of respiratory viruses being detected in the 7-case study. Out of 254 cases, 64 cases had influenza A, 18 cases had influenza B, and 65 cases had rhinovirus. There was an increase in the mortality rate with a rise in PSI records with or without respiratory viral infection. In any event, barring the diagnosis of respiratory viruses, the Pneumonia Severity Index Score is a crucial tool for analysing the forecast of patients with CAP.[14]

Mechanism of Immune Response in Pneumonia

Immunity is commonly defined as the body's mechanism to defend against certain kinds of bacteria, viruses, and microorganisms. There is a presence of innate (by birth) immunity inside every individual which provides the next important line of defence.

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Immunity is majorly classified into:

- Innate immunity (by birth)
- Acquired immunity (gained after birth)

Innate or Native Immunity

This is present in the gene of an individual which is passed down from generation to generation. It is affected by various components like age, hormones, co-morbidities, and nutritional status. [15] The different types of innate White-cells present in the inert respiratory system help in providing the next important line of defence. Lung epithelial cells allow infections and chemicals that are dependent on the host to enter. The alveoli of the lungs can also suppress the pathogens with the help of surfactant proteins (SPA and SPD) released by type II epithelial cells. The immune cells can protect against pneumonia broadly by epithelial cell activation. The AM's stands for 'Alveolar Macrophages' present on the inferior respiratory surface is dominant in providing immune defiant as well as tissue residents. The cytokines produced by innate lymphoid cells also play a key role in the defence mechanism.[16]

Acquired Immunity

This type of immune system is artificially gained by a person in his/ her lifetime. It is applied when innate immunity is no longer able to cope with pathogens. The modification in infection causes the establishment of vaccination. Trained immunity is very significant in the case of pneumonia. The vaccine named Bacillus Calmette Guerin lowers the probability of pneumonia when administered to aged patients after being discharged from the hospital. This immunisation reduced the severity of the initial infection. [17] The memory cells situated in the lobes of lungs trigger systemic and general antibody production. Active immunity is gained by various vaccinations, for example, recently, in the case of COVID-19, people have been forced to take a certain dose of vaccination to boost their immune level. Here, the vaccine works like a helping hand for the antibodies to fight against the Novel coronavirus. Even today many companies' health institutions are researching the exact medicine for the virus. However, vaccination has been playing an essential role in this case.[18]

Line of Defence

Immunity has divided its work on the basis of two lines of differences like fence or barrier against pathogens:

- The first line of defence includes skin and mucosa
- The second line of defence includes antimicrobial proteins and phagocytes

The barriers against pneumonia are provided initially by the primary innate defence mechanism which includes mucous in liquid layers. Another defence barrier is provided by the branching of the bronchiole tree preventing microorganisms having a diameter of more than 6 micrometres from reaching the lower respiratory system (Table 3).

Table 3.Innate and Adaptive or Acquired Immunity provided by Antibodies

Non-specific Defences (Innate Immunity)		Specific Defences (Adaptive Immunity)
First Line of Defence	Second Line of Defence	Third line of Defence
Skin	Phagocytic leukocytes	Lymphocytes
Mucous membrane		Antibiotics
Secretions of skin and mucous membranes		Memory cells

This immunity provides different lines of defence against bacteria.

Pneumonia: Symptoms and Pathology

Congestion

The congestion is when the lobar pneumonia is in its early stages. The parenchyma of the lungs has abundant blood flow through tissue leading the narrow airways to infilter the air because of bacteria and other fluids. Initially, this leads to the recruitment of pathologic cells and haemorrhage in that area causing the alveolar space to be filled with fibres and blood cells (red hepatization). Subsequently, the airways are kept open to facilitate the consolidation of the haemorrhage and the blood cells' tendency to degrade. (grey hepatization). The last stage of pathology is called resolution. Here, the left transduce products are processed with the help of microphages and fibroblast.[19]

Hepatization

Hepatization is the process in which the lung tissue gets converted into a matter that appears like solidifying liver tissue. It refers to the consolidation of lungs.

Red hepatization: The appearance of red blood cells (erythrocytes) in the space of lungs or inside alveoli decreasing alveolar gas exchange is defined as red hepatization. Here, neutrophils can also be observed. Bacteria can be demonstrated in the alveolar space (Figure 5(b)).[20]

Grey hepatization: It is the process in which the blood cells which are present in red hepatization disintegrate along with increased decomposition of fibrin. The bacteria are decreased and the gas in lungs gets contaminated showing a grey and white patchy appearance (Figure 5(a)).[21]

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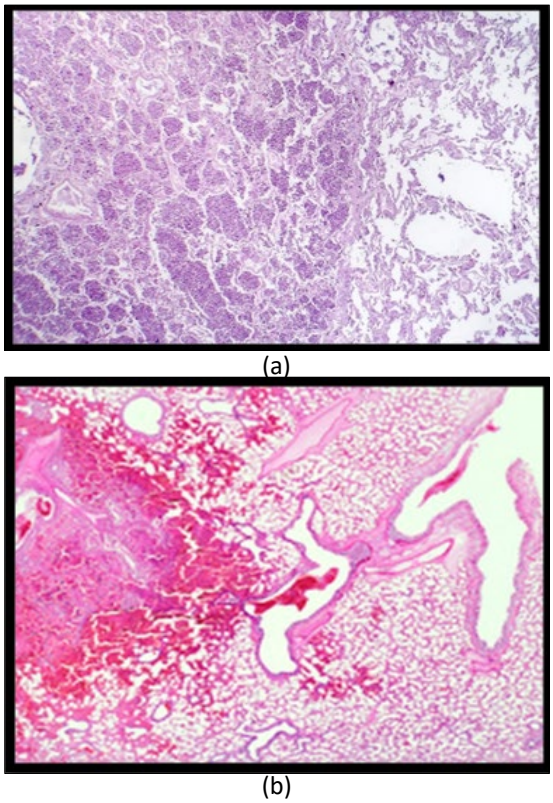

(a)

(b)

Figure5.(b) Histopathology of Grey Hepatization obtained during the Pathological Test (b) Histopathology of Red Hepatization of Pneumonia

Resolution

Figure 6, shows the stages in the evolution of pneumonia. The small debris of components like neutrophils, bacteria, and fibrin is digested and resorbed with the help of phagocytes. Lungs cannot be repaired with additional treatment at this point, which is called the final stage.

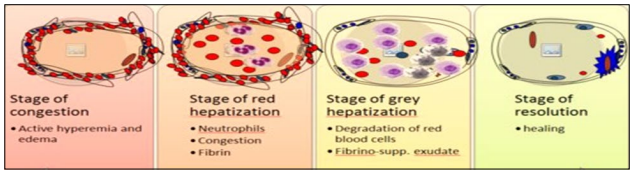

Figure 6.Different Stages in the Evolution of Pneumonia

Mortality Rate

A study done in 2019 showed the death of around 1.23 million elderly people above 70 years. This death rate was due to Lower Respiratory Tract (LRT) infection which surpassed the rate of TB (1.15 million) and HIV (864000). The deaths of children below 5 years caused due to LRTIs were 460/100,000 children in the Central African Republic, 425/100,000 in Chad, and 417/100,000 in Somali.

The child mortality rate diminished as the vaccination against S. pneumoniae and H. influenza was given to them along with antibiotic sessions. However, there are countries which hinder the improvement including India, Pakistan, Nigeria, Ethiopia, and the Democratic Republic of Congo. The factors affecting the mortality rate of adults above 70 years of age include chronic diseases, high dose medications, other disabilities, low immunity, and bad health habits like smoking, drinking alcohol, polluted air, etc. In the case of CAP, the mortality rate calculated was 5% among the adults aged below 65 years, 8% for 65 to 79 years old, and 14% for 80 years old. As per the studies carried out on long-term death rates, 1/3rd of adults die per year due to CAP.[22]

The prevalence of HAP and VAP has a global impact on the death rate due to infection, hospital care, and intubation. Globally, the death rates for HAP and VAP are respectively 20-30% and 20-50%. Similarly, the 30-day mortality risking 3.57 patient with community-acquired pneumonia detected outside of intensive care unit (ICU) and aspiration pneumonia treated in hospital, respectively. According to one study, aspiration pneumonia affected twice as many people as CAP, which had a 12% prevalence. As pneumonia is now associated with COVID patients, the mortality rate of pneumonia is higher today.

Specific Condition in Pneumonia (Extrapulmonary)

Patients who do not exhibit any symptoms of sepsis may experience more pulmonary problems. After 10 years, patients who have spent more time in the hospital, after being discharged are more likely to die.

Sepsis

Sepsis is defined as a life-threatening condition that can cause organ failure and death as well. It consists of three stages: sepsis, septic shock, and severe sepsis. Septic shock is a condition caused due to sepsis usually affecting the circulatory system and cellular and metabolic activities with an increased risk for mortality. In ICUs, approximately 50% of patients have chances to catch infections.

Bacteraemia: Bacterium conditions like pneumonia can easily cause sepsis.

Immunosuppression: When the host defence system is suppressed by certain microorganisms then sepsis can easily invade the organ.[23]

Diabetes: This can impact the immune system indirectly leading to sepsis. CAP- In this case of pneumonia, the patient typically gets pneumonia in 48 hours and requires hospitalisation 5% of the time.

Genetic Factors: Genes regulating the production of antibodies, phagocytes, and Kupffer cells can alter the body's defence mechanism.

The patients hospitalised due to CAP and HAP have a higher chance of getting sepsis as compared to others.

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The active inflammatory reaction involves the release of cytokines. Similar to this, the anti-inflammatory response triggers the immune system to work because there are fewer lymphoid cells.

Heart Disease

Pneumonia can concomitantly affect the cardiovascular system causing various illnesses like myocardia, ischemia, infarction, etc. Those patients who experienced pneumonia whether hospitalised or not, become susceptible to heart diseases as well. The systemic analysis carried out in a 30-day pneumonia study shows 14% of patients having heart failure, 5% arrhythmia, and 5% carrying severe coronary syndrome. Similarly, in 7-day pneumonia cases, approximately 90% of patients felt cardiac complications. Acute pneumonia became a risk factor for cardiovascular disease. The requirement of hospitalisation after pneumonia involved more heart cases. The ventilator patients develop complications of myocardial infarction. However, sepsis patients in ICU can also have severe myocardial infarctions. The inflammatory reaction can cause plaque formation in heart blood vessels. Cardiovascular diseases and pneumonia share an integral connection. Patients presenting with a high risk of heart disease may have suppressed immunity leading to an easy invasion of bacteria. Likewise, hospitalised patients with pneumonia can eventually develop heart disease due to the long-term effect of bacteria, and sepsis.[24] The heart and lungs are closely placed in the thoracic cavity so the infection has a higher chance of infecting each other.

Other Difficulties

The additional complication due to pneumonia causes nervous system disorders. There is a 50% risk of dementia (loss of thinking ability, mental illness affecting the daily activities of life) due to pneumonia. The difficulties caused due to pneumonia include thrombosis, haemorrhage, lesion, headache, brain stroke, hypertension, etc. Due to pro-inflammatory cytokines, the blood-brain barrier can be muddled leading to serious damage. Around 1/5th of patients who are discharged are re-hospitalised due to the involvement of cardiovascular disease, pulmonary disease, brain dysfunction, and so on. In the case of septic patients, vulnerability to pneumonia is increased in the immune-compromised state. The cases of recurrence of pneumonia after recovery are also noticed. One of the research showed that a drop in immunoglobulin and a failure to respond to polysaccharide antigens can both contribute to this recurrent pneumonia. Another study concluded that the lack of microphages and the inability of the host to defend against the secondary infection present in the lower airways can cause pneumonia to reappear.[25]

Imaging Modalities for Pneumonia

Pneumonia in patients is confirmed through imaging processes like chest X-ray and Computed Tomography Chest (NCCT non-contrast computed tomography), (HRCT chest high resolution computed tomography). The detailed information on the category of symptoms should be known during the imaging. While taking a history of the patient, the examiners should ask about symptoms like the presence of cough, chest pains, fever, dyspnoea, the total capacity of lungs to hold oxygen, along with the type of pneumonia (CAP or aspiration pneumonia). The pathological and clinical examinations aid in the imaging process because without clinical manifestation, the radiologist alone will not be able to give an accurate diagnosis. However, the type of pulmonary pneumonia including the lobes or segment distribution cannot be confirmed as conditions like pulmonary oedema and haemorrhage also carry the same visualisation. In cases like diffuse lung abnormalities, the diagnosis would be really tough. The differentiation between pulmonary oedema and ARDS (Adult Respiratory Distress Syndrome) from bronchopneumonia, in a radiograph, is quite challenging.

Routine Chest X-ray (CXR)

Routine radiography is defined as a general imaging procedure which does not require any contrast agent and can be performed through a normal process. As pneumonia develops in lungs, chest radiography is recommended. As per the guidelines of the American Thoracic Society (ATS), postero-anterior (PA) and lateral projections can be performed. A chest X-ray can be helpful in both screening and post-treatment imaging to see the progress of antibiotic therapy. The CXR can detect the extent of involvement, to ascertain disease processes like pneumothorax, pleural effusion, etc, and can also be used for guidance during invasive procedures.[26] The most frequent radiographic findings include segmental consolidations and interstitial pulmonary diseases. In 5 to 10 per cent of cases, PCP-induced lung infection manifests as diffuse homogeneous alveolar consolidations with dense consolidation, opacities, and fibres.

Chest Computed Tomography

A CT scan is also listed as a tool for the diagnosis of pneumonia as high-quality images can be obtained in slice and can be reconstructed in any plane. So, then pathology can be easily determined. As compared to an X-ray, a CT scan gives a three-dimensional image. Many studies supported the anatomical as well as pathological details provided by computed tomography. The tissue difference between parenchymal changes also can be readily identified. Again, the advancement in CT scan including the HRCT (high-resolution computed tomography) scan is capable of providing images in high resolution as even the small details can be identified. The pathologies present in air space, acinar nodules, GGO (Ground Glass Opacities), and consolidation are visualised better in a chest

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CT scan.[27] The pathological flow of pneumonia, initially starting from acinus (6 to 10 mm) till the formation of consolidation, can be simply identified in a chest CT scan. Ground glass opacities are explained as the specific rise in the lung attenuation which helps to view the blood vessels in the affected area. The plain CT images can easily determine findings like stiffened septum, thickening of walls of bronchus, mosaic perfusion, interstitial lesion, etc. However, the patients are always first asked to take the conventional X-ray images before a CT scan if suspected of pneumonia because a CT scan has a high radiation dose and can cause radiation hazards to the patients. When the pathology is suspected in plain radiography, then to confirm the situation, doctors recommend taking an HRCT chest or plain chest CT scan.

A study was carried out by Qiongje Hu on the importance of HRCT during the evaluation of COVID-19.[28] According to him, 46% of patients had CT scan findings of pneumonia. Every lesion had a distinct appearance, making it easy to analyse its origin, size, position (peripheral or central), attenuation (ground glass opacity or consolidation), and other challenges like pulmonary artery dilatation, air bronchoscopy, interstitial thickness, etc. Then a comparison was made between the research CT scan and earlier CT images for estimation of the lesion. According to the result, they found that the location of the lesion was usually peripheral and subpleural with or without fused ground glass opacities. The distinction of pulmonary artery was 89.13% (41/46), and air bronchogram was 69.57%. However, in some people thickening of intralobular interstitial and a solid nodule with a halo sign of ground glass opacity was seen. There was no symptom of cavitation, calcification, and lymphadenopathy. After 14 days of having COVID-19 symptoms, 7 out of 20 patients were reported with reticular markings. In the remaining 2 out of 7 patients (28.57%), the lesion was absorbed totally in 22 to 31 days. Finally, they came to a conclusion by demonstrating that ground glass opacity was evident in the peripheral and sub-pleural region along with an extension of the supply pulmonary artery in patients with COVID-19 pneumonia. Half of the patients had reticulation after the second week, as determined after four weeks. However, reticulation should be researched to see whether it contains irreversible fibrosis or not. The chest CT scan also carries harmful radiation doses and is an expensive method compared to conventional radiography. The advancement in modalities till today has been helpful for all technologists to evaluate clinical conditions like pneumonia, tuberculosis, cardiovascular diseases, and so on.

Ultrasonography

The ultrasonography of the lungs is also a non-invasive procedure, and hence can be commonly used in ICUs. This provides diagnostic sensitivity and specificity.[29] The lung sonography study in the meta-analysis showed a sensitivity of 88%, specificity of 89%, and a diagnosis of pneumonia of almost 90%. Pregnant women who cannot be given radiation are advised ultrasonography (USG) examination to confirm the condition. The ultrasonography does not carry any harmful radiation and the soft tissue can be easily seen, so this can give detailed information on the condition as well. The other method is to perform the MRI (Magnetic Resonance Imaging) which also does not involve any radiation and helps in recording soft tissue detail. Hence, there are different modalities still being invented for the study of this pathology.[30]

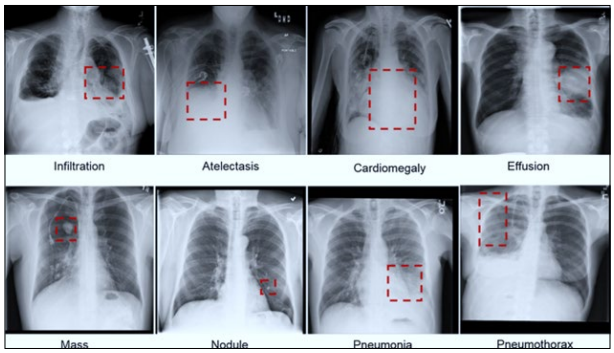

Figure 7.Conventional X-ray images showing the disease that can be occurred due to Pneumonia or after the Treatment of Neumonia. The red mark represents the site of the Pathology in Lungs in both the right and left side

As shown in Figure 7, the various stages include the following:

- Infiltration (when alveoli pneumonia or consolidation prevents the lungs from filtering the air in lungs) in the right lobe of lungs
- Atelectasis (a condition when the lungs are partially collapsed or inflated) found in the left inferior side of lungs
- Cardiomegaly (the heart disease indicating an increase in the size of the heart as compared to the normal size) in the mediastinum as it is the space where the heart is present
- Effusion (a condition which is caused due to abnormal collection of fluid like pleural effusion when fluid is collected in the pleural cavity) in the right middle lobe of lungs
- Mass (a pathological, dense, and radiopaque tissue overgrowth which can be cancerous) in the right upper lobe of lungs just below the middle of the clavicle
- Nodule (this is the least amount of tissue build-up in any one area that may be felt) situated in the cardiac notch
- Pneumonia (acute infection of the lungs caused by microorganisms like bacteria, viruses, or fungi) spreading through the left side of lungs

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- Pneumothorax (a clinical condition of the lung caused due to leakage of a small amount of air onto the interstitial of the lungs causing the lungs to be collapsed) situated in the uppermost right lobe of lungs

Hence, all the issues shown in the above picture are related to lung pathology that can be treated early and the diagnosis of this disease can be done under plain radiography as well. However, some of the pathologies can be hidden as the X-ray provides 2-dimensional images, hence computed tomography is recommended for best evaluation.

CT image demonstrated in the axial plane without the contrast media. Figure 8(a) shows influenza infection in a 23-year-old woman. The arrow indicates the consolidation in the right middle lobe. Figure 8(b) shows a 64-year-old man with a viral infection of the lungs other than pneumonia having both GGO and consolidation present in RML (Right Middle Lobe). Figure 8(c) is the CT image of a 20-year-old young male patient having adenovirus infection along with consolidation in a distal portion of the left lung, and Figure 8(d) reveals cytomegalovirus infecting a 24-year-old patient with GGO (Ground Glass Opacities) and consolidation. Figure 9 shows the ultrasonogram revealing consolidation of lungs along with necrotic lungs.

Figure 9.Ultrasonogram showing the Consolidation of Lungs along with Necrotic Lungs (Where the Lungs Tissue is Dead) and Emphysema (Causing the Air Sacs Alveoli to become Narrow).[31]

Diagnosis

There are several methods for analysing and evaluating the infection. All these methods require hospital services and equipment. The various tests are:

Sputum

- Gram staining
- AFB (Acid Fast Bacilli)
- Giemsa or methenamine silver stain
- KOH mount

Blood

- Complete Blood Count (CBC)
- Blood sugar
- Electrolytes, creatinine
- Blood cultures
- Oxygen saturation by pulse oximetry

Invasive

- Bronchoscopy
- Thoracoscopy
- Percutaneous aspiration biopsy
- Open lung biopsy
- Pleural aspiration

Other Tests

- Bacterial antigen in sputum and urine
- Rapid viral antigen detection in respiratory secretions
- Serological tests mainly for atypical molecular studies
- C-reactive protein
- Serum procalcitonin
- Neopterin

Gram Staining: It is the process in which the cells are coloured using a violet dye. It is used to identify the different types of bacteria.

Acid-fast bacilli (AFB): It is the test in which the sample is smeared and viewed under a microscope to clearly identify the bacteria.

Giemsa or Methenamine silver stain: It is a thin film staining done with the help of giemsa stain solution.

KOH mount: In this, potassium hydroxide is used to stain the specimen which is then looked at under a microscope.

Bronchoscopy: It is an invasive procedure used to examine the airways by the introduction of a bronchoscope through the mouth into the trachea.

Thoracoscopy - It is a procedure that uses a thoracoscope to view the lungs including the pleural cavity and bronchus in pneumonia and other pathological conditions.

Open lung biopsy - This technique is performed by taking a small sample of tissue from the cancerous cell or any pathological lung cell for histopathological examination.

Pleural aspiration - This aspiration process is used to take out the fluid present in the pleural cavity with the help of a small needle or tube.

In the case of CAP, the patients who are not being hospitalised do not usually need the sputum test. However, HAP patients need to undergo swab tests, sputum examinations as well as blood investigations. While diagnosing and confirming the disease, the best sample is sputum, as it collects all the microorganisms from the respiratory tract which can be visualised easily. The sputum should be collected prior to antibiotic treatments. The sputum is sent for Gram staining, where 78% of the staphylococcus SPP and 93-96% of specificity are found in patients with pneumococcal pneumonia. During this pandemic, the PCR test by the collection of pharyngeal swabs is preferred. [31] During the COVID-19 epidemic, people who were being admitted for CAP were compulsorily given a PCR test to confirm the Novel coronavirus. Bronchoscopy can be used to visualise the lower respiratory tract infection in VAP since it is simpler to collect a sample with pertinent data. Bronchoscopy and sputum tests were not advised for patients having HAP as it is not recommended to perform the bronchoscopy examination and sputum is not analysed. VAP patients

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mainly undergo digital respiratory sample tests. These patients have to undergo all the tests before the treatment procedure to confirm the pathology.

Recently the COVID-19 pneumonia test is being performed on every individual. The RT-PCR test is considered a confirmatory test for the disease, however, it still gives some false results. The drawback of this test is the requirement of a technician and equipment which a poor country cannot afford. There are two tests available to confirm the virus; one is an antigen test only useful to identify if the person is contaminated with the virus or not by the use of a nasopharyngeal test. Another method is done indirectly by testing antibodies. In this, the serum is collected to view the immune response directed against coronavirus. There is a chance of a false result as this test is not able to distinguish if the antibody response is due to past infection or present.

Biomarkers like C-reactive protein (CRP) and procalcitonin (PCT) are used for pneumonia.[32] They are useful to differentiate CAP from extrapulmonary infection. CRP rises in inflammation cases due to the existence of corticosteroids as well as late antibiotic treatment. On the contrary, the PCT test is usually for pneumonia caused by bacteria. However, both these tests can be used only for monitoring the disease activity but the treatment cannot be done on this basis only. This test should be followed by a second test after 24 to 48 hours to see the change. The combination of CRP and PCT can be used with the PCR test for viral confirmation. According to the guidelines provided by the ATS), the PCT test cannot be used to guide antibacterial therapy.

Community-Acquired Pneumonia

The sputum culture is mostly performed in many bacterial infections of pneumonia (Table 4). Urinary test is not recommended as pneumonia can be easily identified through respiratory tract secretions.

Prevention

CAP can be caused due to different factors like age, co-morbidities, unhealthy habits like smoking, alcohol consumption, and unwanted use of medication like sedatives, immunosuppressive drugs, etc. To eliminate this risk factor, one should develop healthy habits and good personal hygiene, and avoid interaction with people having pneumonia infection. To fight against certain types of pneumonia, health science has developed vaccinations like pneumococcal vaccine, influenza vaccination, etc. The vaccines recommended for adults are PCV 13 (13-valent pneumococcal conjugate vaccine) and PPV 23 (23-valent pneumococcal polysaccharide vaccine). The PPV 23 vaccine is given to people above 23 years of age. Its effect in decreasing the IPP (Invasive pneumococcal disease) has been good. Though in the case of non-IPD, the PPV 23 vaccination was not that effective. Comparing the efficacy of various vaccines revealed that the PCV 13 vaccine was effective for CAP, IPD, and non-invasive CAP in patients over 65, with distinct efficacy rates of 45.6%, 45.6%, and 75%. PPV 23 vaccine had an efficacy of 25-63% for pneumococcal pneumonia. If children are given these vaccines, the risk of transferring and developing pneumonia at an older age is decreased. They work as infection suppressants and help in developing immunity to fight against pneumonia.[33]

Table 4. Different Conditions of Pneumonia along with the Types of Tests to be performed in a particular Infection

Condition of Pneumonia	Blood Cultures	Respiratory Samples	Urinary Antigen	Comments
Outpatient	x	Sputum culture	x	Serology test when pathology is suspected through epidemiological evidence
Hospitalised patient (ward)	x	x	x	Influenza test during influenza season
Hospitalised patients admitted to ICU	x	BAL/ BAS in intubated patients	x	Serology test when pathology is suspected through epidemiological evidence
Failure of outpatient antibiotic treatment	x	Sputum culture	x	Serology for intracellular pathogens
Hospital-acquired pneumonia	x	x	x	Influenza test during influenza season
Ventricular-acquired pneumonia	x	BAS/ BAL/ min/ BAL	x	x

BAL: Broncho Alveolar Lavage; BAS: Broncho Aspirate; CAP: Community-Acquired Pneumonia

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Similarly, influenza vaccination helps in minimising the risk factor as well. They are usually given to younger children and older and pregnant women as they develop more chance of getting these infections. The influenza vaccine helps to decrease the acuteness of the disease both for HAP as well as CAP. According to a 2019 study, viral sepsis started in 19% of patients admitted to the ICU with CAP, while influenza virus started in 61% of patients with CAP. Currently, 35% of people with low respiratory tract infections were vaccinated, and 57% of people who received the CAP vaccine for influenza saw a 51% increase in effectiveness. Hence, we can measure the effectiveness of these vaccines in any group of patients having any histological confirmation.[33]

HAP is responsible for increasing the mortality rate. It can develop due to various reasons like sepsis, oropharyngeal colonisation of bacteria and antibiotic therapy done for a long period of time. However, the prevention of all of these risk factors is still slow and proper protocols haven't been followed. Isolating contaminated patients while providing appropriate patient care can be one of the concerns. The Pneumonia Zero project that began in Spain involved the implementation of mandatory and highly advocate measures in order to prevent VAP in the patients admitted in 181 ICUs.[34] The inescapable measures included training given to the staff and hospital workers to manage the airway, maintain proper hand hygiene and sanitising with a suitable alcohol solution, oral hygiene by the use of antiseptics like chlorhexidine, reduction of the time for mechanical ventilation to as low as possible, development of awareness regarding the importance of prevention among patients and visitors. Aspiration of sputum that has been secreted in the epiglottis of the ventilated patient who has been intubated for more than 72 hours, SDC (Selective Digestive Contamination), and Selective Oral Contamination (SOC) are more advantageous techniques. After the utilisation of these techniques, a vast difference was observed in the risk of VAP. Its incidence decreased from around 9.3 to 4.34/1000 ventilators over a period of 21 months. Additionally, the patient admitted for VAP recovered quickly (approximately 2.4%-1.9%), lowering the risk. Hence, by following both the mandatory and highly recommend measures, the hospitals were able to decrease the case rate and also the recurrence rate of pneumonia by 10.9% to 7.7% efficiently. These techniques are still followed in the case of VAP.

Recurrent Pneumonia Preventive Measures

Recurrent pneumonia is more common in CAP patients after hospitalisation. It affects around 9% of patients. It is sometimes difficult to distinguish this pneumonia from an old infection because it leaves a mark on the lungs. The risk factors concerned with recurrent pneumonia are failure to vaccinate (pneumococcal vaccination), antecedent series of pneumonia, old age (above 65 years old), COPD, etc. The only and the most effective preventive measure taken for recurrent pneumonia can be vaccination against the infection. The various measures that can be applied in case of aspiration pneumonia have been shown in Table 5.

Table 5.Measures that can be applied in case of Aspiration Pneumonia

Aspiration Pneumonitis	Aspiration Pneumonia
Semi-recumbent body position	Avoid excessive sedation
Enteral feeding	Orotracheal Intubation
Small bore gastric tube	
Promotility agents	
Intubation procedure	
Cormack and Lehane's classification to predict the risk of aspiration	
Mallampati scale to predict the risk of aspiration	

The position of the patient also greatly reduces the risk of VAP.

Methods to Avoid Pneumonia in other Non-Pharmacological Ways

Hygiene is the main concern in this infection. Good hygiene of hands maintained by the use of alcohol sanitisers should be done. The other ways to avoid contamination due to aspiration include proper positioning of the patient. In the supine position, gastric reflux can be a cause so the patient is advised to lie down in a semi-recumbent position. A study was done regarding the head tilt position (Trendelenburg) but it increased the risk of infection so it wasn't recommended. During the case of COVID-19, the patients who were having difficulty breathing were asked to adjust themselves in the prone position so that the pressure can facilitate breathing. VAP patients have endotracheal tubes attached so screening and removal of any contamination is essential. To decrease the risk of lower respiratory tract infection when the patient is given oxygen therapy, the pressure on the cuffs should be more than 25 cm of H_2O; by doing this the bacterial passage will be stopped. The coffee while being used is an important factor in reducing risk. According to other research, minimising the risk of infection was not as effective with polyurethane conical shapes.

Pharmacological Ways to Reduce the Risk Factors

The clinical measures that can be applied to cope with

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the pneumonia infection include hygiene; oral hygiene is regarded as a crucial part in this case. If there is an unhygienic condition, then it will provide a direct path for bacteria to enter the body. When a person is not concerned about keeping his or her mouth clean then the things he eats will eventually get contaminated. Hence the person is asked to clean the mouth with chlorhexidine. However, a recent study on chlorhexidine showed that the patient's mouth may contain a highly toxic chemical which can reach the lungs and can be dangerous. On the other side, SOD and SDD use is preferred as it was found to decrease the risk of pneumonia (VAP) and other microorganisms. However, some countries like the USA have banned the use of SOD because of its less resistance to antibodies. Other countries are still using SDD as a protective measure.[35]

Conclusion

Pneumonia is still a burning issue and research is being done even today on this problem. During the coronavirus infection, people are highly recommended to get a chest CT scan to confirm pneumonia but, because of the varying trend of the COVID virus, the imaging modalities have also changed. Not only in COVID-19, but also in any respiratory distress, the first thing that is suggested is to check for pneumonia as pneumonia is a very common disease and still we have not been able to eliminate it. There are many studies being carried out in various developing countries to find the easiest, fastest and cheapest ways to detect this infection. Hope that the coming generations will be able to eliminate this infection.

Conflict of Interest: None

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