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Review Article

Comprehensive Review of Uropathogenic *Escherichia coli* Virulence Factors and Their Role in Urinary Tract Infection

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Abstract

Escherichia coli is a gram-negative bacterium that lives in numerous places within the environment, including the gastrointestinal framework of people. Most strains of Escherichia coli contribute positively to human health by aiding in digestion and nutrient absorption. However, certain strains can become pathogenic and are capable of causing extraintestinal infections in humans. Among these, uropathogenic Escherichia coli (UPEC) is the primary causative agent of urinary tract infections (UTIs), particularly in women, children, and the elderly. UPEC strains possess unique genetic traits known as virulence factors, which are essential for their ability to colonize, invade, and persist within the urinary tract. The primary objective of this review is to provide a comprehensive analysis of the major virulence factors associated with UPEC and to evaluate their specific roles in the pathogenesis of UTIs. UPEC virulence factors are broadly classified into surface-associated structures and secreted products. Type 1 fimbriae and P fimbriae are the major surface adhesion structures, allowing UPEC to attach to and colonize the uroepithelial cells of the bladder and kidneys. Capsular polysaccharides and lipopolysaccharides (LPS) contribute to immune evasion and biofilm formation, enhancing the bacteria's ability to persist in hostile environments. In addition to surface structures, UPEC also secretes various toxins and effector proteins. These include hemolysin, which lyses host cells; cytotoxic necrotizing factor 1 (CNF1) and cytolethal distending toxin (CDT), which interfere with host cell function; secreted autotransporter toxin (SAT), which promotes tissue damage; and siderophores, which facilitate iron acquisition from the host, an essential nutrient for bacterial growth. Further research is needed to understand the molecular mechanisms underlying UPEC virulence and the factors contributing to the emergence and spread of multidrug-resistant clones. A comprehensive understanding of virulence factor expression, regulation, and interaction with the host immune system could provide new avenues for therapeutic intervention.

Keywords

Escherichia coli, Lipopolysaccharide, Surface Virulence Factors, Toxins

1. Introduction

Infectious diseases in humans are illnesses brought on by bacteria, viruses, fungi, or parasites. Numerous microbes inhabit our bodies. Usually, they are neither harmful nor even beneficial. However, some microbes have the potential to cause illness in specific situations. Certain infectious diseases can spread from person to person. While some infections that are not life-threatening may be treated at home with rest and home treatments, others may need to be hospitalized [25]. Hospitals are the source of infection for many infectious disorders, including urinary tract infections caused by bacteria.

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Additionally, frequent and thorough hand washing helps shield us from the majority of infectious diseases [15].

A little fragment of DNA contains instructions that are read by single-celled bacteria. We are surrounded by bacteria, which are also found on our skin and in our bodies [18]. While many bacteria are beneficial or even innocuous, certain bacteria can cause illness by releasing toxins. *Escherichia coli* is a bacterium; a unicellular organism too small to be seen with the naked eye. *E. coli* got its name, Escherichia, from the German pediatrician Theodor Escherich, who discovered the bacterium in 1885. Many animals, including humans, have gastrointestinal tracts or intestines where the majority of *E. coli* reside and grow innocuously [24].

Unfortunately, the *E. coli* strains that people are most familiar with are the ones that cause disease. *Escherichia coli* is a gram-negative, motile, facultatively anaerobic, rod-shaped bacterium, non-spore-forming, flagellated. *Escherichia coli* continues to be a major concern in clinical microbiology research offices because of the heavy workload related to UTIs. Such bacterial contamination is urinary tract infections (UTI), including the nearness of microbes within the urinary tract which is sterile [20]. A urinary tract contamination may be a condition in which one or more parts of the urinary framework (the kidneys, ureters, bladder, and urethra) get sullied [24].

Virulence factors linked to the pathogenicity of uropathogenic *E. coli* are diverse and possess various functions, ranging from facilitating bacterial colonization to enhancing virulence. These factors are typically encoded on pathogenicity islands (PAIs), plasmids, and other mobile genetic elements. These are the molecules that bacteria make that allow them to enter a host, get past the host's defenses, and spread illness. These factors are secretory, membrane-associated, or cytosolic in nature strains of UPEC. *E. coli* virulence factors can be broadly categorized into two main types: surface virulence factors and export factors, as identified by Bien *et al*. [4]. The primary surface virulence elements of UPEC comprise lipopolysaccharide, capsule, type 1 fimbriae, and P fimbriae, crucial for initiating colonization within the urinary tract. Additionally, surface-displayed virulence factors such as hemolysin, cytotoxic necrotizing factor 1, cytolethal distending toxin, secreted autotransporter toxin, and siderophore facilitate nutrient acquisition from the host cells [22].

Fimbriae adhesins such as *PapG* and *CsgA* are hurtful components that energize the association of *E. coli* [6]. Close to these mechanisms, UPEC can undermine the host's immune system through various means, including damage and evasion of host defense systems, collectively referred to as released damaging tendency components. The era of these damaging tendency factors by UPEC may cause a provocative response which makes a conceivable pathway for UTI signs. In this review, various critical virulence factors of UPEC are discussed, particularly those encoded within pathogenicity islands. These factors encompass adherence mechanisms, toxins, and evasion strategies, collectively constituting significant risk factors for UPEC pathogenicity. This review aims to provide a comprehensive analysis of the major virulence factors associated with UPEC and to evaluate their specific roles in the pathogenesis of UTIs.

2. Review of the Literature

2.1. Surface Virulence Factors

The urine of an uninfected person is sterile due to the urinary stream and antimicrobial development of uric destruction. A typical stream of urine does not allow the microorganism to colonize the insides of the urinary tract. However, the adherence of E. coli to uroepithelial cells enables them to resist the impact of urinary flow. Surface damaging tendency components of UPEC incorporate several unmistakable sorts of cement organelles (fimbriae), which progress bacterial association to have tissues interior the urinary tract [4]. The presence of cement molecules (adhesins) by UPEC is the first basic determinant of pathogenicity. UPEC adhesins contribute to harm in various ways: (i) by activating host and bacterial signaling pathways, (ii) by facilitating the delivery of bacterial components to host tissues, and (iii) by promoting bacterial invasion.

Numerous pathogenic microorganisms are considered as the essential step inside the colonization plans and both the have and *E. coli* work in this handle. UPEC's ability to colonize relies on the expression of specific fimbrial adhesins. For a viable adherence to the have cell surface, UPEC communicates various adherence components that are imperative for association and in this way regarded as harmfulness components. Bacterial pathogens must adhere to host cells to colonize the body, a process known as tissue tropism. This involves specific interactions with target receptors and tissue surfaces. Various surface structures play a significant role in facilitating specific adhesion [29].

2.1.1. Fimbriae

Various bacterial adhesions are organized in a lean filamentous structure called fimbriae or pili showing disdain toward the reality that there are affirmations of the closeness of adhesins inside the cell surface of organisms. Adhesins of fimbrial nature are crucial amid association handling [7]. Fimbriae are long hair-like structures contained inside the cell [14]. Microbial pros and inclining components surface of organisms that recognize specific compounds commonly carbohydrates of the target have cells. Fimbriae contain oligomeric pilin proteins. These slim, helical, circular, and hollow proteinaceous structures, shorter than flagella, are expressed in uropathogenic strains of E. coli and are regarded as harmful components due to their role in specific adhesion. Most of the receptor’s fimbriae are carbohydrates. They consolidate type 1 fimbriae, P fimbriae, and incline aggrega-

tive fimbriae. Various bacterial pathogens can make a cluster of these adhesins, and the regular obstacle of a single grip may fetch adequate for a bacterium to lose its danger. In gram-negative tiny living beings like UPEC, adhesins are uncovered by a chaperone-usher-assisted pathway. This pathway includes two proteins, one may be a periplasmic chaperone, and the other may be a protein called usher. The usher serves as the foundation of the structure, while the chaperone's role involves folding and recruiting the subunits [34]. Usher makes a differentiation to make the fimbriae and its transportation through the exterior guaranteeing cleverness of the exterior layer. In uropathogenic *E. coli* strains, chaperone-usher family fimbriae are more abundant.

Type 1 fimbriae: Type 1 fimbriae are common among *E. coli* strains from all clinical categories of UTI [7]. The adherence of type 1-fimbriated strains to have cells within the urinary tract may advance the advancement of cystitis, their adherence to and incitement of hPMNLs may advance bacterial murdering but may moreover contribute to renal scarring. Several E. coli strains, qualities to encode type 1 fimbriae are shown [33], and amid urinary tract contaminations, they hurt urinary tract cells by mediating an extended bothering.

In organize to enter into the cells of the urinary tract; Type 1 fimbriae play an extraordinary portion. Type 1 fimbriae are shockingly adaptable damaging tendency factors of UPEC that can stabilize the association of the organisms to different types of cells all through the urinary tract. Strong enjoying of Type 1 fimbriae was found in proximal tubules and vessel dividers. Inside the bladder, they tie unequivocally to solid layers and decently to vessel dividers. Receptors for type 1 fimbriae were additionally found inside the distal tubules and collecting channels. They can start their official to the surface of macrophages [10]. Type 1 fimbriae recognize uroplakin from bladder epithelial cells as well as mannose-containing proteins. Colonization by type 1 fimbriae may be restored by expressing plasmids containing appropriate subunits. *FimH* in affiliation with LPS can stimulate toll-like receptor 4 (TLR4) to begin a particular signaling cascade that will order the humoral safe response. Various considerations approximately revealed that the expression of type 1 fimbriae comes almost in damaging tendency and incident of expression [21]. In any case; type 1 fimbriae-mediated association might be a significant arrange of cystitis. The cement tip of these fimbriae, *FimH,* ties to α-D-mannosylated proteins such as UPs, which are communicated by the separated urothelium and in this way relates this adhesin to the lower urinary tract [17]. Due to its authoritative liking, *FimH*-mediated attachment or aggregation of eukaryotic cells (red blood cells) is hindered by mannose. Authoritative of FimH to its receptors intervenes in attachment and invasion.

P fimbriae: P fimbriae are vital within the pathogenesis of UTI since they intercede alpha-*DGalp-(1-4)-beta-D-Galp* adherence to epithelial cells inside the human urinary tract, subsequently allowing bacterial colonization and fortifying inflammation [17]. In compromised the prerequisite for P fimbriae in starting genuine UTI is diminished, proposing that P fimbriae are essential for *E. coli* to overcome certain components of the types have a defense framework. Anti-P-fimbriae resistance secures humans against renal contamination with homologous P-fimbriated strains, but the serological differences of P fimbriae and the restricted effect of anti-P-fimbrial antibodies on adherence complicate endeavors to create anti-P-fimbrial antibodies for human utilize. Inside the kidney, they tie unequivocally to Bowman's capsule, glomerulus, and endothelial cells of vessel dividers. P fimbriae communicated *E. coli* enters the urinary tract; they construct up bacteriuria and offer help to cross the epithelial boundary to enter the circulatory framework and can cause hemagglutination of erythrocytes [17].

There are at smallest nine qualities inside the pap quality cluster with two restriction regions at two closes. The regulatory portion starts the taking after Eco R1 comprising of papI and papa. At that point *papA, papH, papC, papD, papE, papF,* and *papG* are organized. Around 1000 subunits outline a P fimbria, being joined together in a helical way. The protein *PapC,* which is the greatest one with 80 KD of mass, makes a difference in the strategy by transporting the subunits outside the portion of the cell. The minor subunits at the tip of the fimbria choose the specificity of the receptor. *PapH* closes the get-together of the fimbriae and joins in this way portion of *PapG* was found in several varieties of P fimbriae which means they can begin subunit polymerization [7].

Various tests show that expression of these fimbriae isn't important to urinary tract defilement, though more present-day other tests have concluded around their portion in pathogenesis. It shows disdain toward the reality that P fimbriae can begin incendiary responses by actuating TLR4 [12]. It secures UPEC from human polymorph nucleus leukocytes (hPMNLs). In the dynamic environment of the urinary tract, conditions influence the expression of P fimbriae.

Thin aggregative fimbriae (Curli): Curli strands are extracellular amyloid fibrils that are dynamically communicated by *E. coli*. Characteristic of amyloids, curli strands are exceedingly steady, insoluble, tall molecular-weight protein complexes ruled by a beta-sheet auxiliary structure [11]. Curli is the as it is known amyloid filament encoded by *E. coli* and other Enterobacteriaceae.

Curli filaments are intentionally gathered by committed bacterial apparatus. Curli's advanced adherence to epithelial cells and resistance against the human antimicrobial peptide, additionally cause acceptance of the proinflammatory cytokine IL-8. They display a select part in advancing UPEC biofilms and speak to one of the major biofilm components [5]. Curli is delivered at the restriction of supplements and salts, at decreased oxygen pressure, and at a temperature below 30 ℃. In any case, it is accepted that numerous pathogenic microbes and commensal strains can moreover express curli at 37 ℃ amid disease in people.

F1C/ S fimbriae: F1C may be a destructiveness figure ca-

pable of urinary tract diseases, which is encoded by an operon of seven qualities, i.e., focAICDFGH, where FocA is the major subunit and FocH is the tip adhesin [3]. F1C receptors are shown in the bladder endothelium and solid layer. They tie to glomeruli, distal tubules, collecting channels, and vascular endothelial cells. Thinks about appears that F1C fimbriae and pyelonephritis are correlated though there's a small contrast within the predominance of type 1 fimbriae in UTI strains. The predominance of F1C fimbriae is 16% in UTI strains [3]. S fimbriae are hereditarily indistinguishable from F1C fimbriae and contrast as it were by the tip adhesin SfaS. Criteria that are required to be recognized as harmfulness calculates were decided by distinctive ponders concerning S fimbriae.

2.1.2. Lipopolysaccharide

Lipopolysaccharide (LPS) is an irreplaceably component of the cell divider and comprises the exceedingly protected lipid and repeating O-antigen subunits that differentiate massively between strains based on the sugar build-ups and their linkage plans interior the rehashing subunits [28]. LPS is especially well known to enact a response and to incite nitric oxide and cytokine (IL-1, TNF-α) era which progresses the incendiary response. It additionally activates the amalgamation of specific antibodies to the considerable antigen and applies an immune-adjuvant effect that propels the humoral safe response to other antigens of the pathogen. Be that it may, certain antigenic sorts of LPS are also included in the resistance of the pathogen to the killing effect of the commonplace human serum. In animal studies, severe renal failure due to LPS depends on systemic response rather than kidney TLR4 expression. However, LPS's role in UTI-related renal failure in patients is still unclear.

2.1.3. Flagellum

Flagella is an organelle that's capable of bacterial motility and plays a part in the beginning attachment stage of biofilm arrangement. A recent study showed that motility is included in the relocation of the disease from the bladder to the kidneys [3]. Approximately 70–90% of all urinary tract contaminations are caused by flagellated UPEC, and pathogenesis includes contact between the microbes and epithelial cell surface of the urinary tract. Be that as it may, flagella motility upgrades the capacity of *E. coli* by versatile reactions to appealing or repellent natural [35].

2.1.4. Capsule

The primary function of the capsule is to envelop the outer surface of the cell wall, shielding bacteria from phagocytosis and the bactericidal effects of the complement system. Its main purpose is to provide a protective layer, safeguarding the bacterium from various adverse conditions. This protective framework primarily consists of polysaccharides [4]. The capsule protects against engulfment, complement-mediated bactericidal effects, antimicrobial resistance, and antiserum action in the host [13]. Certain capsular, such as K1 and K5, avoid an appropriate humoral safe reaction of the contaminated by appearing as an atomic mimicry to tissue components. The K1 polysaccharide, connected to a sialic corrosive homopolymer, includes an exceptionally vital part in advancement as well as within the numerous stages of UTI pathogenesis.

2.2. Exported Virulence Factors

2.2.1. Toxins

Poisons offer assistance to the pathogen spreading into more profound tissues after disturbing cell judgment; to pick up get to supplements interior they have cell; or to crush safe effector cells and in this way sidestep their potential antibacterial action [17]. A few poisonous substances or proteins emitted by uropathogenic strains of *E. coli* play a considerable part as harmful components in UTIs. Be that as it may, poisons can modify the cell signaling cascade and balance fiery reactions.

A few in vitro and in vivo studies appeared that poisons too contribute to the incitement of the cell passing and discharging of fundamental supplements, which give the capacity to get to more profound tissues inside the urinary tract [1]. In 1987, CDT poison (Cyclomodulins) was, to begin with, detailed as harmful poison in UPEC [31], which opened an unused entryway within the think of the pathogenesis of UTIs.

2.2.2. A-hemolysin

Hemolysin production is associated with human pathogenic strains of *E. coli*, especially those causing more clinically severe forms of UTI. The pro-virulence activity of hemolysin is multifactorial, including disruption of phagocyte function, and direct toxicity to host tissues. Antihemolysin immunity protects against infection with hemolytic strains and should be explored for human use. Among toxins, α-hemolysin (HlyA) is noteworthy, being a lipoprotein and part of the RTX (repeats in toxin) toxin family [2]. It acts as a pore-forming toxin, leading to cell membrane damage and apoptosis mediated by inducible nitric oxide synthase (iNOS). HlyA breaks erythrocytes and nucleated cells, potentially compromising host immune cells, and aiding UPEC's access to host nutrients and iron stores [4]. But when the concentration is low, HlyA can actuate the apoptosis of target cells and advance the peeling of bladder epithelial cells [3].

A later ponder appeared that HlyA controls the dephosphorylation, which may be a multifunctional signaling regulator and mindful for controlling provocative reactions within the have, as well as the cell cycle control. HlyA has the part within the expanded generation of IL-6 and IL-8 by actuating Ca2+ motions in renal epithelial cells.

2.2.3. Cytotoxic Necrotizing Factor 1

Cytotoxic necrotizing factor 1 (CNF1) is a virulence factor

produced by *E. coli*, is plays a role in UTIs by promoting actin stress fiber formation and facilitating E. coli entry into cells [16]. This toxin has a significant effect on the actin cytoskeleton, leading to the formation of large vacuoles within cells [31]. However, a few in vitro and in vivo consider appeared that this protein interferes with polymorphonuclear phagocytosis and inspires apoptotic passing of bladder epithelial cells. In expansion, there's moreover a plausibility of the association of CNF1 with the hemolysin within the harmfulness component, which is useful for the microbes [35].

2.2.4. Secreted Autotransporter Toxin (SAT)

Secreted autotransporter toxin (SAT) could be significant as a virulence factor in the development of UTIs due to its toxin activity against cell lines originating from the bladder or kidney. SAT is a serine protease autotransporter belonging to a subgroup of autotransporters recently categorized as the SPATE (serine protease autotransporters of *Enterobacteriaceae*) family, often found in pyelonephritic *E. coli* strains [9]. SAT may exert cytopathic effects, damaging host tissue and potentially enhancing UPEC proliferation. Additionally, this toxin might facilitate the entry of pyelonephritogenic strains into the bloodstream through specific damage to the glomeruli and proximal tubules [35].

2.2.5. Cytolethal Distending Toxin (CDT)

The cytolethal-distending toxin, notable for its ability to harm the DNA of target cells, was initially discovered in pathogenic *E. coli* in 1987 [31]. This toxin can disrupt the cell cycle and contribute to the development of UTIs. CDT originates from an operon containing three proteins: CdtA, CdtB, and CdtC, which are encoded by the cdtA, cdtB, and cdtC genes, respectively [23]. CDT has DNase I-like enzymatic movement and assaults DNA, whereas the other bacterial poisons assault the cell layer or diverse targets inside the cytoplasm. This special property of assaulting DNA harms the target cell DNA which comes about in dynamic cell distending driving to cell passing [31].

2.3. Iron Acquisition Systems

Siderophores are little natural atoms created by microorganisms beneath iron-limiting conditions which enhance the uptake of iron to the microorganisms [26]. Iron is crucial for various biological processes, including oxygen transport, DNA synthesis, electron transport, and peroxide metabolism in E. coli. However, iron availability decreases in the host urinary tract during UTIs [32]. In reaction to this, *E. coli* has a few numerous practically repetitive frameworks that intercede press take-up by emitting low-molecular-weight Fe_3+ chelating atoms.

Iron utilization, interceded by these siderophores, is basic for the colonization of the urinary tract by UPEC. *E. coli* possesses four siderophore systems: yersiniabactin, aerobactin, enterobactin, and salmochelin [23]. These systems are activated in low-iron environments and are controlled by ferrous iron and the ferric uptake regulator Fur (Figure 1).

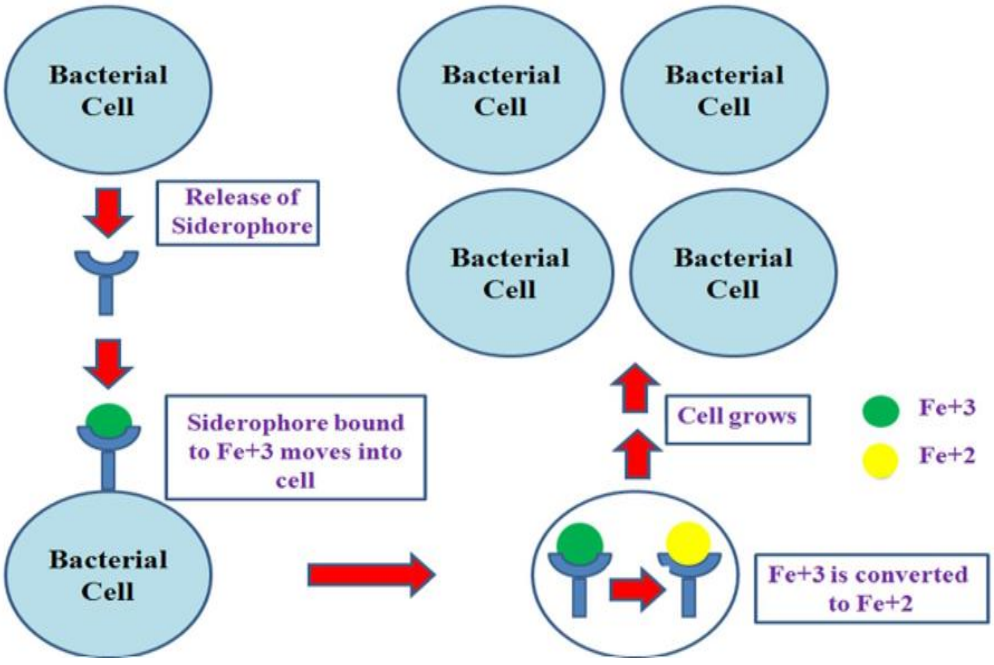

Figure 1. *Explain how siderophore works [23].*

Under iron-limited conditions, the bacterial cell releases a siderophore. The siderophore forms a complex with insoluble ferric ions (Fe_3+), which then bind to the surface of the bacterial cell. This complex is transported into the cell, where the insoluble ferric iron (Fe_3+) is transformed into the soluble ferrous form (Fe_2+). Siderophores are either degraded within the bacterial cell or released into the extracellular environment in their free form. The bacterial cell then utilizes this ferrous iron for its growth, leading to an increase in its population [23].

2.3.1. Aerobactin

Aerobactin could be a little particle shaped from the condensation of two lysine particles and one citrate taken after discharge by *E. coli* cells; aerobactin extricates (separate) Fe3+ from iron-binding proteins and is taken up through external film receptor protein [17]. Strains with the aerobactin framework have a development advantage in low-iron conditions. The chromosomal aerobactin framework is related to other uropathogenic harmfulness component determinants, though the plasmid aerobactin framework is often carried by plasmids encoding different antimicrobial specialist resistance [17].

2.3.2. Enterobactin

Enterobactin, another specialized and widely prevalent catecholate siderophore, is less soluble and stable than aerobactin. However, it exhibits a higher affinity for iron and can bind transferrin more rapidly than aerobactin in a liquid environment. In any case, the press is discharged from enterobactin through the hydrolysis of this siderophore [30]. Apart from these, enterobactin enables UPEC to thrive in iron-limited environments like the urinary tract. However, this siderophore has a drawback as it can be deactivated by proteins like serum albumin and siderocalin, which are components of mammalian defense mechanisms functioning as antimicrobial agents [30].

2.3.3. Yersiniabactin

A phenolate siderophore is prevalent in Enterobacteriaceae, including *E. coli*, and is encoded on the high-pathogenicity island [19]. Yersiniabactin includes a tall iron partiality and delivers yersiniabactin-Fe_3+ complex official to the press atom which recognizes the particular bacterial external film TonB-dependent receptor and Fyu (Psn). The press molecule is discharged from yersiniabactin inside the cytosol with the help of membrane-embedded proteins [19]. In expansion, this siderophore increments resistance to copper push by chelating Cu_2+.

2.3.4. Salmochelin

Enterobacteriaceae, including *E. coli*, produce a glucosylated form of enterobactin, termed salmochelin, to evade host immune responses like siderocalin recognition. Salmochelin is synthesized by glucosylation via glucosyltransferase, preventing its binding by siderocalin. However, recent studies indicate salmochelin may facilitate urothelial cell invasion, implicating iron in urinary tract infections [27]. Apart from enterobactin, the hemin uptake system, involving ChuA and Hma, is crucial for iron acquisition during UTIs and biofilm formation. ChuA expression is regulated by RfaH, while Hma operates independently, both aiding in hemin utilization essential for efficient kidney colonization [8].

3. Conclusions and Future Perspectives

Numerous investigations have identified uropathogenic *E. coli* as the primary pathogen linked with UTIs. Recent advancements in our comprehension of *E. coli's* virulence factors in UTIs have been substantial. Multiple studies have demonstrated that *E. coli* can inhabit the urinary tract and ascend towards the bladder, leading to the onset of cystitis. If not treated early, uropathogenic *E. coli* can completely damage the kidneys and bladder, eventually leading to death. To assess the distribution of uropathogenic *E. coli* strains, we need to examine the degree of *E. coli* virulence genes in different hosts. Enhanced comprehension of the virulence factors associated with UPEC can reveal new strategies for managing UTIs. This deeper understanding gained from virulence studies can pave the way for practical applications, potentially improving the precision of phenotypic or molecular diagnosis and epidemiological approaches. More concrete studies need to address the virulence factors of urinary tract infections related to *E. coli.* A brief search for *E. coli* surface virulence factors is required to characterize its structure and further research on the siderophore and its important factors is needed.

Abbreviations

CDT	Cytolethal Distending Toxin
CNF1	Cytotoxic Necrotizing Factor 1
Fur	Ferric Uptake Regulator
FimH	Fimbrial Adhesin H
ChuA / Hma	Hemin Uptake Systems in E. coli
hPMNLs	Human Polymorphonuclear Leukocytes
iNOS	Inducible Nitric oxide Synthase
IL-6	Interleukin-6
IL-8	Interleukin-8
LPS	Lipopolysaccharide
PAI	Pathogenicity Island
RTX	Repeats in Toxin (Toxin Family)
SAT	Secreted Autotransporter Toxin
SPATE	Serine Protease Autotransporters of Enterobacteriaceae
TLR4	Toll-like Receptor 4

UTI	Urinary Tract Infection
UPEC	Uropathogenic Escherichia coli

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Author Contributions

Wondwesen Mitiku: Writing-original draft, editing, Validation, Methodology, and Conceptualization.

Debebe Landina Lata: Writing-review, Facilitating, Investigation, Supervision, Material acquisition, Data curation, and Resources.

Ethics Approval

There is no ethics problem and the manuscript is original and has not been published elsewhere.

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Data and Material Availability

Data will be made available on request.

Conflicts of Interest

The authors declare no conflicts of interest.

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