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Review Article

Comparative Safety and Efficacy of Different Classes of Antibiotics for Treating Common Bacterial Infections: A Systematic Review and Meta Analysis

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Abstract

Antibiotics are medications used to treat bacterial infections in humans and animals. They function by killing germs or making it difficult for bacteria to thrive and multiply. Antibiotics can be administered in a variety of ways: Orally (via the mouth). This could be in the form of pills, capsules, or liquids. Topically. This could be a cream, spray, or ointment applied to your skin. Eye ointment, eye drops, or ear drops are all possibilities. By injection or intravenously (IV). This is often reserved for more serious infections. There's various classes of antibiotics used for the treatment of bacterial infections. Some of the major classes are penicillin, cephalosporins, macrolides, tetracyclines, fluoroquinolones, aminoglycosides and sulphonamides. Antibiotics are used to treat a wide range of illnesses that impact many different regions of your body, from your innermost organs to the skin's outer surface. Hence determining safety and efficacy of antibiotics in treatment of antibiotics is important since it is also known to have risk factors.

Key words: antibiotics; bacterial infections; safety; efficacy; risk factors; antibiotic resistance

Introduction

Role of Antibiotics: Antibiotics are a class of medications used to treat illnesses caused by certain bacteria. Antibiotics must be used correctly in order to help reduce antibiotic resistance. [1] Antibiotics may be used to treat bacterial infections that: are unlikely to clear up without antibiotics; may infect others if not treated; may take too long to clear up without treatment; and may carry the risk of more serious complications. [2]. Antibiotics are classified according to their chemical structure. However, antibiotics within each class often have various effects on the body and may be effective against different microorganisms. [3]

1.Penicillin
2.Cephalosporins
3.Macrolides
4.Tetracyclines
5.Fluoroquinolones
6.Aminoglycosides
7.Sulfonamides [3]

1. Penicillin: One of the most widely used antibiotics in the world, penicillin has a wide range of therapeutic indications. Penicillin is effective against a wide range of infections caused by gram-positive cocci, gram-positive rods, the majority of anaerobes, and gram-negative cocci. [4].

Mechanism of Action: Penicillin kills bacteria by blocking the completion of the production of peptidoglycans, the structural component of the bacterial cell wall [5].

Efficacy: These antibiotics have an extended track record of usage, and the shortage of significant side effects documented in these investigations lends credence to their reputation as safe medications. The fact that no rise in significant adverse events has been recorded in the literature despite widespread use provides reassurance. [6]

Adverse effects: Diarrhea, Headache, Stomach upset, Nausea or vomiting, Rash or hives (typically mild to moderate), Injection site pain (with penicillin G) are the most common adverse effects of penicillins (affecting at least 1%

of users). Muscle spasms, black hairy tongue, oral thrush, and vaginal yeast infection [7]

Storage: Keep this medication in the original container, properly closed, and out of the reach of children. Keep the pills at room temperature and away from excessive heat and moisture (do not store them in the bathroom). Keep the oral solution tightly covered in the refrigerator and discard any unused medication after 14 days. It should not be frozen [8].

2. Cephalosporins: Cephalosporins are an antibiotic class. Antibiotics are drugs that are used to treat bacterial infections. Antibiotics are classified into various categories, which are generally referred to as classes. Cephalosporins are beta-lactam antibiotics. Depending on the infection, they can be given orally or injected into a vein (intravenous injection). [9]

Mechanism of action: Many cephalosporins, such as cephalexin, cefotaxime, and ceftazidime, bind to Penicillin binding protein 3 (PBP3) in a manner similar to penicillin, resulting in the production of elongated and filamentous cells. Transpeptidase is an enzyme found in bacteria that cross-links with the existing peptidoglycan chain to maintain the cell wall's integrity. Cephalosporin binding to the PBP3 receptor deforms the cell wall and kills bacteria. Cephalosporin also activates autolytic enzymes in bacteria, causing bacterial lysis. [10]

Efficacy: First-generation cephalosporins are more effective against Gram-positive bacteria, while some Gram-negative bacteria are also affected. Gram-positive and Gram-negative bacteria are both targeted by second-generation cephalosporins. However, they are slightly less efficient against Gram-positive bacteria than first-generation cephalosporins. Many Gram-negative bacteria and bacteria that have not reacted to first- or second-generation cephalosporins are effective against third-generation cephalosporins. Cephalosporins of the fourth generation are effective against both Gram-positive and Gram-negative bacteria. They are typically used for more serious infections or in patients with compromised immune systems. In the United States, ceftaroline is the only fifth-generation cephalosporin available. It's frequently used to treat infections that are resistant to other antibiotics, such as MRSA. [11]

Adverse Effects: Adverse responses to cephalosporins are uncommon in the laboratory. Eosinophilia and thrombocytosis are frequently observed, but they are most likely not unfavorable reactions, but rather indicators of infection healing. Other hematological responses have been recorded in a small number of patients and have been quickly reversed when medication was discontinued [12]

Storage: This medication must be carefully preserved. Consult your doctor or pharmacist about proper storage methods. Dry powder vials should be kept at room temperature and away from direct sunlight. Before using a reconstituted solution, check the expiration date. [13]

3. Macrolides: Macrolides are a type of antibiotic that is used to treat gram-positive and gram-negative bacterial infections. Erythromycin, azithromycin, and clarithromycin are examples of these drugs. All of these antibiotics can be taken orally to treat mild to severe bacterial infections of the respiratory, gastrointestinal, and genitourinary tracts; erythromycin can also be given intravenously, and azithromycin has an ocular formulation to treat bacterial conjunctivitis. [14]

Mechanism of action: Macrolide antibiotics work by inhibiting protein synthesis by targeting the bacterial ribosome. They bind to and partially occlude the nascent peptide exit tube. As a result, macrolides have been regarded as 'tunnel plugs' that halt protein production. Recent research, on the other hand, shows that macrolides selectively impede the translation of a subset of cellular proteins, and that their activity is critically dependent on the nascent protein sequence and the antibiotic structure. [15]

Efficacy: A judgment was reached regarding the efficacy of the pharmaceuticals used. The final effectiveness of erythromycin in infectious illnesses was 60%, azithromycin was 80%, and midecamycin was 55%. In dysbiosis, erythromycin and azithromycin were 100% effective, while midecamycin was 90% effective. The use of macrolide antibiotics for prevention also considerably lowered mortality rates, which were 35% for infectious illnesses and 10% for dysbiosis in the control group. [16]

Adverse effects: There is a possibility of common unpleasant effects such as nausea, vomiting, abdominal discomfort, and diarrhea with macrolides. Abdominal symptoms are mostly caused by macrolides being motilin agonists, which increase the likelihood of gastrointestinal discomfort and side effects. [17]

Storage: Store in a cool and dry place, away from direct sunlight. Keep this medication away from children.[18]

4. Tetracyclines: Tetracyclines are antibiotics that are used to treat infections and to manage acne. Demeclocycline, doxycycline, and minocycline may also be prescribed for other conditions by your doctor. Tetracyclines are ineffective against colds, flu, and other viral illnesses [19].

Mechanism of action: Tetracycline diffuses passively through porin channels in the bacterial membrane and binds reversibly to the 30S ribosomal subunit, blocking tRNA binding to the mRNA-ribosome complex and so interfering with protein synthesis.[20]

Efficacy: Tetracyclines have numerous qualities that make them attractive antibiotic medicines, such as effectiveness against Gram-positive and -negative bacteria, demonstrated clinical safety, tolerability, and the availability of intravenous (IV) and oral formulations for most members of the class.[21]

Adverse effects: Tetracycline's common adverse effects include tooth discoloration in children, light sensitivity, and stomach difficulties. [22]

Storage: Keep this medication in the original container, properly closed, and out of the reach of children. Keep it at room temperature, away from light, excessive heat, and moisture (but not in the bathroom) [23].

5. Fluoroquinolone: Fluoroquinolone are highly effective antibiotics with many advantageous pharmacokinetic properties such as high oral bioavailability, large volume of distribution, and broad-spectrum antimicrobial activity. Fluoroquinolone use is typically reserved for cases where the benefits clearly outweigh the risks. [24]

Mechanism of Action: Fluoroquinolones function by blocking two enzymes involved in bacterial DNA synthesis, both of which are DNA topoisomerases lacking in human cells but required for bacterial DNA replication, allowing these drugs to be both selective and bactericidal. DNA topoisomerases are in charge of separating the strands of duplex bacterial DNA, inserting another strand through the breach, and then resealing the previously separated strands.[25]

Efficacy: powerful new medications predominantly oriented against gram-negative bacteria, whereas newer members of this class show more efficacy against gram-positive pathogens such as Streptococcus pneumoniae. Although these drugs are clinically successful against a wide range of infectious pathogens, the emergence of resistance and related clinical failures has caused them to be reconsidered. [26]

Adverse effects: Serious side effects reported to the FDA include an increase in aortic ruptures or tears, significant drops in blood sugar levels, ruptured tendons, pain, "pins and needles" sensations, and depression, anxiety, suicidal ideation, and other mental health issues. [27] [28]

Storage: Keep away from children. Keep in a cool dry place, away from direct sunlight, store at room temperature.[29]

6. Aminoglycosides

Gentamicin, amikacin, tobramycin, neomycin, and streptomycin are examples of aminoglycosides. Because aminoglycosides are polar medicines with low gastrointestinal absorption, they must be administered

intravenously or intramuscularly. They are eliminated through the kidneys. [30]

Mechanism of action: Aminoglycosides are selectively active against oxygen-dependent (aerobic), gram-negative bacterial cells because these cells have the chemical properties that attract aminoglycosides as well as the specific transport mechanisms that allow the drugs to enter the cells. Once within bacterial cells, aminoglycosides work by binding to ribosomes, which are essential for protein synthesis. Protein synthesis is blocked as a result, and the bacterial cell dies. [31]

Efficacy: Antimicrobials and aminoglycosides have shown clinical usefulness in combating infections. Aminoglycosides have a wide range of activity that includes aerobic organisms such as gram-negative bacteria and mycobacteria.[32] Gentamicin is the most often utilized aminoglycoside due to its low cost and consistent action against gram-negative aerobes. Local resistance patterns, on the other hand, should impact therapeutic selection. Gentamicin, tobramycin, and amikacin are frequently used interchangeably in comparable situations. [33]

Adverse effects: Toxicity of aminoglycosides includes nephrotoxicity, ototoxicity (vestibular and auditory), and, on rare occasions, neuromuscular blockade and hypersensitivity reactions. Nephrotoxicity receives the greatest attention, maybe due of the ease with which impaired renal function can be documented, yet it is frequently reversible.[34] [35]

Storage: Sterile reconstituted solutions should be protected from light and may be stored at room temperature for one week without significant loss of potency [36]

7. Sulfonamides

Sulfonamides are a class of synthetic medications that contain the sulfonamide chemical group. This class also includes thiazide diuretics, furosemide, acetazolamide, sulfonylureas, and certain COX-2 inhibitors, in addition to antibiotics.[37]

Mechanism of Action: Sulfonamides suppress bacterial proliferation by acting as competitive inhibitors of p-aminobenzoic acid in the folic acid metabolic cycle. Bacterial sensitivity to the multiple sulfonamides is the same, and resistance to one sulfonamide implies resistance to all. [38]

Efficacy: Sulphonamides are an important class of antibiotic medicines having a broad spectrum of activity, particularly against gram-positive and select gram-negative bacteria (White and Cooper 2003). Klebsiella, Salmonella, Escherichia coli, and Enterobacter species are among the sensitive gram-negative bacteria; however, sulfonamides have no inhibitory effect (bacterial resistance) against Pseudomonas aeruginosa and Serratia species. (2017, Lavanya) [39]

Adverse effects: Adverse Effects: A drug may have some unfavorable side effects. Although not all of these negative effects are possible : Itchy skin rash, Aches and pains in the joints and muscles, redness, blistering, peeling, or loosening of skin painful throat and fever unusual bleeding or bruising unusual weariness or weakness yellow eyes or skin [40] Other significant sulfonamide adverse effects include diarrhea, nausea, skin rash, headaches, and dizziness.[41]

Storage: Store below 30°C (86°F). Protect from cold. Cream darkens with age; potency is maintained through labeled expiration date when stored as directed.[42]

Conclusion

After a systematic review, meta analysis consisting of a thorough data extraction process and assessment of the Comparative study of Safety and efficacy of different classes of antibiotics in treating common bacterial infections has been determined. With various risk factors that also stand a chance of major improvement. This study has given a broad outlook on the spectrum of antibiotics and their generations in the treatment and resistance of bacteria.

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