GSC Biological and Pharmaceutical Sciences
eISSN: 2581-3250 CODEN (USA): GBPSC2
Cross Ref DOI: 10.30574/gscbps
Journal homepage: https://gsconlinepress.com/journals/gscbps/

(REVIEW ARTICLE)

Check for updates

Urinary tract infection and damage caused by *Escherichia coli* Uropathogenic factors

Wafaa Tali radef [1,*], Farkad Hawas Musa [2] and Ibtehal Mohammed Khalaf [1]

[1] *Biology, University of Anbar, College of education for women, Iraq.*
[2] *Biology, College of education for Pure Sciences, university of Anbar, Iraq.*

GSC Biological and Pharmaceutical Sciences, 2025, 31(03), 310-316

Publication history: Received on 17 May 2025; revised on 23 June 2025; accepted on 25 June 2025

Article DOI: https://doi.org/10.30574/gscbps.2025.31.3.0250

Abstract

The vast majority of UTIs in healthy people and in patients transplanted by kidney transplants are caused by UP Esherichia coli, including cystitis and pyelonephritis, and complicated infectious disease, which can lead to an acute renally failure (UPEC). A variety of virulence factors are expressed in the UPEC to break down mucosal barrier inertia. Cytokine synthesis, the neutrophil infection inflow as well as the part of the inflammatory HOST responses to the UPEC urinary tract. During UPEC infection, several signals interact with calcium-dependent signaling pathway, including routes causing natural immune reactions. However, such UPEC isolates could have strategies to postpone the host response elements in the urinary tract or to inhibit them. New information on how uropathologic *E. coli* virulence factors trigger the innate host response is obtained from recent studies. UPEC can live in the urinary tract in spite of many host defense mechanisms and function as a reservoir for chronic diseases and serious complications. In order to develop successful strategies to prevent human UTIs and urologically related UTIs, it is important to provide molecular data on these cases.

Keywords: Urinary Tract; Infection; *Escherichia coli*; Uropathogenic Factors

1. Introduction

The bacterium *Escherichia coli* (*E. coli*) lives naturally in the intestines of healthy people and animals. Most types of *Escherichia coli* are harmless or cause relatively brief diarrhea. However, there are a few dangerous strains, such as the O157: H7 strain of *Escherichia coli*, that can cause severe abdominal cramps, bloody diarrhea and vomiting. *E.coli* from contaminated water or food - especially raw vegetables and undercooked ground meat. Healthy adults usually recover from *E. coli* O157: H7 infection within a week [1], but children and the elderly are at greater risk of developing a life-threatening kidney failure called hemolytic uremic syndrome [1-3-4]. Pathogenic forms of *E. coli* are generally known as *E. coli* enteric or diarrheal (ExPEC). *E. coli* pathotypes are most commonly seen, including *E. coli* pathotype and enterotoxin *E. coli* pathotypes, *E. coli* pathotypes, enterogenesis, *E. coli* and *E. coli* (UPEC), neonatal meningitis (NMEC) and two pathotypes (EPE). Several enteric diarrhea pathotypes, *E. coli*, cause gastroenteritis, but rarely cause disease outside the gut. ExPEC stresses appear free in the intestines, however, and can dispense or colonize host niches such as blood, due to diseases. [5-7]

The greatest common infection in humans are urinary tract infections (UTIs). The development of UTIs focuses on host defense integrity and anatomic factors for virulence. UTI was split into multiple site-based disease types: cystitis (bladder), bacteriuria and pyelonephritis. Bacterial pathogens are effectively developed by host cell adherence, tissue colonization, and intracellular invasion, subsequent proliferation, distribution and persistence to other tissues, for others. Urinary colonization is called asymptomatic bacteriuria in the absence of clinical symptoms (ABU). The majority of ABU patients should not be treated and may help avoid infection with other, more virulent bacteria by colonizing ABU strains[7-9]. UPECs and a large proportion of nosocomial UTIs in the acquired population around the world pose

* Corresponding author: Wafaa Tali radef

Copyright © 2025 Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution License 4.0.

significant medical costs and deaths. The capacity of UPEC to induce symptomatic UTIs is associated with a wide range of virulence factors, with adhesive molecules probably being the main pathogenic determinant[10].

Unlike UPEC symptoms, it is not correctly known why ABU patients have symptoms. Nonsubstantive and non-haemolytic effects of several ABU strains were nevertheless clarified on a number of observations. Able to express functional P and type 1 fimbria isolated from the third-year-old ABU patient, strain *E. coli* 83972 lost the possibility of no immune response from the host. Contrary to other genetic microorganisms, *E. coli* was of gene and transformation, Pathogenesis adhesines.[10,11].

2. Symptomatic strains of the UPEC

The bladder generally connected to the normal UTI symptoms (e.g., pain) (sudden compelling desire to uri- nate). UTIs can, however, continue to cause bladder-borne pyelonephritis via ureters, resulting in irreversible damage to the kidneys and death. *E. coli* is the most common pathogens of gram negative bacteria causing acute renal failure. Furthermore, UTIs, e.g. after renal transplantation, and *E. coli* are the most frequent isolates [12-15].

UPEP activates a robust inborn response, including inflammatory cytokines or chemokines, to the decline in the usually sterile urinary tract. The formation of incendiary mediators is the product of quickly recruiting in combination with other antimicrobial bodies. Composition [16]. These bacteria may also have a series of delaying or suppressing innate immune response strategies that encourage bacterial growth and survival in adverse urinary areas.

3. Causes of Surface Virulence

A number of different types of adhesive organelles include UPEC Surface Virulence Factors for hot tissue in the urinary tract. The most significant determinant is the pathogenicity of UPEC adhesive molecules (adhesins). Advanced virulence genes are widely distinguished from genes of UPECs in mobile genetic elements known as islands of pathogenicity. The theoretically defined *E. coli* virulence factors as important in the determination of the UTIs can be subdivided [17].

UPEC adhesines are capable of leading to various virulences promoting the transfer of additional bacterial prod-ucts into tissues of host tissue; and the virulence of Type 1 fimbriae should be the model animal for an infection in the urinary tract, but its function in human anatomy is unsure. It is difficult to reconcile the status of fimbria type 1, since pathogenic and commensal strains are present in these cases. There is no important distinction among strains that are the frequency of film genes [18-21].

The murine UTI model shows that type 1 fimbriae enhance the survival of bacteria, promote inflammation of the mucous membranes and facilitate biofilm invasion and growth. fimbrium is bound in urothélial mannylated glycoproteins uroplakin Ia and IIIa by the adhesive subunit FimH, situated in the tip of the fimbrium (UPIIIa).

Interaction contributes to the development, and can contribute to an increase in urothelic cell levels of intra-cell Ca2+, which is necessary to stimulate invasion and the pathways of signals induced by apoptosis. [22] A Tamm Horsfall (THP), which obstructs bacterial cells contact with host cells in the human urine, is also developed through kidney cells and the soluble Fim H receptor that restricts UPEC urinary tract colonization capability[23]. The tissue and mucus matriz are binding and cytokines are produced. In their growth, they play a role. Heteropolymeric fibers P Fimbriae consists of various protein sub-units, and is coded with the PapA-K gene operon[24]. In these glyco-Glycosphingolipids, a kidney that bears the Galα is recognized. Fimbria attachment to this receptor contributes to the release of ceramide, a receptor that activates the immune cell response and acts as an agonist to the toll-like receptor (TLR4). This leads to local inflammation and UTI pain, on the other hand. Melican and his colleagues recently have unknown synergistic roles in both types of fimbriae which facilitate in vivo complex conditions colonisation of bacteria. The early colonization of tubular epithelia has proved to increase P fimbriae, while a fimbrial mechanism for binding interbacteria and the development of biofilms mediates the tubular center colonization type1. The heterogeneous population of bacteria inside the tubule then influences renal filtration, resulting in complete nephronic obstruction. This blockage contributes to the full production of pyelonephritis pathophysiological [25-27].

4. Polymorphous Genetic

The inflammatory reaction and vulnerability to kidney damage has proven influenced by gene polymorphism. Hyposensitivity to LPS, loss of neutrophil recruitment and delays in clearing urinary tract bacteria in mices are associated with polymorphism in the TLR4 gene[28]. gene in humans might also influence the inflammatory reaction.

In TLR4 Asp299Gly Allel, persons who were vulnerable to sepsis were indicated. Shock with increased incidence. recently described a new approach to human TLR variation based on TLR4 that promotes polymorphisms influencing gene expression in vitro-dynamics in asymptomatic bacteriurian patients and inborn dynamics of immune response.[29]. They suggest that lower TLR4 alleviates the inborn response to mucosa and promotes demonstrate that stopping codon polymorphism TRL5 prevents signaling flagellum and increases the susceptibility of legionnaires. These murine experiments have shown that people with TLR5 of this type are more UTI resistant. Cytocin polymorphism was also associated, perhaps due to heterogeneity in the immune response of these patients[30,31].

In reflux nephropathy patients, for example, TNFα-associated gene polymorphism was observed. Similarly, the predisposition of persons to the transforming growth factor-β1 (TGf-β2) gene was shown by Cotton et al. TGF-β1, formed by other cytokines (IL-6, IL-8, IL-1 and TNF-α), causes additional cell matrix exposures induced by increased matrix protein synthesis and reduced matrix degradation following suppression of protease expression (TIMPs). It is all backed by the hypothesis that TGF-β1 is important for parenchymal renal scarring pathogenesis after UTI. As a result of a heterogeneity in the TGF-β1 gene the TGF-β1 protein may be present with a variable constitutive or induced expression, which in turn may be related differential effects of cell growth or extracellular matrix deposition contributing to kidney scar [32].

During UPEC is crucial to inborn immune response and infection pathogenesis. A number of lines show that the Ca2+ SigNA pathway interacts with the pathways to the signals involved in a birth control. It assumes that there is a chance that Ca2+ regulation may have an effect on the innate immune response[33]. In addition, IL-6 is responsible for triggering the response not only through the Ca-µp route, but through the frequency-modified transcription of the NF-β-faktor B, as well as for mobilizing secondary messengers, Ca2 + and CAMP. IL-6 also activates an artificially inducedCa2+ oscillation Hosts of hosts can be caused by increased Ca2+ concentrations due to various bacterial virulence factors. UPEC α-haemolysin induces oscillation of the intracellular Ca2+ in the sublytic stages. Ca2+ waves have been shown, equivalent to one 12 min periodical, particularly for human renal epithelial cells that stimulate IL-6 and IL-8 growth. Experiments to identify intracells signaling path components which lead to Ca2+ oscillation have shown, in order to achieve Ca2+ oscillations, that a specific HlyA activity and activation of the L-type Ca2+ canals were necessary. The IP3-receptor-gated Ca2+ [34,35].

5. Activation of the cytokine secretion

For activating the cytokine secretion, UPEC E different signaling pathways were identified. Also CREB could make Coli faster than NF-SB. When people in the first place respond to the challenge of the microbial urinary tract, the ability of the epithelial bladder cells to mobilize the secondary messenger. The host signals transduced by the cascade have been known for their association with UPEC-related urothel pathogens.

The effects are also known for their effects. FimH is involved in urothelial cell adhesion, invasion and apoptosis by binding the bladder disease to the receptor complex. Blood vessel anatomy Recently, during bacterial invasions and apoptosis the signaling feature UPIIIa was presented in the past. The UPIIIa is the only uroplakin of significant importance with a potential cytoplasmic region. The concentration of intracellular Ca2+ Ca2+ in a certain threonine residue by casein kinaase 2, as a response to the adhesive FimH binding in the cytoplasmic tail of the UPIIa, increases. As a result of releases from intracellular shops and mineral sources, Ca2+ is mediated by FimH. Ca2+ is an improvement in global UPEC pathogenesis, including cytokine activation, membrane trafficking and apoptosis [36-39].

The cytokine-signaling gene ex-pressure is upregulated by UPEC-infection in the murine bladder. This can be an ineffective host defensive tactic that allows UPEC to live in the bladder. In addition, some genes involved in biosynthesis LPS (e.g. rfa and rfb) and SurA are affected by the phenotype, which show that the notstimulatory properties of UPEC can be emphasized when alternating in LPS structures [40,41]. the non-pathogenic *E. coli*, that bladder epithel cells are segregated from IL-6 or IL-8 but not mount the same cytokine reaction after UPEC, revealing a dominant removal of inborn immune responses via a partially independent pathway between LPS and TLR4.

Reducing bacterial load and reducing kidney renal damage, demonstrating the significance of these proteins to pathogenesis of the urinary tract infection. In addition, UPEC has shown itself to be a significant phenotype in late neutrophil activity during initiation, growth, or the development of a subsequent reservoir of the UPEC bladder[42,43], in the first instance. The capacity of UPEC to suppress inborn immune responses plays a role in urinary pathogens' continuity.

6. Other infections

Escherichia coli was isolated from 20% of septicemia, and it has also been shown that it may be the cause of infections following surgical interventions. Infants and newborns. Intestinal infections are related to many factors, the most important of which is the presence of fecal contamination in food or water, and infections can be sporadic or appear in outbreaks that often occur in places where health conditions are lacking, and a number of individuals refer to a single source of food or drink. As for urinary infections, they are self-originating from the germs of the patient himself, and they are generally sporadic cases, and are more common in women, and the infection may recur in the same person. Other infections arise from blood infections, meningitis and other accidents and sterile interventions[44,45]

Infections are diagnosed by investigating bacteria, and identifying their offspring in feces, blood, urine, or cerebrospinal fluid, and they must be singled out and their sensitivity to antibiotics studied. Some techniques, such as CT scan, echography, and radioactive isotopes are useful in interpreting results that are difficult to interpret with conventional laboratory methods. Intestinal infections are treated by replacing fluids and electrolytes, and antibiotics are not given except in severe cases, preferably those that are taken orally and have a local effect. As for urinary infections and others, it is necessary to give appropriate antibiotics with good spread in the affected place, according to the results of the transplant, due to the increase in resistant strains by the emergence of a mutation in them, or by their acquisition of external genetic materials[46].

7. Renal bacterial infections

The innate immune system identifies pathogenic agents through its receptors and activates their virulence determinants. However, the bladder increases ureters and kidneys after colonization, as the proinflammatory reaction is delayed or suppressed. There is an irreversible kidney scar at this juncture and bacteria will enter the blood. In response to a defense of first line, reneal cells activate proinflammatory mediators. However, if severe acute or chronic pyelonephritis is reported [47], this can cause serious harm and renal insufficiency. The acute pyelonephritis is the active renal parenchyma and inflammation of the pelvic cord associated with bacterial infection. Clinical symptoms range from a mild to a lifelong disease or death, a severe type of urinary tract infection with acute pyelonephritis [47-49]

Due to complications, the renal function may become chronically scarce and deficient. Pyelocaliceal and renal parenchyma have been identified by chronic pyelonephritis as a damaged inflammatory mechanism[50]. renal parenchymal lesions. Moderate parenchymal lesions in the kidney may result in the final stage. UTIs caused by UPEC that are capable of affecting the long-term renal graying process are the most common infectious complications for patients with renal transplant [51].

Finally, additional studies are needed to identify UPEC renal disappointment and renal allographing degradation. At the same time, an improved understanding of the functions associated with *E. coli* in the kidney will help regulate the immune response of the kidney and help to effectively manage *E. coli*-caused diseases in the kidney. most commonly associated with UTI. UPEC onizing the urinary tract can climb up to the cystitis bladder.

7.1. Cytokine and chemical development of epithel cells of the urinary tract

Inflammation by specific host-pathogen interactions is essential on the basis of cytokine and the chemical production by urinary tract epithelial cells. Organelle adhesives are expressed to allow penetrate tissue. Additionally, UPEC provides a variety of toxins that cause serious tissue damage, promote the spread of bacteria, release host nutrients and impair cells. The recognition of TLR bacterial products allows for the NF-μ-dependent sign-naling route, resulting in NF-ć transplants and pro-inflammatory mediators like expression. epithelial allow additional signaling pathways, NF-SB-independent[52].

Multiple mediators can also in UPEC urothelesis cells. The modified urothel Ca2+ signaling canister be caused adhesine can also suppress proinflammatory NF-μB signaling. These findings indicate that early events in UTI pathogenesis are more complicated, which may raise the risk of recurrent UTIs. The latest new IRF3 signage indicates that IRF3 genetics affects the individual who is susceptible to renal disease and the new method aimed at potential evaluation in this patient population[53].

8. Conclusion

Urinary tract infection-causing *Escherichia coli* (UPEC) is the primary causative agent of most urinary tract infections, including complex cases that can lead to acute renal failure. This article reveals that these bacteria utilize a variety of virulence factors to overcome host defenses and can manipulate immune responses to evade clearance. The ability of UPEC to persist in the urinary tract despite these defenses makes them a reservoir for chronic disease and serious complications. This underscores the urgent need for a deeper understanding of their virulence mechanisms and host response, with the aim of developing more effective preventive and therapeutic strategies.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] F. Yan and D. B. Polk, "Commensal bacteria in the gut: learning who our friends are," Current Opinion in Gastroenterology, vol. 20, no. 6, pp. 565–571, 2004.

[2] J. B. Kaper, J. P. Nataro, and H. L. T. Mobley, "Pathogenic *Escherichia coli*," Nature Reviews Microbiology, vol. 2, no. 2, pp. 123–140, 2004.

[3] T. A. Russo and J. R. Johnson, "Proposal for a new inclusive designation for extraintestinal pathogenic isolates of *Escherichia coli*: ExPEC," Journal of Infectious Diseases, vol. 181, no. 5, pp. 1753–1754, 2000.

[4] T. J. Wiles, R. R. Kulesus, and M. A. Mulvey, "Origins and virulence mechanisms of uropathogenic *Escherichia coli*," Experimental and Molecular Pathology, vol. 85, no. 1, pp. 11– 19, 2008.

[5] L. E. Nicolle, "Urinary tract infection in geriatric and institutionalized patients," Current Opinion in Urology, vol. 12, no. 1, pp. 51–55, 2002.

[6] B. Foxman, "Epidemiology of urinary tract infections: incidence, morbidity, and economic costs," Disease-a-Month, vol. 49, no. 2, pp. 53–70, 2003.

[7] B. W. Trautner, R. A. Hull, and R. O. Darouiche, "*Escherichia coli* 83972 inhibits catheter adherence by a broad spectrum of uropathogens," Urology, vol. 61, no. 5, pp. 1059–1062, 2003.

[8] R. O. Darouiche, W. H. Donovan, M. Del Terzo, J. I. Thornby, D. C. Rudy, and R. A. Hull, "Pilot trial of bacterial interference for preventing urinary tract infection," Urology, vol. 58, no. 3, pp. 339–344, 2001.

[9] R. Hull, D. Rudy, W. Donovan et al., "Urinary tract infection prophylaxis using *Escherichia coli* 83972 in spinal cord injured patients," Journal of Urology, vol. 163, no. 3, pp. 872– 877, 2000.

[10] T. M. Hooton and W. E. Stamm, "Diagnosis and treatment of uncomplicated urinary tract infection," Infectious Disease Clinics of North America, vol. 11, no. 3, pp. 551–581, 1997.

[11] C. Svanborg and G. Godaly, "Bacterial virulence in urinary tract infection," Infectious Disease Clinics of North America, vol. 11, no. 3, pp. 513–529, 1997.

[12] I. Sadler, A. Chiang, T. Kurihara, J. Rothblatt, J. Way, and P. Silver, "A yeast gene important for protein assembly into the endoplasmic reticulum and the nucleus has homology to DnaJ, an *Escherichia coli* heat shock protein," Journal of Cell Biology, vol. 109, no. 6 I, pp. 2665–2675, 1989.

[13] H. L. T. Mobley and J. W. Warren, Urinary Tract Infections: Molecular Pathogenesis and Clinical Management, ASM Press, Washington, DC, USA, 1996.

[14] T. A. Russo, A. Stapleton, S. Wenderoth, T. M. Hooton, and W. E. Stamm, "Chromosomal restriction fragment length polymorphism analysis of *Escherichia coli* strains causing recurrent urinary tract infections in young women," Journal of Infectious Diseases, vol. 172, no. 2, pp. 440–445, 1995.

[15] A. R. Manges, J. R. Johnson, B. Foxman, T. T. O'Bryan,K. E. Fullerton, and L. W. Riley, "Widespread distribution of urinary tract infections caused by a multidrug-resistant *Escherichia coli* clonal group," New England Journal of Medicine, vol. 345, no. 14, pp. 1007–1013, 2001.

[16] M. A. Mulvey, Y. S. Lopez-Boado, C. L. Wilson et al., "Induction and evasion of host defenses by type 1-piliated uropathogenic *Escherichia coli*," Science, vol. 282, no. 5393, pp. 1494–1497, 1998.

[17] J. J. Martinez, M. A. Mulvey, J. D. Schilling, J. S. Pinkner, andS. J. Hultgren, "Type 1 pilus-mediated bacterial invasion of bladder epithelial cells," EMBO Journal, vol. 19, no. 12, pp. 2803–2812, 2000.

[18] B. Kaijser and S. Ahlstedt, "Protective capacity of antibodies against *Escherichia coli* O and K antigens," Infection and Immunity, vol. 17, no. 2, pp. 286–289, 1977.

[19] C. Svanborg Eden, L. A. Hanson, and U. Jodal, "Variable adherence to normal human urinary tract epithelial cells of *Escherichia coli* strains associated with various forms of urinary tract infection," Lancet, vol. 2, no. 7984, pp. 490–492, 1976.

[20] U. Lindberg, L. A. Hanson, and U. Jodal, "Asymptomatic bacteriuria in schoolgirls—II. Differences in *Escherichia coli* causing asymptomatic and symptomatic bacteriuria," Acta Paediatrica Scandinavica, vol. 64, no. 3, pp. 432–436, 1975.

[21] P. Klemm, V. Roos, G. C. Ulett, C. Svanborg, and M. A. Schembri, "Molecular characterization of the *Escherichia coli* asymptomatic bacteriuria strain 83972: the taming of a pathogen," Infection and Immunity, vol. 74, no. 1, pp. 781– 785, 2006.

[22] V. Roos, M. A. Schembri, G. C. Ulett, and P. Klemm, "Asymptomatic bacteriuria *Escherichia coli* strain 83972 carries mutations in the foc locus and is unable to express F1C fimbriae," Microbiology, vol. 152, no. 6, pp. 1799–1806, 2006.

[23] D. Scholes, T. M. Hooton, P. L. Roberts, K. Gupta, A. E. Stapleton, and W. E. Stamm, "Risk factors associated with acute pyelonephritis in healthy women," Annals of Internal Medicine, vol. 142, no. 1, pp. 20–27, 2005.

[24] N. E. Tolkoff-Rubin and R. H. Rubin, "Urinary tract infection in the immunocompromised host. Lessons from kidney transplantation and the AIDS epidemic," Infectious Disease Clinics of North America, vol. 11, no. 3, pp. 707–717, 1997.

[25] D. E. Ramsey, W. T. Finch, and A. G. Birtch, "Urinary tract infections in kidney transplant recipients," Archives of Surgery, vol. 114, no. 9, pp. 1022–1025, 1979.

[26] K. C. Abbott, J. D. Oliver, I. Hypolite et al., "Hospitalizations for bacterial septicemia after renal transplantation in the United States," American Journal of Nephrology, vol. 21, no. 2, pp. 120–127, 2001.

[27] J. C. Rice, T. Peng, Y. F. Kuo et al., "Renal allograft injury is associated with urinary tract infection caused by *Escherichia coli* bearing adherence factors," American Journal of Trans- plantation, vol. 6, no. 10, pp. 2375–2383, 2006.

[28] J. D. Schilling, S. M. Martin, C. S. Hung, R. G. Lorenz, and S.J. Hultgren, "Toll-like receptor 4 on stromal and hematopoi- etic cells mediates innate resistance to uropathogenic *Escherichia coli*," Proceedings of the National Academy of Sciences of the United States of America, vol. 100, no. 7, pp. 4203–4208, 2003.

[29] L. Hang, M. Haraoka, W. W. Agace et al., "Macrophage inflammatory protein-2 is required for neutrophil passage across the epithelial barrier of the infected urinary tract," Journal of Immunology, vol. 162, no. 5, pp. 3037–3044, 1999.

[30] J. M. Bower, D. S. Eto, and M. A. Mulvey, "Covert operations of uropathogenic *Escherichia coli* within the urinary tract," Traffic, vol. 6, no. 1, pp. 18–31, 2005.

[31] M. A. Mulvey, J. D. Schilling, J. J. Martinez, and S. J. Hultgren, "Bad bugs and beleaguered bladders: interplay between uropathogenic *Escherichia coli* and innate host defenses," Proceedings of the National Academy of Sciences of the United States of America, vol. 97, no. 16, pp. 8829–8835, 2000.

[32] T. A. Oelschlaeger, U. Dobrindt, and J. Hacker, "Pathogenic- ity islands of uropathogenic *E. coli* and the evolution of virulence," International Journal of Antimicrobial Agents, vol. 19, no. 6, pp. 517–521, 2002.

[33] L. Emo¨dy, M. Kere´nyi, and G. Nagy, "Virulence factors of uropathogenic *Escherichia coli*," International Journal of Antimicrobial Agents, vol. 22, no. 2, pp. S29–S33, 2003.

[34] M. A. Mulvey, "Adhesion and entry of uropathogenic Escher- ichia coli," Cellular Microbiology, vol. 4, no. 5, pp. 257–271, 2002.

[35] G. Bergsten, B. Wullt, M. A. Schembri, I. Leijonhufvud, and C. Svanborg, "Do type 1 fimbriae promote inflammation in the human urinary tract?" Cellular Microbiology, vol. 9, no. 7, pp. 1766–1781, 2007.

[36] J. A. Snyder, B. J. Haugen, E. L. Buckles et al., "Transcriptome of uropathogenic *Escherichia coli* during urinary tract infec- tion," Infection and Immunity, vol. 72, no. 11, pp. 6373–6381, 2004.

[37] H. Connell, W. Agace, P. Klemm, M. Schembri, S. Ma˚rild, and C. Svanborg, "Type 1 fimbrial expression enhances *Escherichia coli* virulence for the urinary tract," Proceedings of the National Academy of Sciences of the United States of America, vol. 93, no. 18, pp. 9827–9832, 1996.

[38] S. J. Hultgren, T. N. Porter, A. J. Schaeffer, and J. L. Duncan, "Role of type 1 pili and effects of phase variation on lower urinary tract infections produced by *Escherichia coli*," Infection and Immunity, vol. 50, no. 2, pp. 370–377, 1985.

[39] L. Hagberg, I. Engberg, and R. Freter, "Ascending, unobstructed urinary tract infection in mice caused by pyelonephritogenic *Escherichia coli* of human origin," Infection and Immunity, vol. 40, no. 1, pp. 273–283, 1983.

[40] L. Hagberg, U. Jodal, and T. K. Korhonen, "Adhesion, hemagglutination, and virulence of *Escherichia coli* causing urinary tract infections," Infection and Immunity, vol. 31, no. 2, pp. 564–570, 1981.

[41] J. P. Duguid and D. Old, "Adhesive properties of enterobac- teriaceae," in Bacterial Adherence, Receptors and Recognition,

[42] E. Beachey, Ed., pp. 185–217, Chapman & Hall, London, UK, 1980.

[43] K. Plos, H. Lomberg, S. Hull, I. Johansson, and C. Svanborg, "*Escherichia coli* in patients with renal scarring: genotype and phenotype of Galα1-4Galβ-, Forssman- and mannose- specific adhesins," Pediatric Infectious Disease Journal, vol. 10, no. 1, pp. 15–19, 1991.

[44] G. G. Anderson, J. J. Palermo, J. D. Schilling, R. Roth, J. Heuser, and S. J. Hultgren, "Intracellular bacterial biofilm-like pods in urinary tract infections," Science, vol. 301, no. 5629, pp. 105–107, 2003.

[45] T. A. Oelschlaeger, U. Dobrindt, and J. Hacker, "Virulence factors of uropathogens," Current Opinion in Urology, vol. 12, no. 1, pp. 33–38, 2002.

[46] M. A. Schembri and P. Klemm, "Biofilm formation in a hydrodynamic environment by novel FimH variants and ramifications for virulence," Infection and Immunity, vol. 69, no. 3, pp. 1322–1328, 2001.

[47] P. Thumbikat, R. E. Berry, G. Zhou et al., "Bacteria-induced uroplakin signaling mediates bladder response to infection," PLoS Pathogens, vol. 5, no. 5, Article ID e1000415, 2009.