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Overview Of The Main Bacterial Infections In Humans

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Abstract

Bacterial infections are one of the main challenges of modern medicine, affecting millions of people every year. The ubiquitous microorganisms, such as bacteria, cause many various diseases that can be asymptomatic or mild as well as life-threatening. The purpose of the research is to gain insight into contemporary knowledge about pathogenic bacteria causing the most common diseases in human beings: Gram-Positive Cocci, including *S. aureus*, *S.* epidermidis, *S. pyogenes*, *S. agalactiae*, *E. faecalis*, *S. pneumoniae*, Gram-Negative Cocci, such as *N. gonorrhoeae*, *N. meningitidis*, Gram-Negative Bacilli (Enterobacteriaceae), like *E. coli*, *Salmonella*, *Shigella*, *K. pneumoniae* as well as bacteria of the genus *Clostridioides*, *Pseudomonas*, *Acinetobacter* i *Mycobacteria*.

Information searches were carried out in online databases, scientific, and educational editions, including PubMed, Elsevier, Research Gate, Web of Science, Springer.

Bacterial infections are still a huge concern in the modern world. It is necessary not only to constantly update knowledge but also to carry out researces to improve the effectiveness of treatment and prevention against these pathogens.

Keywords: Pathogenic bacteria, Bacterial infections, Carrier, Antibiotherapy, Prevention of infection

Gram - Positive Cocci

Staphylococcus aureus is the main human pathogen that causes a wide range of infections. It is one of the main causes of bacteremia and endocarditis. In addition, it is responsible for osteoarthritis, infections of skin and soft or pleural tissues. It has been found that the risk group of *Staphylococcus aureus* infection includes age,

sex, ethnicity and even the presence of HIV virus in the body. A large percentage of infections (and at the same time the most deadly one) is the group of people after operations connected with insertion of all kinds of implants (e.g. valves). Treatment is based on intravenous antibiotic therapy for at least 2 weeks. It was found that taking antibiotics for less than 2 weeks was associated with a recurrence rate of 8%. Staphylococcus aureus is currently the most common cause of bacterial endocarditis. It is associated with mortality of between 22 and 66%.
S. aureus also causes skin and soft tissue infections - from mild, i.e. impetigo, to those that are directly life-threatening. Staphylococcus aureus is a dangerous bacterium that is relatively easy to become infected and very difficult to cure, because *S. aureus* is resistant to high temperature and most antibiotics. Infection with it can lead to sepsis (Tong et al. 2015).

Staphylococcus epidermidis causes opportunistic infections. *S. epidermidis* takes the form of cocci slightly smaller than the colony of *S. aureus*. This bacterium is common on the mucosa of the nose and throat or the genitourinary system. Therefore, the bacterial cultures of *S. epidermidis* from hemoculture indicate an incorrect sample of material or an incorrect disinfection of the puncture site. This microorganism is an etiological agent of sepsis, causing infections in patients with weakened immune systems. As in the case of *S. aureus*, patients who have recently undergone valve replacement surgery or catheterization are particularly vulnerable to staphylococcal skin infections. This bacterium ranks third place in the list of pathogens causing hospital-acquired infections (Virella 2000, Dzierżanowska 2024).

Streptococcus pyogenes is type A streptococcus. It is known to cause a common condition - angina, but it is a bacterium that causes many other human diseases; however, it is usually limited to respiratory system's infections. Other diseases include, for example, scarlet fever, rheumatic fever or glomerulonephritis. Type A streptococcus is transmitted via droplets; large groups of people or lack of washing hands, fruits and vegetables increase the risk of infection. Due to the route of this streptococcal infection, people who work in the hospital or who are patients are at risk. The infection is accompanied with a high fever and a characteristic pharyngeal tonsils' rash with swelling. In addition, swelling, and pain of muscle and lymphadenopathy may occur. Antibiotherapy lasts from 7 to 10 days. By using that, the patient avoids complications and fully combats the disease. In extreme cases or with an untreated primary infection, infection with type A streptococcus can lead to scarlet fever and toxic shock syndrome (Pawlak and Żmuda-Trzebiatowski 2019).

Streptococcus agalactiae is a type B pathogen. It can be transmitted through sexual contact with an infected person or carrier (when the pathogen is present in the urinary tract) or through droplets and as a result of poor hygiene (lack of washing of hands and vegetables) when the pathogen is present in the respiratory tract. In both cases, the infection is treated by the use of antibiotics for 7 to 10 days.
One of the important forms of infection with streptococcus type B is the transfer of the pathogen from the mother to the fetus during childbirth. When the newborn is infected, it may turn out that the bacteria are harmless and do not cause the development of infection. However, many cases end with complications. Children after being infected with *S. agalactiae* are prone to hearing and vision defects, and even cerebral palsy or sepsis. However, it is possible to screen pregnant women for the presence of this bacterium - the test is performed between 35 and 37 weeks of pregnancy. In extreme cases, the bacteria can enter the uterus through the vagina, causing intrauterine infection. Then there is a risk of premature rupture of the fetal membranes and thus childbirth. This is a condition posing a direct threat to the fetus, which can cause its death (Raabe and Shane 2019).

Enterococcus faecalis is a component of the intestinal flora of many organisms. With the advent of antibiotics, it gained immunity, becoming one of the most multidrug resistant pathogens acquired in the hospital. Virulent strains of *E. faecalis* secrete an exotoxin (called cytolysin), causing the lysis of both bacterial and eukaryotic cells. Enterococcus are unique pathogens that are believed to date back at least to the last common ancestor of mammals, birds, reptiles and insects as a component of their bacterial flora. They are also facultative anaerobic bacteria. *E. faecalis* are capable of causing endocarditis, sepsis, postoperative wound infections or urinary tract infections. When antibiotherapy is introduced, there is a reduction in species diversity in the gut microbiota, as a result of which the patient loses protection against colonization of the host. Drug-resistant enterococci use this moment to invade and settle. The cytolysin secreted by *E. faecalis* increases the mortality of sepsis five times. Knowing the mechanism of this exotoxin may be the only key to effectively inhibit the invasion of this bacterium in the future (Van Tyne et al. 2013).

Streptococcus pneumoniae is a pathogen commonly found in the population. It is caused by the carrier of this bacterium. It is commonly called pneumococcus. It lives in the upper respiratory tract, but can attack the middle ear, lungs, cardiovascular system, and even the meninges. Up to 65% of children and less than 10% of

adults are carriers of *S. pneumoniae*. Infection can lead to meningitis and sepsis. In 2017, the World Health Organization included this pathogen in one of the top 12 priorities - increasing rates of its resistance to penicillin caused an increased interest in prevention. It was shown that *S. pneumoniae* is responsible for 5.1% of hospital pneumonias. Currently, there are vaccines against *S. pneumoniae*, whereas antibiotics are used in case of illness: most often penicillin derivatives and cephalosporin. Pneumococcus is also treated symptomatically, with drugs that lower intracranial pressure, are antipyretic and anti-inflammatory and often with oxygen as well (Suaya et al. 2021).

Gram - Negative Cocci

Neisseria gonorrhoeae causes septic arthritis and gonorrhoea - one of the diseases transmitted mainly by sexual contact or, in the case of newborns, during childbirth. It is estimated that gonorrhoea affects 86.9 million adults worldwide. *Neisseria gonorrhoea*e attacks the mucous membranes covering elements of the reproductive system (cervix, vagina, fallopian tubes) as well as the urethra, conjunctiva, bladder, anus, throat and oral cavity. This can result in inflammation, swelling, redness and pain of the infected areas along with purulent effusion. In the pharmacotherapy of this disease, antibiotics are used - for example, penicillin or ceftriaxone intramuscularly together with azithromycin given orally, but it should be borne in mind that more and more *N. gonorrhoeae* is resistant to some antibiotics. Untreated leprosy can lead to an ectopic pregnancy (in women), an increased risk of developing prostate cancer (in men) or neonatal conjunctivitis, which can result in visual impairment (in newborns), while in both sexes it can cause septic arthritis or even infertility. However, many men and most women do not show any symptoms of this disease, which is why its prevention is so important, which includes avoiding casual sexual contact, not using others' personal hygiene items (towels, sponges, underwear) and, if necessary, gonorrhea testing. The immune system of a person who has gone through gonorrhea does not show resistance to the bacteria that cause this disease due to its different surface proteins between particular grains (Hill et al. 2016, Berger et al. 1979, Lian et al. 2015).

Neisseria meningitidis causes meningococcal disease, which can occur as severe infections with relatively high mortality, such as meningitis and chronic meningococcal septicaemia, in which dangerous septic shock and DIC (disseminated intravascular coagulation) can occur. Inflammation of the lungs, joints, conjunctiva, bones, together with bone marrow, heart muscle and pericardium is rare. Depending on the course of the disease, symptoms in infected people can vary. The bacteria that cause these infections are transmitted via droplets (through the saliva and respiratory secretions) or by direct contact with an ill person. The most susceptible to becoming infected with meningitis are young children due to insufficiently developed immune system and people aged 15-24 years because of their lifestyle. These groups can also be carriers in which the disease does not manifest directly. In children under 5 years, it is less than 2%, while in adolescents and young adults - from 20% to 25%. It is also estimated that about 10% of adults are carriers of this bacterium - in this case, it is found in the nasopharynx. Moreover, increased infectiousness is also observed in more enclosed environments such as nurseries, kindergartens, schools and boarding schools. Effective antibiotic therapy is used to treat diseases caused by this bacterium, however, due to the high virility of Neisseria meningitidis protective vaccinations for those at risk, as well as prophylactic antibiotics in case of recent contact with an infected person (within a week) are recommended (Hitchcock et al. 1993, Christensen et al. 2010, Cianciara and Juszczyk 2007, Gabutti et al. 2015, Long et al. 2017, Brigham and Sandora 2009).

Gram - Negative Bacilli (*Enterobacteriaceae*)

Escherichia coli is a bacterium found in the human colon, where it does not exhibit pathogenic properties. It is one of the elements of the intestinal microflora and by symbiosis it provides the body with a certain amount of B and K vitamins, as well as inhibits the development of pathogenic bacteria in the place of its being. However, there are certain serotypes of this bacterium, which can cause various diseases primarily of the urinary and gastrointestinal system. Among the diseases caused are urinary tract infection, sepsis, various infections and poisoning of the digestive system (for example in the case of strains producing exotoxin), organ abscesses which can lead to poisoning, Leśniowski-Crohn disease and in newborns - meningitis. In most cases, the infection is manifested by vomiting, diarrhea, as well as cramps within the abdomen. Symptoms depend on the virulence of the strain, because some of them can cause necrosis of part of the intestine or pneumonia. In treatment, antibiotic therapy is used, for example, by taking fluoroquinolones. By *Escherichia coli* one can be infected by consumption of water or food containing this bacterium or by transferring it from the large intestine to another place in the body - therefore, during surgery in this area, patients are given a prophylactic antibiotic to avoid infection (Bentley and Meganathan 1982, Dzierżanowska 2024).

Salmonella, depending on its serotype, can cause various diseases. These bacteria are classified into a group of facultative anaerobic. The vast majority of infections occur as a result of the food consumption (e.g.

meat, eggs or unwashed fruit) contaminated with feces, but they can also occur through dirty water. It is considered that there are two main types of salmonella. Both groups are responsible for infections of the digestive system. The first group causes primarily salmonellosis or, in some areas, paratyphoid, with 0.1-1% of infected people showing no symptoms of the disease, making them considered as asymptomatic carriers. On the other hand, the second group leads to typhoid as well as paratyphoid due to the fact that the bacterium with these serotypes moves into the bloodstream, from where it also reaches to other systems in the human body. This group can even result in a very dangerous, potentially fatal septic or hypovolemic shock. Depending on the cause of the disease, treatment of the infected patient differs. Antibiotherapy is used in case of typhoid and paratyphoid, as well as in salmonellosis invading organs and its generalized form, while it is avoided in salmonellosis of gastrointestinal form (apart from exceptional situations resulting from, for example, the age of the infected person) (Ryan et al. 2004, Cianciara and Juszczyk 2007).

Shigella is one of the main bacteria that causes inflammation of the colon's intestinal epithelium, therefore causing diarrhea - each year it contributes to 80-165 million cases worldwide. Infections are most common in young children (especially in more enclosed environments such as schools and kindergartens) and in people who travel. In primates, including in humans, it can also cause shigellosis. Symptoms of this disease include diarrhea, fever, abdominal pain of varying severity, abnormal feces (for example, it may contain blood and mucus), mucosal ulceration, and rectal bleeding. In some cases, shigellosis can lead to seizures, sepsis, Reiter syndrome, or hemolytic uremic syndrome. Infections occur through feces containing these bacteria - as a result of the consumption of contaminated food, water, lack of hygiene (unwashed hands) or through sexual contact. During the infection, it is necessary to drink lots of fluids to avoid dehydration of the body (due to the large amount of water loss due to diarrhea). Usually the disease goes away on its own within 7-8 days, but in some more severe cases it is crucial to give the patient an antibiotic. Currently there is no vaccine against *Shigella* available yet (Ryan et al. 2004, Bowen 2016, CDC 2024).

Klebsiella pneumoniae belongs to the bacterial flora of the gut, skin and oral cavity, but transferred to other systems can cause various infections. This occurs through the respiratory system or bloodstream, most often through direct contact (e.g. through an open wound) with another person or, for example, with contaminated hands or intravenous cannula. This makes it extremely easy to become infected while being in hospital (it is estimated to occur in about 20% of cases), especially since the risk of infection is increased during antibiotic therapy. Most infections occur in people exposed to pathogens penetrating through the respiratory system, at risk are mainly middle-aged or older men with various other diseases, such as diabetes, kidney failure or alcoholic disease. *K. pneumoniae* can cause pneumonia (with expectoration), as well as other respiratory system's diseases, infections within the wound, gastrointestinal tract (especially the bile duct), urinary tract, and even bones and joints. Characteristic symptoms include fever, vomiting along with nausea, and acceleration of the heart action. In more chronic cases, sepsis or meningitis may occur. Appropriate antibiotic therapy is used during treatment - *K. pneumoniae* shows resistance to penicillin, while some strains also show resistance to other antibiotics (Zaremba and Borowski 2001, Virella 2004, Ryan et al. 2004).

Clostridioides

Clostridium difficile are bacteria spread by eating food or water contaminated with feces, as well as by poor hygiene, especially in the hospital. It is estimated that these bacteria can be found in about 5% of all adults, while in patients who stay in the hospital for more than 4 weeks it can be even up to 50%. In children it is estimated to be around 15-70%, but most often they do not cause any symptoms. Risk factors include using antibiotics (mainly clindamycin, cephalosporin and fluoroquinolones) due to the destruction of the natural microbiological flora of the colon (it is the main factor protecting the body from infection, and the risk occurs up to 90 days from the start of antibiotherapy), as well as older age and staying at the hospital. *Clostridium difficile* causes an infection of the colon manifested mainly by diarrhea, abdominal pain of varying severity, nausea and fever. In more severe cases, there may be many complications, such as acute colonic distension, sepsis, pseudomembranous enteritis or perforation of the colon. In milder cases, specialized treatment is not required, however special attention should be paid to maintain a high fluid intake. In severe cases, some antibiotics are used, to which particular strain of *Clostridium difficile* does not show resistance. In case of failure of this method, there is an intestinal microbiota transfer, which is the most effective method of treatment that works in the vast majority of patients (Leffler and Lamont 2015, Hensgens et al. 2012, Luciano and Zuckerbraun 2014, Clabots et al. 1992, Dodin and Katz 2014).

Clostridium perfringens is a part of the natural bacterial flora of the human intestines, however it can lead to food poisoning most often as a result of meat or poultry consumption which was contaminated with toxins produced by these bacteria. It is considered to be an anaerobic bacteria. Usually, the standard symptoms

of *Clostridium perfringens* infection include diarrhea, vomiting, abdominal pain of varying severity and fever. In some cases, serious complications such as gas gangrene can occur as a result of infection, which results in blisters, accelerated heart rate, muscle necrosis and swelling along with severe pain. Untreated this condition can even lead to death in a short period of time, followed by coma. Prevention includes thermal processing of meat at high temperature (or reheating it in the case of previously cooked meals), as well as not leaving meat dishes outside the refrigerator for a long time (up to 2 hours after preparation) and storing them at a low temperature. In the treatment of more serious cases of infection with this bacterium, antibiotherapy (most often penicillins) is used simultaneously with immediate removal of infected tissues to prevent further growth of the bacteria (Lentino 2016, CDC 2015).

Clostridium tetani is a bacterium that one can get infected by contaminating the wound with bacterial spores found in the soil or animal digestive tract. Then they secrete tetanospasmin, which is a neurotoxin that blocks inhibitory neurotransmitters (such as GABA and glycine) in the central nervous system. This manifests in an infected person as an increased tension of the skeletal muscles along with the onset of severe spasms (called as spastic paralysis). The incubation period of the tetani in the body ranges from 2 to 21 days depending on the severity of the disease. Tetanus can be demonstrated in three forms. The first of them is generalized, it occurs in the vast majority of cases. Its characteristic symptoms include opisthotonus (presenting as the spontaneous bending of the spine in the arch backwards), contraction of mimic muscles, lockjaw, as well as damage of the autonomic nervous system, which manifests with, among others, abnormal dilation of the pupil and heart arrhythmia. The second form is local, it occurs in the area of the infected site, while the third - neonatal- may occur if the mother of the child has not been vaccinated against tetanus. The most rare condition is cerebral tetanus related to the effect of tetanospasmin on the cranial nerves. An infected person is given tetanus antitoxin. Untreated disease can lead to death, it is the second leading cause of death among newborns. That is why preventive action consisting of the use of vaccinations to prevent disease is so crucial. Their basic program includes 4 doses within a period from 2 to 16-18 months of age (Todar 2005, Szczeklik and Gajewski 2017, Khan et al. 2013, Felter and Zinns 2015).

Bacteria from the groups *Pseudomonas* and *Acinetobacter*

Pseudomonas aeruginosa is one of the opportunistic microorganisms because it causes infections only in people with immune deficiency (most often due to another disease, e.g. cystic fibrosis, AIDS, but also after transplantation of an organ or through used treatment). This bacterium causes various types of inflammation (e.g. lungs, endocardium, cornea, meninges), infections (including urinary tract, burn wounds, external ear - manifesting with so-called swimmer's ear, and middle ear) and can lead to bacteremia resulting in the sepsis. One can get infected through direct contact with a pathogen developing, for example, on damp hospital equipment (e.g. on a catheter) that has direct contact with the patient’s body. Even with the use of all precautions by medical personnel, proper hygiene and disinfection of all equipment, infection with this bacterium can happen due to the fact that it is really common in the environment. Treating an ill person is difficult due to the natural resistance of the bacteria to a large majority of antibiotics. In the greatest number of cases, antibiotherapy adapted to the susceptibility of the strain is used based on laboratory tests. For people at risk of infection with *Pseudomonas aeruginosa* (e.g. with severe burns), a vaccine to reduce the risk of infection is given prophylactically (CDC 2014, Children’s Hospital of Illinois 2014).

Bacteria of the genus *Acinetobacter* cause a large number of hospital infections, very often in patients staying in specialized wards such as ICU, but also at risk are people with diabetes, open wounds or even in hospital for a long period of time. Similar to bacteria of the genus *Pseudomonas*, *Acinetobacter* is commonly found in the environment primarily in soil and water and does not show sensitivity to many disinfectants, therefore the path of infection is very similar - this pathogen can also be on damp hospital equipment having direct contact with the patient's body or on the skin of an infected person. One of the species belonging to this genus is *Acinetobacter baumannii*, which occurs primarily in the hospital environment and can also belong among opportunistic microorganisms. Infections caused by this pathogen include various inflammations (lungs, meninges and wounds, which can lead to necrosis), bacteremia and urinary tract infections. In addition, symptoms such as fever, vomiting, pain in infected areas, cough, nausea, rash or breathing problems may occur. Infection with this bacterium may also be asymptomatic. Certain antibiotherapy is used in the treatment due to the fact that bacteria from this group are resistant to many antibiotics used (e.g. penicillin and chloramphenicol). Phage therapy has also been shown to be effective (Rodríguez-Baño et al. 2003, Doughari et al. 2011, Antunes et al. 2014, Mother Jones 2018).

Mycobacteria

Mycobacterium tuberculosis is an etiological agent of tuberculosis. This pathogen was discovered by Robert Koch over a century ago. In 2016, approximately 10.4 million people were diagnosed with tuberculosis, including about 600,000 cases of rifampicin-resistant and 490,000 cases of multidrug tuberculosis. In addition to causing pulmonary tuberculosis, this pathogen is associated with other diseases such as autoimmune diseases and metabolic syndromes and extra-pulmonary tuberculosis (e.g., lymph node tuberculosis, pleural tuberculosis). In addition, *M. tuberculosis* can interact with the microbiome, negatively affecting it and disrupting the human bacterial flora. The pathogen causes diseases mostly in weakened organisms with additional diseases. Nowadays, this bacterium spreading in institutions is still a dangerous pathogen, and hospital reactions for its presence may vary - from isolation of the patient, by performing sputum smears, to testing among health care workers for hidden tuberculosis infection. For the patient, a six-month treatment regimen is used - for the first 2 months, rifampicin, pyrazinamide, ethambutol and isoniazid (the so-called intensive phase), and for the next 4 months alone rifampin and isoniazid (the so-called continuation phase) (Diel et al. 2020).

Mycobacterium kansasii is one of the most common pathogens that causes non-tuberculous mycobacterial (NTM) disease. However, little is known about its pathogenicity or mode of transmission. This pathogen is found in tap water, sometimes in rivers or lakes. In patients with normal immunity, *M. kansasii* causes tuberculosis-like lung disease, while in people with impaired immunity it can cause extra-pulmonary versions of the disease - people with HIV are particularly vulnerable. It is believed that *M. kansasii* does not spread from person to person - the main reservoir is tap water. The pathogen is resistant to pyrazinamide, but sensitive to ethambutol (Taillard et al. 2003).

Discussion

Human pathogenic bacteria play a crucial role in the development of many infectious diseases that pose a major threat to public health worldwide. In order to treat those infections many different types of antibiotics are used, however some of the bacteria lose their susceptibility resulting in multi drug resistance. Therefore, it is very important to continue to study and research about pathogenic bacteria in order to counter the threat posed by bacterial infections (Ventola 2015, Schmidt and Schaechter 2011).

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Author's contribution:

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