Journal of Scientific and Human Dimensions

مجلة الأبعاد العلمية والإنسانية

Volume 2, Issue 2, 2026, Pages: 16-31

Journal homepage: https://jshd.com.ly/index.php/jshd/en

Clinical Impact and Pathogenic Role of Streptococcus Pneumoniae in Human Respiratory and Systemic Diseases

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الأثر السريري والدور الممرض للمكورات الرئوية في أمراض الجهاز التنفسي والأمراض الجهازية لدى الإنسان

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Received: February 14, 2026	Accepted: March 25, 2026	Published: April 06, 2026

Abstract:

This study examined the prevalence of Streptococcus pneumoniae and its antibiotic susceptibility among patients with respiratory and systemic infections at Tripoli Medical Center, Libya. A total of 50 clinical samples were collected and analyzed using routine laboratory methods.

The results showed that 38 samples (76%) were positive for Streptococcus pneumoniae. Infection was more common in males than females, with the highest prevalence in the 41–60 years age group. Pneumonia was the most common clinical diagnosis, and sputum samples were the most frequently used specimens for bacterial isolation.

Antibiotic susceptibility testing revealed high sensitivity to vancomycin, levofloxacin, and ceftriaxone, while increased resistance was observed against erythromycin and penicillin.

In conclusion, Streptococcus pneumoniae remains a major cause of respiratory and systemic infections. Proper laboratory diagnosis, appropriate antibiotic use, and vaccination are essential to reduce disease burden and antibiotic resistance.

Keywords: Streptococcus Pneumoniae, Antibiotic Susceptibility, Tripoli Medical Center, Pneumonia, Clinical Diagnosis**.**

الملخص

تناولت هذه الدراسة مدى انتشار المكورات الرئوية وحساسيتها للمضادات الحيوية لدى مرضى يعانون من التهابات الجهاز التنفسي والأمراض الجهازية في مركز طرابلس الطبي، ليبيا. جُمعت 50 عينة سريرية وحُللت باستخدام الطرق المختبرية الروتينية.

أظهرت النتائج أن 38 عينة (76%) كانت إيجابية للمكورات الرئوية. كان انتشار العدوى أكثر شيوعًا بين الذكور منه بين الإناث، مع أعلى معدل انتشار في الفئة العمرية من 41 إلى 60 عامًا. كان الالتهاب الرئوي هو التشخيص السريري الأكثر شيوعًا، وكانت عينات البلغم هي العينات الأكثر استخدامًا لعزل البكتيريا.

كشف اختبار حساسية المضادات الحيوية عن حساسية عالية للفانكومايسين والليفوفلوكساسين والسيفتركسون، بينما لوحظت مقاومة متزايدة للإريثروميسين والبنسلين. في الختام، لا تزال المكورات الرئوية سببًا رئيسيًا للعدوى التنفسية والجهازية. ويُعد التشخيص المختبري الدقيق، والاستخدام الأمثل للمضادات الحيوية، والتطعيم، أمورًا أساسية للحد من عبء المرض ومقاومة المضادات الحيوية.

الكلمات المفتاحية: المكورات الرئوية، حساسية المضادات الحيوية، المركز الطبي في طرابلس، الالتهاب الرئوي، التشخيص السريري.

Introduction

Bacteria are single-celled microorganisms that belong to the kingdom of prokaryotes. They lack a true nucleus and membrane bound organelles (Marangi & Boughattas, 2025). Bacteria reproduce mainly through binary fission and exhibit diverse shapes such as cocci (spherical), bacilli (rod-shaped), and spirilla (spiral). They play essential roles in nature, including nitrogen fixation, decomposition, and various industrial applications (Pan et al., 2025). However, some species are pathogenic and can cause diseases in humans, animals, and plants .

Streptococcus pneumoniae is one of the most significant bacterial pathogens affecting humans, responsible for a wide spectrum of respiratory and systemic infections. It is a leading cause of community acquired pneumonia, acute otitis media, and sinusitis, as well as invasive diseases such as meningitis and bacteremia (Graf et al., 2024). The clinical burden of pneumococcal infections remains substantial worldwide, particularly among children under five years of age, the elderly, and immunocompromised individuals. The pathogenicity of S. pneumoniae is largely attributed to its diverse virulence factors, including the polysaccharide capsule, surface proteins, and toxins, which enable colonization, immune evasion, and tissue invasion (Yan et al., 2024). Furthermore, the emergence of antibiotic-resistant strains poses a major challenge for treatment and public health. Despite the availability of effective vaccines, pneumococcal diseases continue to account for significant morbidity and mortality, highlighting the importance of ongoing research into its clinical impact and pathogenic mechanisms (Miller & Arias, 2024).

Research Objectives

Determine the prevalence of bacterial infection among individuals with respiratory and systemic diseases. Evaluate the diagnostic methods used to detect the bacteria and their effectiveness, such as staining, culture, biochemical, and serological tests. Analyze the relationship between age, gender, and the severity or type of resulting disease. Assess the bacterial sensitivity and resistance to antibiotics.

Time limits for research

The study was conducted during the period from November to 2025. Place limits for research

The results were obtained from Tripoli Medical center .

Problem statement:

The research problem in studying the clinical impact and pathogenic role of Streptococcus pneumoniae in respiratory and systemic diseases lies in the widespread presence of the bacterium, the diversity of its strains causing various types of infections, and its ability to cause opportunistic infections beyond the respiratory system. Additionally, there is an urgent need to understand its pathogenic mechanisms and clinical effects to improve early diagnosis, effective treatment, and preventive measures.

Research Importance

Research on Streptococcus pneumonia is extremely important as it contributes to understanding the serious diseases it causes, such as pneumonia, meningitis, and sepsis, as well as otitis media and sinusitis. This research enables the development of effective vaccines like PCV13 and PPSV23, which have significantly reduced invasive diseases. It also enhances understanding of antibiotic resistance mechanisms, improves diagnostic and treatment methods, and supports the development of biotechnological applications using bacterial compos.

Respiratory system

The respiratory system is considered one of the most important systems in the human body, as the breathing process is considered as a fuel station that provides the body with energy that a person cannot live without at all, as it has an essential role in maintaining the activity and continuity of vital processes. It refers to a lack of oxygen and its deficiency, which infects the brain with perfusion, as abnormal symptoms appear, including dizziness, and the respiratory process is divided into two successive phases inhalation. As for the other process, it is known exhalation.

It includes parts related to the respiratory process and complements the function of breathing among them: lungs / nose/pharynx / larynx /trachea/bronchi/alveoli.

One of the functions of the respiratory system is to supply the body with oxygen and oxidize oxygen through the lungs, maintain the balance of body temperature from disturbance, and stimulate cells to perform their functions by taking air, entering the body and expelling it (Yam, 2024).

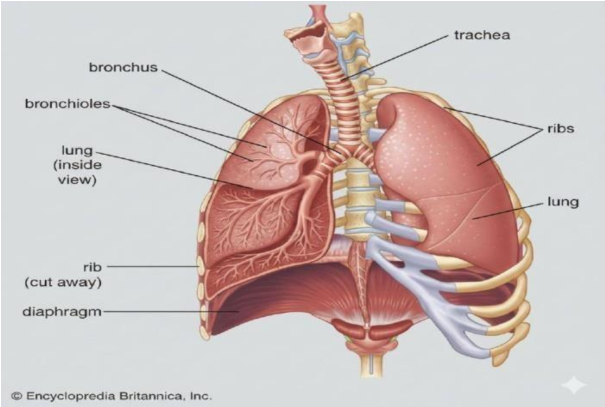


Figure 1 The structure of the human respiratory system

Morphological and biochemical features of Streptococcus pneumonia

Streptococcus pneumoniae exhibits distinctive morphological features that aid in its identification:

1. **Cellular Shape:**

The bacterium appears as Gram-positive, lancet-shaped (Pointed ovoid) cocci that typically arrange in pairs (diplococci) or short chains. This characteristic lancet shape is a distinguishing feature that makes them easily recognizable under microscopy.

2. **Capsule Structure:**

S. pneumoniae possesses a prominent polysaccharide capsule surrounding the cell wall, which is the primary virulence factor. This capsule can measure up to 400 nanometers in thickness, comprising more than half of the bacterial volume. Currently, 98 distinct capsular serotypes have been identified.

3. **Gram Staining:**

The organism is Gram-positive, appearing purple under Gram staining.

4. **Colonial Morphology:**

Colony Appearance: The morphology of *S. pneumoniae* colonies varies depending on capsule formation: Heavily encapsulated strains produce large (several millimeters in diameter), gray, highly mucoid colonies Less encapsulated variants form smaller colonies Hemolysis Pattern: On blood agar plates, S. pneumoniae produces alpha hemolysis, creating a greenish discoloration around colonies due to neurolysin production, which converts hemoglobin to a green pigment. Opacity Variation: Colonies exhibit phase variation between transparent and opaque forms, reflecting differences in pathogenicity and virulence potential. Transparent variants are more effective at nasopharyngeal colonization, while opaque forms show greater virulence in invasive disease models. Biochemical Characteristics, Basic Biochemical Properties Fundamental Tests: Gram stain: Positive Catalase: Negative Oxidase: Negative, Urease: Negative Motility: Non-motile Spore formation: Non-sporing Oxygen requirements: Facultative anaerobe Key Diagnostic Tests: The optochin test is one of the most important diagnostic procedures for S. pneumoniae identification:

5. **Principle:**

Optochin (ethylhydrocupreine hydrochloride) is a quinine derivative that selectively inhibits S. pneumoniae growth at low concentrations (5 mg/mL or less). The chemical affects bacterial cell membrane fragility, causing lysis due to surface tension changes.

6. **Procedure:**

Alpha-hemolytic colonies are streaked onto blood agar an optochin disk is placed on the inoculated surface Incubation at 35°C for 18-24 hours in 5-10% CO_2 Zone of inhibition diameter is measured Susceptible: Zone diameter ≥14 mm (indicates *S. pneumoniae*)

7. **Resistant:**

Zone diameter <14 mm (indicates viridans group streptococci)

8. **Performance:**

The test demonstrates 99% sensitivity and 98% specificity for *S. pneumoniae* identification(11) Bile Solubility Test :This test is considered among the most sensitive and specific assays for *S. pneumoniae* identification:

9. **Principle:**

S. pneumoniae contains an intracellular autolytic enzyme (amidase) that can be activated by bile salts such as sodium deoxycholate. Bile salts reduce surface tension between the bacterial cell membrane and medium, accelerating the organism's natural autolytic process.

Prepare bacterial suspension in saline Add 2% sodium deoxycholate to test tube Incubate at 35-37°C for 10-15 minutes Observe for clearing of turbidity

Positive: Complete clearing of turbidity (indicates S. pneumoniae)،Negative: No clearing (indicates other viridans streptococci)

Performance: The deoxycholate tube test shows 100% sensitivity and 99% specificity (Yam, 2024).

Biochemically, S. pneumoniae is catalase-negative and oxidase negative. It is bile soluble (positive in bile solubility test) and sensitive to optochin, which are highly specific tests used to distinguish it from viridans streptococci) (Yam, 2024).

Figure 2 The Streptococcus pneumonia shows bacteria

Virulence Factors of Streptococcus pneumoniae

1. **Structural Virulence Factors :**

Structural factors are components of the bacterial structure the capsule, cell wall and its components, surface proteins, etc. that help the bacteria survive, parasitize, or evade the immune system. Capsule (Polysaccharide Capsule) One of the most important virulence factors in Streptococcus pneumoniae. The microbe is virtually incapable of causing serious disease unless it is encapsulated. Its function: It protects bacteria from phagocytosis by preventing the attachment of complement C3b to the surface of bacteria and preventing the interaction of immune antibodies with them. The capsule thickness is usually about 200-400 nm Cell Wall Components: Peptidoglycan: Forms the rigid structure of bacteria, plays a role in maintaining shape, and triggers a strong inflammatory response when stimulated by the host (14). Surface Proteins These proteins are bound to:

- peptidoglycan
- or bound to phosphocholine residues
- or bound to lipids or LPxTG (linked via sortase).

Pneumolysin (although not structural‖ in the classic sense of internal structure, it is released from bacteria and affects the surface/cellular structure after lysis) It is a cholesterol-dependent cytolysin toxin produced in the cytoplasm, often released during bacterial lysis by autolysin (LytA).

Forms pores in host cell membranes, kills or damages cells, and stimulates a strong inflammatory response .

2. **Secreted Toxins and Enzymes**

Streptococcus pneumoniae produces a variety of enzymes and toxins that help it cause disease. These include tissue degrading enzymes such as hyaluronidase and streptodornase, as well as toxins that affect red blood cells like streptolysin, which enable the bacteria to invade and cause infections.

Main Toxins and Enzymes:

Streptolysin: A cytotoxin responsible for breaking down red blood cells (hemolysis), and also damages other host cells.

Hyaluronidase: An enzyme that breaks down hyaluronic acid, a key component of connective tissue, facilitating bacterial spread through tissues.

Streptodornase: An enzyme that degrades DNA, reducing the viscosity of pus and aiding bacterial dissemination. The bacteria may also produce additional enzymes that assist in tissue (Yuan et al., 2023).

3. **Pigments and Iron Acquisition**

Streptococcus pneumoniae has developed multiple specialized systems to obtain iron from the host because iron is not freely available in human tissues and is essential for bacterial growth and pathogenicity. The main transporters for iron uptake in S. pneumoniae are three. ATPbinding cassette (ABC) transporter systems:

- PiaABC
- PiuABC
- PitABC.

Recent studies discovered an additional transporter SPD_1590, which also binds hemin (iron containing porphyrin (Yam, 2024).

Streptococcus pneumoniae relies on complex systems to acquire iron, such as hijacking heme from hemoglobin and hemocyanin, and absorbing other iron compounds from the host. This ability is vital for its survival and growth, allowing it to colonize the nasopharynx and subsequently cause infections in other parts of the body (Chapman et al., 2020).

Diseases Caused by Streptococcus pneumonia :

Streptococcus pneumoniae is a major pathogen that causes a range of diseases in humans, from mild upper respiratory infections to severe invasive diseases.

1. Pneumonia (community-acquired pneumonia)
2. Bacteremia / Sepsis (invasive bloodstream infection)
3. Meningitis (pneumococcal meningitis)
4. Otitis media (middle ear infection)
5. Sinusitis (nasal sinus infection)
6. Bronchitis (especially exacerbations or in predisposed individuals) (Yam, 2024).

Symptoms:

tinged sputum When infected with this type of bacteria, symptoms may appear in various forms depending on the site of infection (lungs, blood, meninges, ear, sinuses, etc.). The following are the main symptoms in the pulmonary form

(pneumonia):

1. Sudden fever with chills
2. Cough (often accompanied by sputum production)
3. Chest pain (pleuritic pain) that worsens with deep breathing or coughing
4. Shortness of breath (difficulty in breathing / rapid exhalation)
5. Increased respiratory rate (tachypnea)
6. Increased heart rate (tachycardia)
7. General fatigue and weakness
8. Mucous or mucopurulent sputum, which may contain slight blood streaks (rust-colored‖ or blood)

Sometimes, gastrointestinal symptoms such as nausea or vomiting may occur In elderly individuals or those with weakened immune systems, the classic symptoms may not appear, and confusion or general weakness may be the predominant signs (Yam, 2024).

Materials

1. Blood Agar

Blood agar is an enriched medium commonly used for the cultivation of fastidious organisms such as Streptococcus pneumoniae.

The basal medium is prepared first, then sterile blood is added at 5% (v/v) after steam sterilization and before pouring into Petri dishes. On blood agar, Streptococcus pneumoniae exhibits alpha hemolysis, which appears as a greenish discoloration surrounding the colonies. This partial hemolysis is due to the production of hydrogen peroxide, which oxidizes hemoglobin to methemoglobin in red blood cells (Chen et al., 2023).

Table 1: Composition of Blood Agar

Component	Amount (per liter)
Peptone	10 g
Beef extract	10 g
Sodium chloride	5 g
Agar	15 g
Blood	5% (v/v)
Distilled water	1000 ml

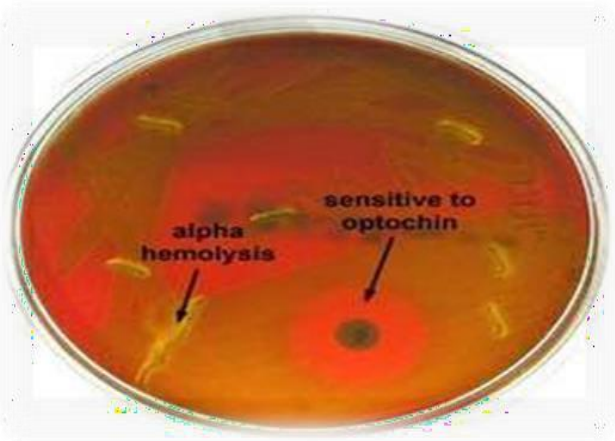


Figure 3 shows Streptococcus pneumonia colonies on Blood Agar.

2. Chocolate Agar

Chocolate agar is an enriched medium used to isolate. Streptococcus pneumoniae and other fastidious bacteria such as Neisseria species and Haemophiles influenzae. The medium is prepared by heating blood agar until the red blood cells lyse, releasing nutrients such as hemin (factor X) and nicotinamide adenine dinucleotide (factor

V) into the agar. These factors support the growth of nutritionally demanding organisms. On chocolate agar, Streptococcus pneumoniae produces small, round, glistening colonies that may become umbilicated (depressed in the center) after incubation (Chen et al., 2023).

Table 2 Showing the components of Chocolate Agar

Component	Amount (per liter)
Peptone	10 g
Beef Extract	10 g
Sodium chloride	5 g
Agar	15 g
Defibrinated Blood(heated to 80C)	5-10 %
Distilled Water	1000 ml

Figure 4 shows Streptococcus pneumonia colonies on Chocolate Agar

Methods

Sample Collection and Processing

A total of 50 clinical samples were collected from patients suspected of having respiratory and systemic infections. The samples were obtained from Tripoli Medical Center (TMC), Tripoli, Libya, which is a major tertiary hospital receiving patients from different age groups and clinical conditions. The collected specimens included sputum, throat swabs, blood, and stool samples, which were obtained as part of routine diagnostic procedures. All samples were collected under aseptic conditions and transported immediately to the microbiology laboratory for bacteriological culture, isolation, and identification of the causative bacterial pathogens. Further biochemical and microbiological tests were performed according to standard laboratory protocols.

Media Preparation

Blood Agar is considered the most common and best medium for isolating and culturing S. pneumoniae from clinical specimens.

The appearance of alpha-hemolysis (α-hemolysis) is a characteristic feature of this bacterium on blood agar The procedures used for sterilization at 121°C for 15-20 minutes, and cooling to 45-50°C before adding blood, are standard steps in preparing media containing heat-sensitive components like blood. The 5% concentration of sterile blood is the recommended ratio to provide necessary growth factors and determine hemolysis patterns Sealing the plates and storing them at 4°C ensures their viability and prevents contamination before use The optimal incubation temperature is 35-37°C.

The need for an atmosphere containing 5% carbon dioxide (CO_2) is critical, as some strains of this bacterium are entirely dependent on the presence of carbon dioxide for optimal growth (capnophiles).

Figure 5 Culture Media

Inoculation of samples

To prepare a sample of Streptococcus pneumoniae bacteria, enriched media such as blood agar are typically used, and the samples are incubated in an atmosphere rich in carbon dioxide (CO2). The exact method varies depending on the type of sample and the purpose of the inoculation .

Sample Dilution

Enriched culture media such as blood agar must be used for the growth of Streptococcus pneumoniae. The bacteria require specific incubation conditions, and the inoculation method varies based on the original sample source, such as blood, sputum, or cerebrospinal fluid .

Microscope examination

Gram Staining

Gram staining is a differential staining technique used for the preliminary classification of bacteria. Streptococcus pneumoniae is a Gram-positive bacterium, which means it appears blue or purple under the microscope after staining.

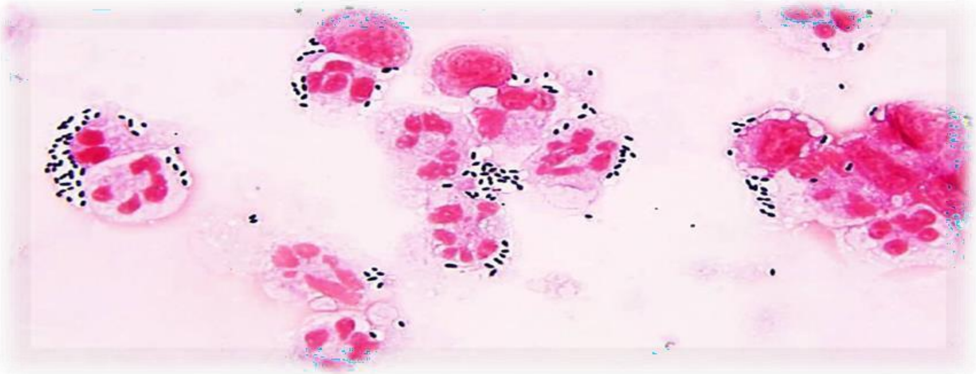


Figure 6 shows Streptococcus pneumonia under microscope

Gram-positive bacteria appear purple due to their thick peptidoglycan layer in the cell wall. This test provides essential information for bacterial identification and guides further biochemical testing.

The characteristic appearance of S. pneumoniae under the microscope is that they are spherical (cocci) and typically appear in pairs (diplococci). They are often described as being "lancet shaped", due to their slightly pointed ends. Additionally, these bacteria possess a polysaccharide capsule which does not stain with Gram stain, and therefore typically appears as a clear area or unstained halo around the stained bacterial cell (Fan et al., 2025).

Identification of Isolated Bacteria

Bacterial isolates suspected of being Streptococcus pneumoniae require specific biochemical tests for confirmation and differentiation from other alpha-hemolytic streptococci. The optochin susceptibility and bile solubility tests are the main tests used for phenotypic identification Identification of Isolated Bacteria .

Catalase Test :

Streptococcus pneumoniae is catalase-negative. When a drop of hydrogen peroxide (H_2O_2) is added to a colony, no bubbling occurs, because the organism does not produce the catalase enzyme that breaks H_2O_2 into water and oxygen. This result helps differentiate Streptococcus species (catalase-negative) from Staphylococcus species (catalase-positive) (Fernandes Queiroga Moraes et al., 2021).

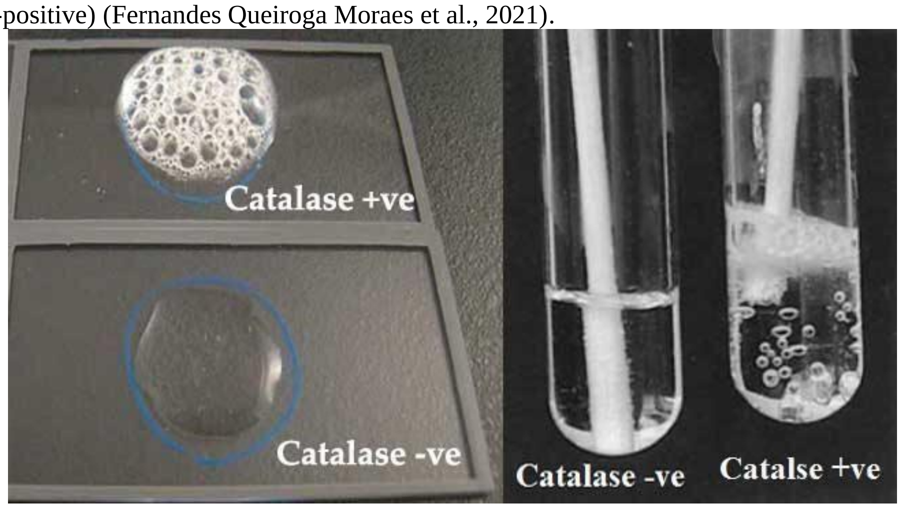


Figure 7 shows Catalase Test

Susceptibility Optochin Test

a common method used to identify Streptococcus pneumoniae. This test relies on the organism's sensitivity to the chemical optochin The Optochin susceptibility test is a method used in microbiology to differentiate Streptococcus pneumonia (pneumococcus) from other alpha-hemolytic streptococci, such as the viridans group. The test is based on the susceptibility of S. pneumoniae to the chemical compound optochin, while other alpha-hemolytic species are resistant (Chen et al., 2023).

Table 3 showing the components of Optochin Susceptibility Test:

Component	Amount (per liter)
Culture Medium	Blood Agar 5%
Bacterial Strain	Pure culture of S. pneumonia
Optochin Discs	5 µg
Incubation	35-37 °C, CO2 5%
Reference Strain	S. pneumonia ATCC 49619
Control Strain	Streptococcus mitis

Figure 8 shows Streptococcus pneumonia colonies on Susceptibility Optochin

3.2.6.3 Bile Solubility Test

The Bile Solubility Test is a biochemical test used to identify and differentiate Streptococcus pneumoniae from other alpha-hemolytic streptococci (viridans group streptococci). S. pneumoniae is characterized by its ability to lyse in the presence of bile salts due to an intracellular autolytic enzyme activated by bile salts such as sodium deoxycholate (Chen et al., 2023).

Table 4 showing the components of Bile Susceptibility Test:

Component	Amount (per liter)
Bacterial Culture	Pure culture
Sodium Deoxycholate	Bile salt reagent, 2% or 10% concentration.
Sterile Distilled Water	control tube
Sterile Saline Solution	bacterial suspension
Test Tubes or Agar Plates	Vessel for performing the test
Incubator	35-37 degrees Celsius.

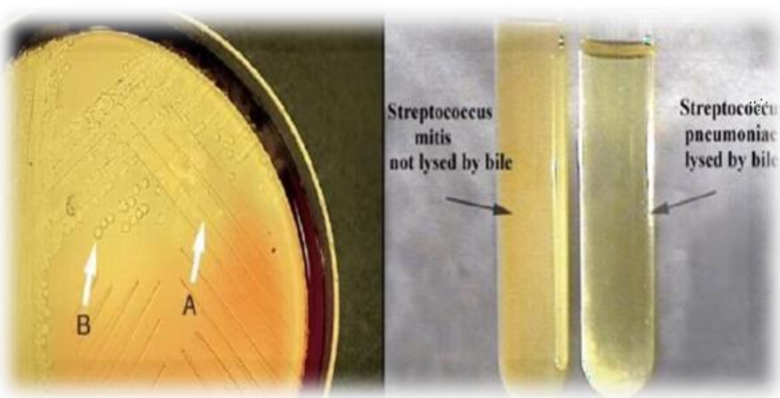


Figure 9 shows Streptococcus pneumonia colonies on Susceptibility Bile

Antibiotic Susceptibility Testing

Antibiotic Susceptibility Testing (AST) for Streptococcus pneumoniae is critically important for guiding appropriate treatment and tracking resistance patterns, given the increasing resistance of this bacterium to many common antibiotics. These susceptibility tests help prevent treatment failure and improve overall public health surveillance.

S. pneumoniae requires specific growth conditions, typically a blood enriched culture medium and an atmosphere with an increased concentration of carbon dioxide (CO_2), to obtain reliable results. Standardized guidelines must be followed, such as those from the Clinical and Laboratory Standards Institute (CLSI) or the European Committee on Antimicrobial Susceptibility Testing (EUCAST).

Common methods include:

Disk Diffusion Method (Kirby-Bauer): Paper disks impregnated with specific antibiotic concentrations are placed on an agar plate inoculated with the bacteria. After incubation, the diameter of the "zone of inhibition" (the area where bacteria do not grow) is measured and compared to interpretive charts to determine if the isolate is susceptible (S), intermediate (I), or resistant (R).

Minimum Inhibitory Concentration (MIC) Test:

This method determines the lowest concentration of an antibiotic that inhibits visible bacterial growth. Important Considerations for S. pneumonia Penicillin: Specific breakpoints for penicillin susceptibility are used depending on the site of infection. Infections in the cerebrospinal fluid (CSF), indicating meningitis, use lower breakpoints than non-meningitis infections, such as pneumonia.

Resistance Mechanism: Resistance to beta-lactam antibiotics (such as penicillin and cephalosporins) primarily occurs due to mutations in penicillin-binding proteins (PBPs), which reduces the antibiotic's binding affinity to its target. These bacteria do not produce beta-lactamase enzymes.

Tested Antibiotics: Common antibiotics tested include: amikacin, imipenem, ceftazidime, ciprofloxacin, colistin, and piperacillin tazobactam, among others.

Susceptibility test results are categorized as susceptible (S), intermediate (I), or resistant (R) based on standard breakpoints. This classification helps clinicians select effective treatments for the patient (Chen et al., 2023).

Figure 10 shows Antibiotic Susceptibility Testing.

The Results and Discussion

The results of the present study demonstrated that Streptococcus pneumoniae remains one of the most significant pathogens associated with respiratory and systemic infections. Out of the total samples analyzed, a considerable proportion tested positive, indicating its high prevalence among patients suffering from respiratory tract infections

Study Setting and Sample Distribution

This study was carried out at Tripoli Medical Center (TMC), Tripoli, Libya, a major hospital that receives patients with different types of respiratory and systemic infections. The hospital serves a large number of patients from various age groups and clinical conditions. A total of 50 clinical samples were collected from patients suspected of having respiratory or systemic infections. The samples included sputum, throat swabs, blood, and stool Specimens, which were collected as part of routine diagnostic procedures. This variety of samples helped in identifying the most common bacterial pathogens, particularly Streptococcus pneumoniae, among the studied patients.

Out of the 50 collected clinical samples, 38 samples were identified as positive for Streptococcus pneumoniae, while the remaining 12 samples showed either no bacterial growth or growth of other bacterial species. Therefore, all subsequent analyses in this study were based on the 38 confirmed

Streptococcus pneumoniae cases.

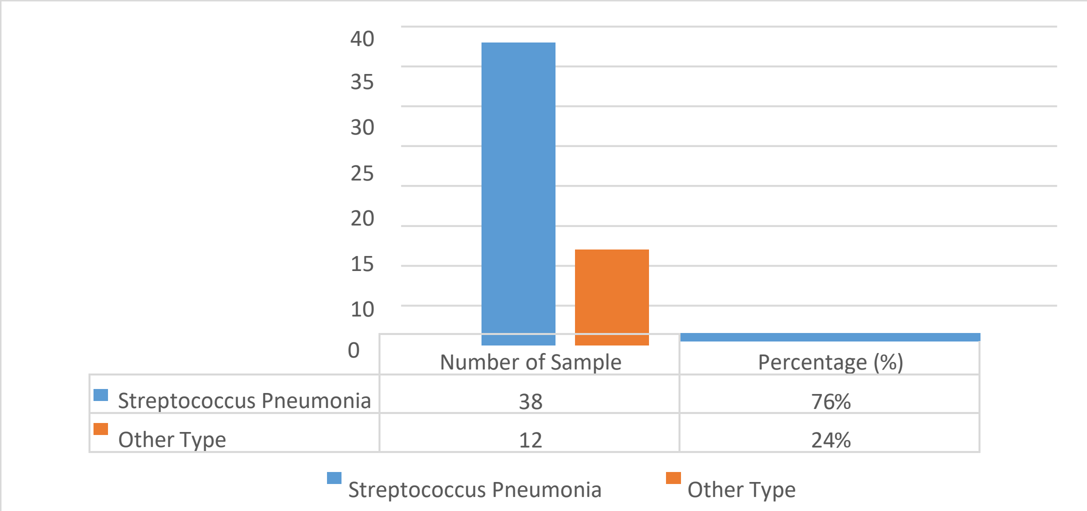
Distribution of Bacterial Growth Result

Out of the 50 clinical samples collected from Tripoli Medical Center, 38 samples (76%) showed positive bacterial growth, while 12 samples (24%) revealed no bacterial growth.

Table 5 Bacterial Growth Results

Growth Result	Number of Sample	Percentage (%)
Streptococcus Pneumonia	38	76%
Other Type	12	24%
Total	50	100%

The table shows the results of bacterial culture. Positive bacterial growth was detected in 76% of the samples, indicating a high prevalence of bacterial infections among patients attending Tripoli Medical Center.



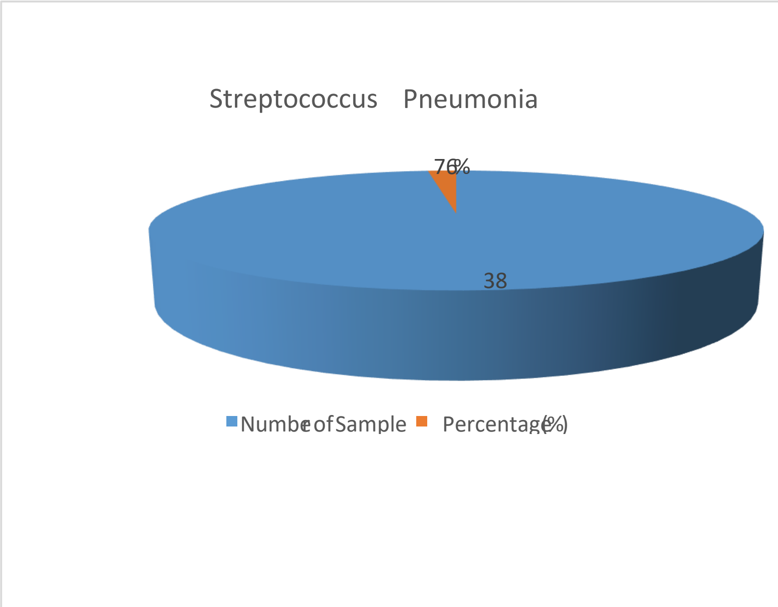


Figure 11 Distribution of bacterial growth results among collected clinical samples

Gender Distribution of Patients

The gender distribution was analyzed among positive cases only (N = 38) to evaluate the relationship between infection and gender.

Table 6 Gender Distribution of Patients

Gender	Number of Patients	Percentage (%)
Male	22	57.9%
Female	16	42.1%
Total	38	100%

This table shows the distribution of patients according to gender. The results indicate a slightly higher proportion of males (57.9%) compared to females (42.1%). This difference may be related to increased exposure of males to environmental and occupational risk factors associated with respiratory infections.

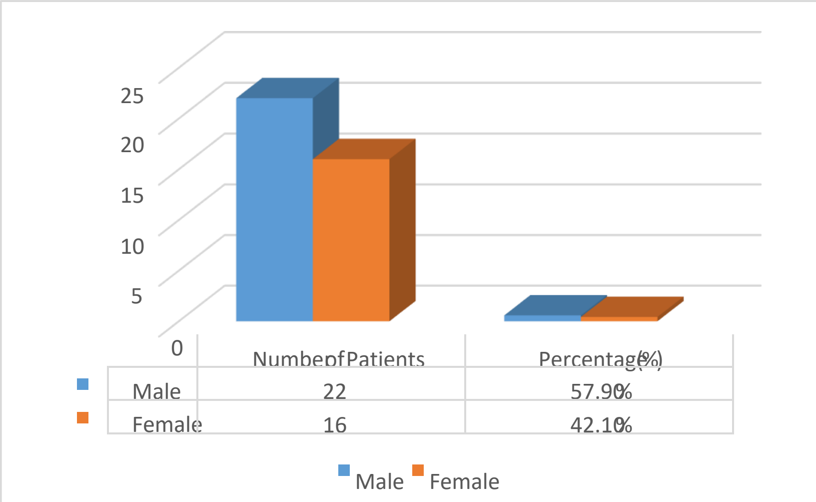


Figure 12 Gender distribution of patients infected with Streptococcus pneumoniae

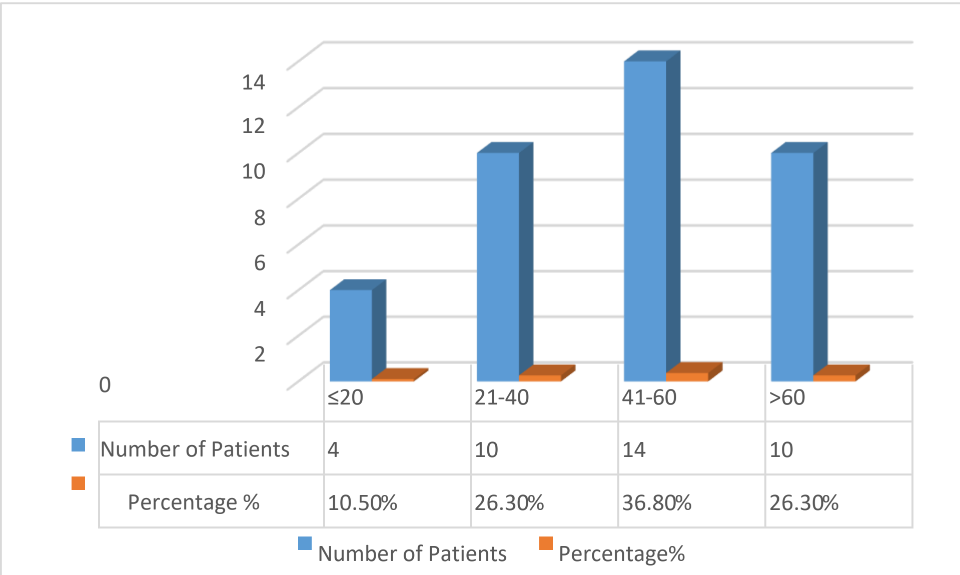
Age Distribution of Patients

Patients were categorized into age groups to assess the prevalence of infections across different age ranges. The highest number of cases was observed among adults aged 41–60 years.

Table 7 Age Distribution of Patients

Age group(years)	Number of Patients	Percentag%
≤20	4	10.5%
21-40	10	26.3%
41-60	14	36.8%
>60	10	26.3%
Total	38	100%

This table illustrates the age distribution of the studied patients. The highest number of cases was observed in the 41–60 years age group (36.8%), This suggests that middle-aged and elderly individuals are more susceptible to respiratory and systemic infection.



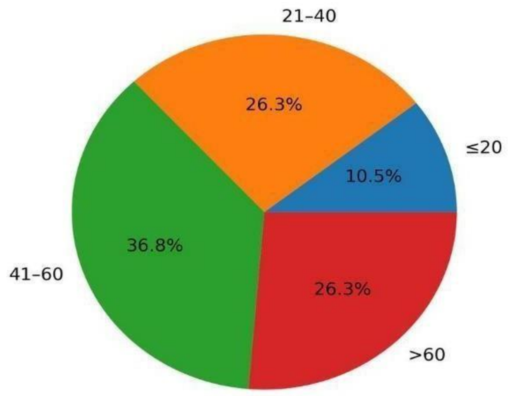


Figure 13 Age distribution of Streptococcus pneumoniae positive cases

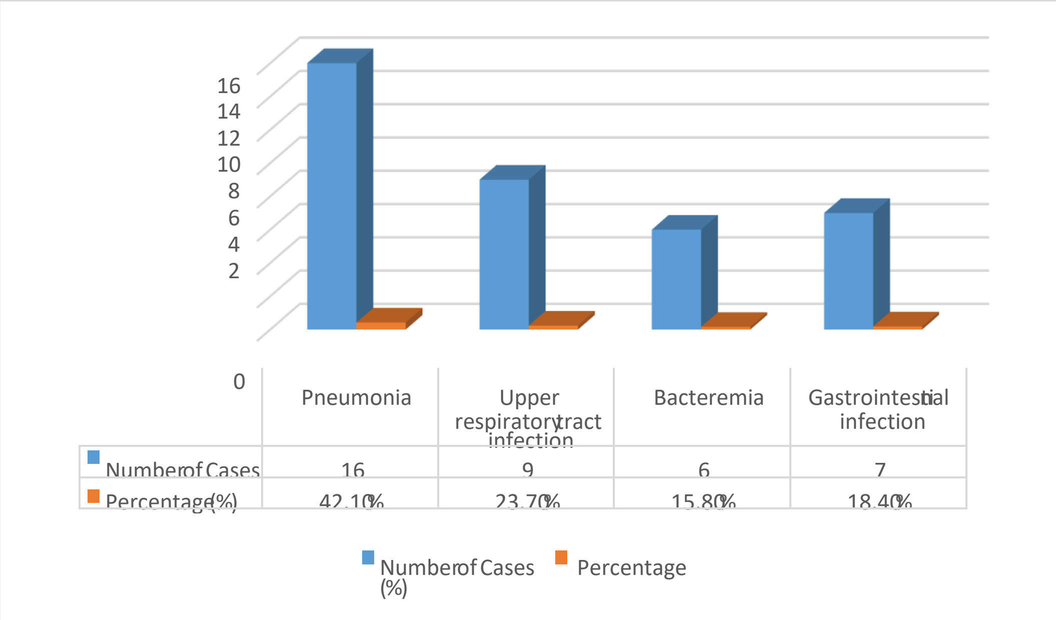
Distribution of Clinical Diagnoses

The clinical diagnoses of infected patients were analyzed to determine the association between bacterial infection and disease type.

Table 8 Distribution of Clinical Diagnoses

Clinical diagnosis	Number of Cases	Percentage (%)
Pneumonia	16	42.1%
Upper respiratory tract infection	9	23.7%
Bacteremia	6	15.8%
Gastrointestinal infection	7	18.4%
Total	38	100%

This table shows the distribution of clinical diagnoses among positive cases. Pneumonia was the most common condition, highlighting the significant role of bacterial pathogens in respiratory infections, while systemic infections such as bacteremia were also present



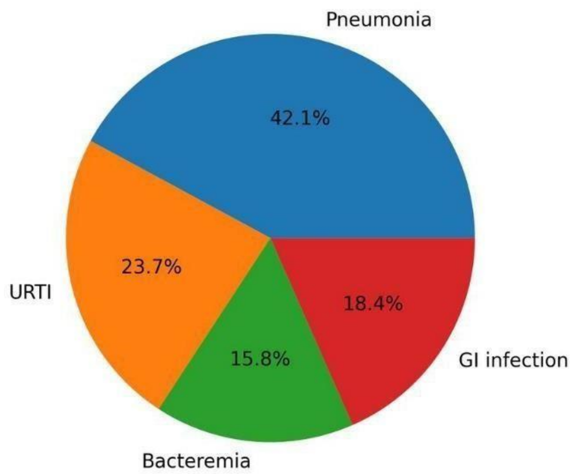


Figure 14 Distribution of clinical diagnoses among infected patients

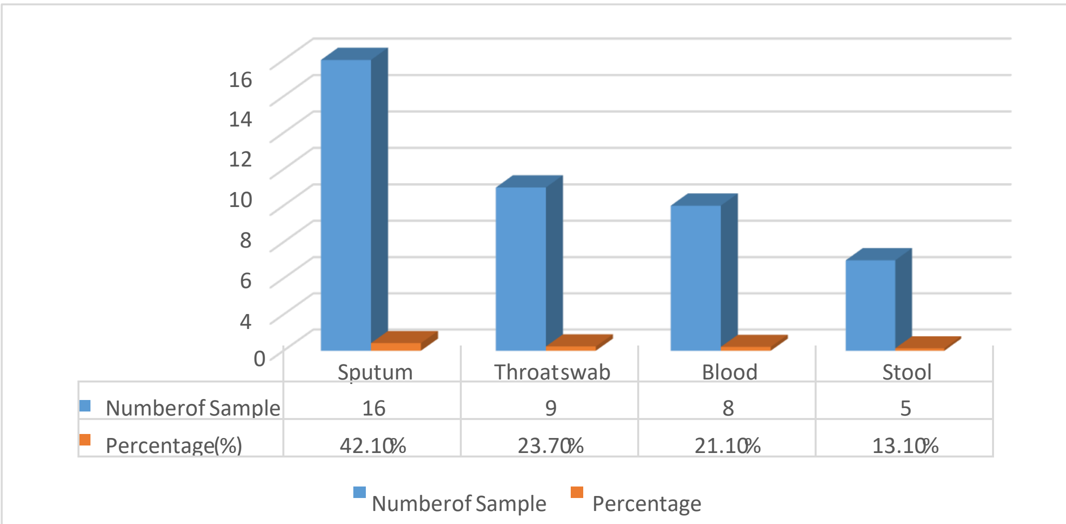
Types of Clinical Samples Used for Diagnosis

Various clinical samples were collected from patients suspected of having respiratory and systemic infections in order to identify the causative bacterial pathogens.

Table 9 Distribution of Clinical Samples

Sample Type	Number of Sample	Percentage (%)
Sputum	16	42.1%
Throat swab	9	23.7%
Blood	8	21.1%
Stool	5	13.1%
Total	38	100%

This table presents the distribution of clinical sample types which *Streptococcus pneumoniae* was isolated. Sputum samples were the most common, reflecting the predominance of respiratory tract infections, followed by blood samples indicating systemic involvement.



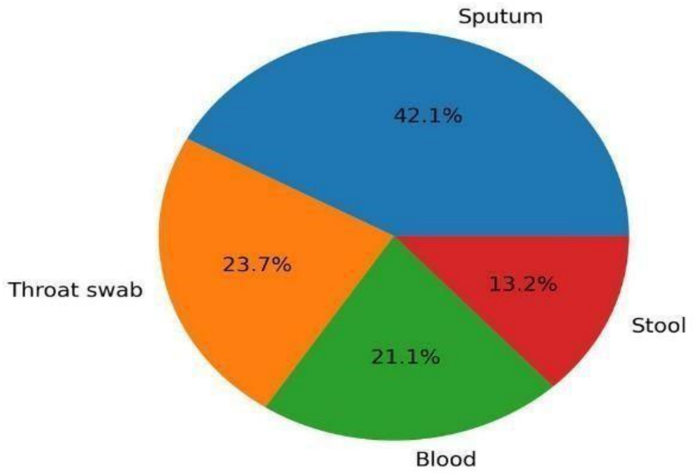


Figure 15 Types of clinical samples used for isolation of Streptococcus pneumoniae

Distribution of Bacterial Isolates

This table summarizes the bacterial species isolated from positive samples. *Streptococcus pneumoniae* was the most frequently isolated organism (36.8%), highlighting its major role in respiratory and systemic infections.

Table 10 The distribution of bacterial isolates is shown in

Isolated Organism	Number of Isolates	Percentage (%)
Streptococcus Pneumoniae	38	76.0%
Klebsiella pneumonia	3	1.5%
Pseudomonas aeruginosa	2	1%
Enterococcus faecalis	2	1%
Enterococcus faecium	2	1%
Acinetobacter baumannii	1	0.5%
Staphylococcus Epidermidis	2	1%
Total	50	100%

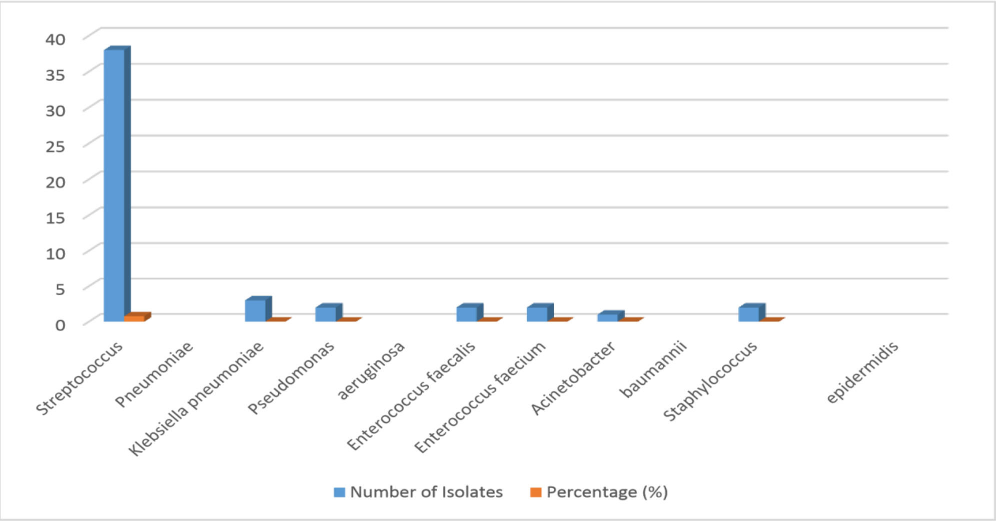


Figure 16 Distribution of Bacterial Isolates

Antibiotic Susceptibility Pattern of Streptococcus pneumoniae

The antibiotic susceptibility of *Streptococcus pneumoniae* isolates obtained from positive clinical samples (N = 38) was evaluated using standard microbiological techniques.

Table 11 Distribution of Antibiotic Susceptibility Pattern of Streptococcus pneumoniae

Antibiotic	Resistant (R)	Sensitive (S)
Penicillin	16	22
Amoxicillin	11	27

Ceftriaxone	8	30
Erythromycin	22	16
Levofloxacin	5	33
Vancomycin	0	38

The antibiotic susceptibility testing of Streptococcus pneumoniae isolates was performed using the standard disk diffusion method in accordance with Clinical and Laboratory Standards Institute (CLSI) guidelines. The results demonstrated variable susceptibility patterns among the isolates. A high level of susceptibility was observed toward β-lactam antibiotics, particularly penicillin and ceftriaxone, indicating their continued effectiveness in the treatment of pneumococcal infections. In contrast, increased resistance was noted against macrolides and tetracycline, which may reflect the widespread and inappropriate use of these antibiotics in clinical practice. The presence of resistant strains highlights the growing challenge of antimicrobial resistance and underscores the importance of routine antimicrobial susceptibility testing to guide appropriate therapy.

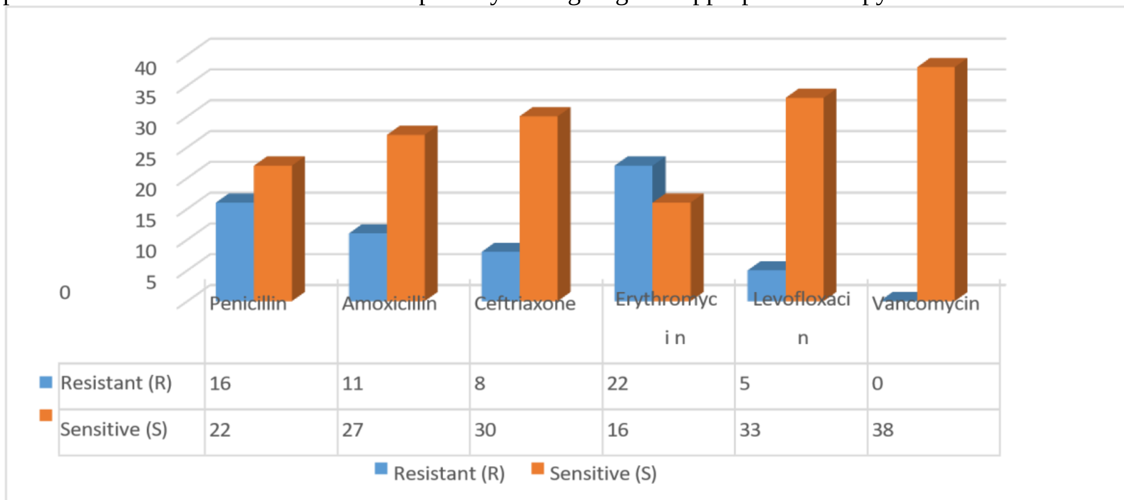


Figure 17 Antibiotic susceptibility pattern of Streptococcus pneumoniae isolate

Conclusion

The present study was conducted to investigate the clinical impact and pathogenic role of Streptococcus pneumoniae in respiratory and systemic diseases among patients attending Tripoli Medical Center in Tripoli, Libya. A total of 50 clinical samples were collected and analyzed using standard microbiological techniques, including culture, Gram staining, biochemical tests, and antibiotic susceptibility testing.

The results of this study demonstrated that Streptococcus pneumoniae remains a major causative agent of respiratory and systemic infections. Out of the total samples examined, 38 samples (76%) were confirmed to be positive for Streptococcus pneumoniae, indicating a high prevalence of this pathogen among the studied patients.

Analysis of demographic data revealed that males were slightly more affected than females, and the highest prevalence of infection was observed in the age group of 41–60 years. This finding suggests that middle-aged and elderly individuals may be more susceptible to pneumococcal infections, possibly due to weakened immunity or the presence of chronic underlying diseases

Clinically, pneumonia was the most common diagnosis associated with Streptococcus pneumoniae, followed by upper respiratory tract infections, bacteremia, and gastrointestinal infections. Sputum samples were the most frequent specimen from which the bacteria were isolated, emphasizing the strong association between this pathogen and respiratory tract infections.

Antibiotic susceptibility testing showed that most isolates were highly sensitive to vancomycin, levofloxacin, and ceftriaxone, while varying degrees of resistance were observed against penicillin, amoxicillin, and erythromycin. The presence of antibiotic-resistant strains highlights the growing problem of antimicrobial resistance and the importance of rational antibiotic use.

In conclusion, Streptococcus pneumoniae continues to pose a significant public health challenge due to its high prevalence, wide range of clinical manifestations, and emerging antibiotic resistance. Accurate diagnosis, appropriate antimicrobial therapy, and effective preventive measures are essential to reduce the burden of pneumococcal diseases.

Recommendations

Based on the findings of this study, the following recommendations are suggested:

1. Routine antimicrobial susceptibility testing should be performed for all confirmed cases of Streptococcus pneumoniae to ensure appropriate and effective antibiotic therapy.

2. Rational use of antibiotics must be encouraged to reduce the development and spread of antibiotic-resistant strains, especially macrolide resistance.
3. Early diagnosis and prompt treatment of pneumococcal infections should be emphasized, particularly in high-risk groups such as the elderly and immunocompromised individuals.
4. Strengthening vaccination programs against Streptococcus pneumoniae is highly recommended, especially for children, older adults, and patients with chronic diseases.
5. Further studies with larger sample sizes and molecular diagnostic methods are recommended to better understand the epidemiology, resistance patterns, and virulence factors of Streptococcus pneumoniae in Libya.
6. Continuous surveillance programs should be established in hospitals to monitor trends in pneumococcal infections and antibiotic resistance.
7. Public health awareness campaigns should be conducted to educate the community about the importance of vaccination, hygiene practices, and adherence to prescribed antibiotic treatment

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