



URINARY TRACT BACTERIAL INFECTIONS: *ESCHERICHIA COLI*, *KLEBSIELLA PNEUMONIAE*, *PROTEUS MIRABILIS*, *STAPHYLOCOCCUS SAPROPHYTICUS*, *ENTEROCOCCUS FAECALIS*

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ABSTRACT

Urinary tract infections (UTIs) are very common bacterial infections that occur more often in women than in men and mainly affect the kidneys, ureters, bladder, and urethra. Bacteria enter the urinary tract through the urethra and travel up to the bladder, the route that is responsible for most UTIs. In rarer cases, bacteria can spread to the urinary system from the bloodstream, especially in immunocompromised patients. Once inside the urinary tract, bacteria adhere to the lining cells of the urinary tract using Pili (as in *E. coli*), type 1 fimbriae that bind to mannose receptors, and P-fimbriae that bind to specific receptors on kidney cells, contributing to pyelonephritis. The classic symptoms of UTIs include the frequent urge to urinate, a burning sensation during urination, the passage of frequent, small amounts of urine, cloudy or strong-smelling urine, and pelvic pain in women and rectal pain in men. If left untreated, these can progress to more serious symptoms and other complications such as kidney infection or sepsis. UTIs are frequently treated with antibiotics such as Trimethoprim-sulfamethoxazole, Nitrofurantoin, Ciprofloxacin (used less frequently due to potential side effects), and Amoxicillin/clavulanate.

KEYWORDS: *urinary tract, infection, Escherichia coli, Klebsiella pneumoniae, Proteus mirabilis, Staphylococcus saprophyticus, Enterococcus faecalis*

INTRODUCTION

Urinary tract infections (UTIs) are predominantly caused by bacteria, although viruses can also contribute to these infections. Understanding the biological and molecular mechanisms of UTIs involves examining how pathogens invade, adhere to, and propagate within the urinary tract. UTIs are infections that affect any part of the urinary system, including the kidneys, ureters, bladder, and urethra. Most infections involve the lower urinary tract in the bladder and urethra. UTIs are typically caused by bacteria entering the urinary tract through the urethra and multiplying in the bladder (1). These infections can lead to persistent or severe symptoms, including high fever, back pain, or blood in the urine, and can be recurring. Proper diagnosis and treatment are essential to prevent complications, such as kidney infections or sepsis, which can arise from untreated UTIs (2).

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Common bacteria that cause UTIs include *Escherichia coli*, *Staphylococcus saprophyticus*, *Klebsiella pneumoniae*, *Proteus mirabilis*, and *Enterococcus faecalis* (3). Uropathogenic *E. Coli* (UPEC) is the most common cause of UTI (4). *S. saprophyticus* is the second- leading cause, especially in younger women (5). In addition to these, other bacteria, viruses, or fungi can also cause UTIs (Table I).

Table I. Common bacterial and viral pathogens that cause urinary tract infections (UTIs).

Bacterial pathogens	<ul style="list-style-type: none"> • Uropathogenic <i>Escherichia coli</i> (UPEC): The most common causative agent • <i>Klebsiella pneumoniae</i> • <i>Proteus mirabilis</i> • <i>Staphylococcus saprophyticus</i> • <i>Enterococcus faecalis</i>
Viral pathogens	<ul style="list-style-type: none"> • Adenoviruses • Polyomaviruses: BK virus and JC virus • Cytomegalovirus (CMV)

DISCUSSION

UTIs begin with the colonization of the urethra, and subsequently the bladder, by uropathogens through the action of specific adhesins. UTIs are commonly initiated by UPEC which enter the urinary tract through the urinary meatus and ascend the urethra into the bladder lumen (6). The bacterium can adhere to the urothelium and UPEC strains and uses mannose-sensitive type 1 fimbriae and papG adhesion P pili to adhere to epithelial cells of the bladder and kidney (7,8).

Adhesins are proteins that help bacteria bind to glycoproteins on the surface of uroepithelial cells (9). Pathogenic bacteria begin invasion after attachment to targets and can invade uroepithelial cells, creating intracellular bacterial communities (IBCs) (10). At the intracellular level, these bacteria replicate and evade the host's immune response (11). Bacteria can form biofilms, which protect them from antibiotics and the host immune system, on urinary catheters and inside the bladder, contributing to chronic and recurrent infections (12).

These bacteria can produce hemolysin, toxins such as alpha-hemolysin produced by *E. Coli*, capable of lysing host cells and releasing nutrients for bacterial growth (13). The release of bacterial cytotoxins damages host tissues and causes the immune reaction. Additionally, bacterial pathogens produce siderophores to scavenge iron from the host, which is essential for bacterial growth (14). The bacteria are capable of evading the immune system by forming a protective layer around the capsule, which allows them to protect themselves from the phagocytosis of macrophages and polymorphonuclear cells (15).

Escherichia coli

E. Coli is the most common cause of UTIs, responsible for up to 80-90% of all cases (16,17). *E. Coli* bacteria normally live in the intestines and are harmless there. However, when they enter the urinary tract, they can cause an infection. *E. Coli* can enter the urinary tract from the intestines through several pathways. By ascension through the urethra, *E. Coli* from the intestines can reach the urethra and travel up into the bladder or can transfer *E. Coli* from the anal area to the urethra due to improper hygiene (18). Sexual transmission is another route for infection and can facilitate the movement of *E. Coli* from the vaginal or anal area to the urethra.

Symptoms of UPEC UTIs are similar to those of other UTIs and can include the frequent urge to urinate, a burning sensation during urination, the passage of frequent, small amounts of urine, cloudy or strong-smelling urine, pelvic pain in women and rectal pain in men (19). The diagnosis of the infection is made by collecting urine which is analyzed for the presence of bacteria, white blood cells, and red blood cells. A urine culture is then performed, which helps to identify the specific bacteria causing the infection and determines sensitivity to antibiotics.

E. Coli infections are primarily treated with antibiotics. The choice of antibiotic and duration of treatment depend on the severity of the infection and any patterns of antibiotic resistance. Commonly used antibiotics include Trimethoprim/sulfamethoxazole (Bactrim, Septra), Nitrofurantoin (Macrobid, Macrochantin), Fosfomycin (Monurol), Ciprofloxacin (Cipro), and other fluoroquinolones (usually reserved for more complicated cases) (20).

Klebsiella pneumoniae

K. pneumoniae is a bacterium that can cause a variety of infections, including UTIs. This pathogen is known for its ability to acquire resistance to multiple antibiotics, making infections challenging to treat (21). Symptoms of a *K. pneumoniae* UTI can include the frequent urge to urinate, pain or a burning sensation during urination, cloudy or strong-smelling urine, blood in the urine, lower abdominal pain or discomfort, and fever and chills, particularly if the infection has spread to the kidneys.

Proteus mirabilis

P. mirabilis is a gram-negative, facultatively anaerobic bacterium that is a well-known cause of UTIs. *P. mirabilis* is a rod-shaped bacterium with numerous peritrichous flagella and is very motile. It is characterized by rapid movements with ease of colonizing tissues. *P. mirabilis* produces the enzyme urease, which hydrolyzes urea into ammonia and carbon dioxide, leading to an increase in urine pH (22). In humans and some animals, it is present in the gastrointestinal tract and can play an important role in the pathogenesis of UTIs (23). It can colonize and infect the bladder and kidneys. *P. mirabilis* alkalizes urine, promoting the formation of struvite (magnesium ammonium phosphate) and apatite (calcium phosphate) kidney stones (24). *P. mirabilis* can cause acute cystitis with inflammation of the bladder and painful urination (dysuria), and pyelonephritis with fever. Therapy uses first-line agents such as trimethoprim-sulfamethoxazole, fluoroquinolones, or ampicillin (25). Understanding the specific features and behaviors of *P. mirabilis* helps in effectively diagnosing and treating UTIs caused by this bacterium, thereby reducing complications and recurrence rates.

Staphylococcus saprophyticus

S. saprophyticus is a notable pathogen in the context of UTIs, particularly among young women. *S. saprophyticus* is a Gram-positive, coagulase-negative bacterium that is a common cause of UTIs. Its ability to adhere to the urinary tract and form biofilms, along with its production of urease, contributes to its pathogenicity (26). Prompt diagnosis and appropriate antibiotic treatment are essential for effective management and to prevent complications. Its incidence in causing UTIs is 5-15% (27) and in addition to women, it can also infect men of all ages. Very often, there is a high rate of infectivity in autumn. *S. saprophyticus* has the ability to adhere to the lining of the urinary tract (urothelium) using proteins and lipoteichoic acids (28). It can hydrolyse urea into ammonia and increase the pH of urine, an action that contributes to its colonization (29). Some strains of *S. saprophyticus* can form biofilms that aid their ability to persist in the urinary tract and resist host immune responses (30).

The typical symptoms of UTI infection by *S. saprophyticus* include painful urination, pain in the lower abdomen, and the presence of hematuria. Untreated or recurring infections can lead to complications such as pyelonephritis. These UTI infections are usually treated with antibiotics such as Nitrofurantoin, Trimethoprim-sulfamethoxazole or Fluoroquinolones of which *S. saprophyticus* are sensitive (31). However, resistant *S. saprophyticus* models can also be formed.

Enterococcus faecalis

UTIs caused by *E. faecalis* require careful diagnosis and targeted treatment. Given its potential for antibiotic resistance, appropriate antibiotic selection is crucial (32). Preventive measures and proper hygiene can significantly reduce the risk of UTIs. *E. faecalis* is a facultative anaerobic Gram-positive bacterium that causes UTI infection, can cause various symptoms such as frequent urination with pain and burning, and can alter the urine making it cloudy and blood-filled. Furthermore, *E. faecalis* can induce fever and chills and promote the development of UPEC. *E. faecalis* is part of the intestinal bacterial flora, can become pathogenic under certain conditions, and can develop considerable resistance (32).

CONCLUSIONS

UTIs are very common bacterial infections caused by several bacterial species. The main bacteria responsible for these infections are *E. Coli*, *K. pneumoniae*, *P. mirabilis*, *S. saprophyticus*, and *E. faecalis*. Each of these bacteria has particular characteristics and mechanisms that allow them to cause infection after colonizing the urinary tract and evade the host immune response.

Conflict of interest

The authors declare that they have no conflict of interest.

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