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Analysis of the Pathogen Distribution and Antimicrobial Resistance after Plastic Surgery of the Urogenital System

Fengli Jiang, MM*
Qi Chen, BM†
Yuanyuan Wu, MM*
Jinhao Lin, BM‡
Xueshang Su, MM§
Jun Zhuang, MM§
Sien Zhan, MD*

Background: We aimed to summarize the distribution of pathogenic bacteria for postoperative infection of different genitourinary plastic surgery and the antimicrobial resistance of the major pathogens.
Methods: Between January 2011 and December 2021, following plastic surgery of the urogenital system, microbial strains from infected patients were collected, identified, and counted. The antibiotic sensitivity and distribution characteristics of common pathogens in relation with the surgical procedures were studied by WHONET 5.6, along with the main bacteria accounting for early infection.
Results: A total of 76 cases were included in the study. Among these, 53 Gram-negative bacteria were detected, with *Escherichia coli* (18 of 53) and *Pseudomonas aeruginosa* (nine of 53) accounting for the majority. There were also 23 Gram-positive bacteria, among which *Staphylococcus aureus* (six of 23) and Coagulase-negative *Staphylococcus* (five of 23) were the most common. In terms of antimicrobial resistance, *E. coli* was highly sensitive to amikacin, piperacillin/tazobactam, cefoxitin, and imipenem, whereas *P. aeruginosa* was highly sensitive to gentamicin, amikacin, cefepime, piperacillin/tazobactam, imipenem, ceftazidime, and ciprofloxacin. Procedures for urethral repair, urethral reconstruction, and lump resection were most commonly associated with infection. Among these, urethral repair was responsible for the majority of infections. The pathogenic bacteria involved in postoperative infections varied overall, but the most prevalent was *E. coli*.
Conclusions: Gram-negative bacteria are the major cause of infection following genitourinary plastic surgery. The specific bacterial strains, degrees of antimicrobial resistance, and length of infection varied among the various procedures. The results of this study may provide references for clinical medication and the prevention and control of such infections. *(Plast Reconstr Surg Glob Open 2024; 12:e6165; doi: 10.1097/GOX.0000000000006165; Published online 18 September 2024.)*

INTRODUCTION

As new surgical techniques have developed, the demand for genitourinary surgical procedures has grown. The major common urogenital plastic surgery procedures involved include urethral repair surgery, urethral reconstruction surgery, and lump resection, the aim being to correct the function and appearance of the reproductive organs. Infection is one of the most frequent postoperative complications[1–3] of these procedures, often causing patients both emotional and economic distress. In recent years, owing to the abuse of antibiotics and the emergence of drug-resistant strains, the treatment of infection has become increasingly challenging. Thus, the precise selection of antibiotics is crucial to delay the emergence of drug-resistant strains and strengthen the effects of infection prevention and control. Former related studies mainly presented the efficacy and prognosis of a single surgical procedure,[4,5] with urethral surgery being the most reported, but no description of the pathogens and drug susceptibility of the corresponding infections were shown. Therefore, we

*From the *Department of Medical Laboratory, Plastic Surgery Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China; †Department of Clinical Medicine, Xinjiang Medical University, Xinjiang, China; ‡School of Basic Medicine, Xinjiang Second Medical College, Karamay, China; and §Department of Cosmetic Injection Center, Plastic Surgery Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China.*

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Fengli Jiang and Qi Chen contributed equally to this work.

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collected cases of postoperative infection after urogenital plastic procedures, calculated the drug resistance of common infectious agents, and analyzed the distribution of the bacteria over the years, the distribution of pathogens involved in different urogenital plastic procedures and the time of occurrence of postoperative infection. Our report is as follows.

METHODS

Case Inclusion Criteria

The studied cases comprised infections occurring between 2011 and 2021 after plastic surgery of the urogenital system at the Plastic Surgery Hospital, Chinese Academy Medical Sciences and Peking Union Medical College.

Surgical Procedures

The surgical procedures mainly included urethral repair surgery (hypospadias repair surgery, epispadias repair surgery, urethral anastomosis, urinary fistula repair surgery, and so on), urethral reconstruction surgery (correction of external urethral orifice opening, urethroplasty, and so on), penile reconstruction, vaginal tightening, lump resection (partial resection of penile vascular malformation, keloidal resection, and so on), and other procedures (debridement, removal of penile prosthesis, penile straightening, and so on).

Identification of Microbial Species and Antimicrobial Resistance Test

The selected cases were studied in strict accordance with the Diagnostic Criteria for Nosocomial Infection of the Ministry of Health. All specimens were subjected to routine smear, Gram staining, inoculation culture, isolation, and identification according to the *National Operating Procedures for Clinical Examination* (4th ed.). After the removal of duplicates, a total of 76 strains of bacteria were isolated. The clinical specimens for those strains came mainly from wound secretions and abscess extracts.

Microbial samples were cultured and inoculated using blood and MacConkey Agar (Antu, Zhengzhou). Different types of samples were incubated in the respective Petri dishes and placed in the corresponding incubators for 18–24 hours, as needed, before being removed to observe colony morphology. According to normal microbiologic techniques, the pathogens were detected by API identification strips (bioMérieux, France). Antibiotic susceptibility was tested by the Kirby-Bauer article-flake diffusion method using the susceptibility article produced by the British Oxoid Company. The judgment standard was based on the 2021 Clinical and Laboratory Standards Institute document M100.[6] The 16 antibiotics used in the study included levofloxacin, gentamicin, amikacin, piperacillin/tazobactam, cefepime, imipenem, ceftazidime, ciprofloxacin, ampicillin, cefazolin, cefuroxime, cefoxitin, cefotaxime, cotrimoxazole, tetracycline, and aztreonam.

Takeaways

Question: Our study mainly focused on the distribution of pathogenic bacteria and antimicrobial resistance after plastic surgery of the urogenital system.

Findings: In this study, we included 76 cases of urogenital system surgery and found that the infectious strains that appeared after plastic surgery of the urogenital system were mainly Gram-negative bacteria. We summarized the distribution of these strains, their sensitivities to common antibiotics, the types of bacteria common to different surgical procedures, and the differences in early infection pathogens of genitourinary plastic surgery.

Meaning: The results shown should help clinicians prevent and control infection after different plastic surgery procedures for urogenital system.

Statistical Analysis

Microsoft Excel 2016 was used to input and process the data, and the percentages were then calculated. The categorical data were represented using frequencies and percentages. WHONET 5.6 and SPSS 22.0 software was used for data analysis. The detection rate of pathogenic bacteria was analyzed by trend chi-square tests. P values of less than 0.05 were considered statistically significant.

RESULTS

The Overall Distribution of Pathogens

From January 2011 to December 2021, a total of 76 strains of pathogenic bacteria were detected. Of these, 53 strains were Gram-negative. *Escherichia coli* and *Pseudomonas aeruginosa* represented the majority and accounted for 35.6% of all pathogenic bacteria. A total of 23 strains were Gram-positive, including six strains of *Staphylococcus aureus*, five strains of coagulase-negative *Staphylococcus* (*CoNS*), four strains of enterococci, and three strains of streptococci, as shown in Table 1. From 2011 to 2021, the proportion of *S. aureus, Acinetobacter baumannii,* and *Klebsiella pneumoniae* and other pathogenic bacteria represented an increasing trend ($P < 0.05$), whereas *Streptococcus, Enterococci* and *P. aeruginosa* represented declining trends ($P < 0.05$). *CoNS*, *E. coli*, and the overall pathogens reflected no obvious trend ($P > 0.05$).

Antimicrobial Susceptibility of *E. coli* and *P. aeruginosa* to Common Antibiotics

According to the drug sensitivity results for *E. coli* and *P. aeruginosa* (Table 2), *E. coli* was highly sensitive to amikacin, piperacillin/tazobactam, cefoxitin, and imipenem, whereas *P. aeruginosa* was highly sensitive to gentamicin, amikacin, cefepime, piperacillin/tazobactam, imipenem, ceftazidime, and ciprofloxacin. Both were highly sensitive to amikacin, imipenem, piperacillin/tazobactam. No strains resistant to piperacillin/tazobactam were found. The sensitivity of *P. aeruginosa* to gentamicin, amikacin, and cefepime was 100%. The resistance of *E. coli* to levofloxacin, gentamicin, and cefepime was much higher than that of *P. aeruginosa*, as shown in Table 2.

Table 1. Distribution of Pathogenic Bacteria Isolated after Genitourinary Plastic Surgery (%)

Species	*S. aureus*	*CoNS*	*Streptococcus*	*Enterococci*	*E.coli*	*E.cloacae*	*P. aeruginosa*	*A. baumanii*	*K. pneumoniae*	Other Pathogenic Bacteria	Total
2011	0 (0.0)	0 (0.0)	1 (25.0)	2 (50.0)	0 (0.0)	1 (25.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (5.3)
2012	1 (14.3)	1 (14.3)	1 (14.3)	0 (0.0)	1 (14.3)	0 (0.0)	2 (28.6)	0 (0.0)	0 (0.0)	1 (14.3)	7 (9.2)
2013	2 (18.2)	1 (9.1)	1 (9.1)	0 (0.0)	5 (45.5)	0 (0.0)	1 (9.1)	0 (0.0)	0 (0.0)	1 (9.1)	11 (14.5)
2014	1 (10.0)	2 (20.0)	0 (0.0)	0 (0.0)	2 (20.0)	1 (10.0)	2 (20.0)	0 (0.0)	0 (0.0)	2 (20.0)	10 (13.2)
2015	0 (0.0)	0 (0.0)	0 (0.0)	1 (6.7)	2 (13.3)	2 (13.3)	2 (13.3)	0 (0.0)	0 (0.0)	8 (53.3)	15 (19.7)
2016	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (100.0)	2 (2.6)
2017	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	5 (62.5)	0 (0.0)	1 (12.5)	0 (0.0)	0 (0.0)	2 (25.0)	8 (10.5)
2018	1 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (33.3)	0 (0.0)	1 (33.3)	3 (3.9)
2019	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (25.0)	1 (12.5)	1 (12.5)	1 (12.5)	2 (25.0)	1 (12.5)	8 (10.5)
2020	1 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (66.7)	3 (3.9)
2021	0 (0.0)	1 (20.0)	0 (0.0)	1 (20.0)	1 (20.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (40.0)	5 (6.6)
Total	6 (7.9)	5 (6.6)	3 (3.9)	4 (5.3)	18 (23.7)	5 (6.6)	9 (11.8)	2 (2.6)	2 (2.6)	22 (28.9)	76 (100.0)
χ^2	4.743	0.890	94.160	34.390	0.045	24.625	23.555	24.932	23.002	71.705	2.604
P	0.029	0.346	<0.001	<0.001	0.831	<0.001	<0.001	<0.001	<0.001	<0.001	0.107

Table 2. *Sensitivity and Resistance to Common Antibiotics of E. coli* and *P. aeruginosa*

	E. coli		*P. aeruginosa*	
Antibiotics	**Sensitivity**	**Resistance**	**Sensitivity**	**Resistance**
Levofloxacin	38.9%	61.1%	77.8%	22.2%
Gentamicin	47.1%	47.1%	100%	0
Amikacin	82.4%	11.8%	100%	0
Piperacillin/tazobactam	100%	0	87.5%	0
Cefepime	57.1%	35.7%	100%	0
Imipenem	100%	0	87.5%	12.5%
Ceftazidime	66.7%	27.8%	87.5%	12.5%
Ciprofloxacin	47.1%	47.1%	87.5%	0
Ampicillin	11.1%	88.9%	—	—
Cefazolin	11.1%	88.9%	—	—
Cefuroxime	17.6%	82.4%	—	—
Cefoxitin	93.8%	6.2%	—	—
Cefotaxime	22.2%	77.8%	—	—
Cotrimoxazole	58.8%	41.2%	—	—
Tetracycline	50.0%	50.0%	—	—
Aztreonam	50.0%	43.8%	50.0%	25.0%

Distribution of Pathogenic Bacteria in Various Types of Surgical Procedures

Only 59 of the 76 cases in our study included clear surgical records. The latter comprised 21 urethral repairs, seven urethral reconstructions, seven penile reconstructions, two vaginal tightenings, 10 lump resections, and 12 miscellaneous procedures. The total number for patients undergoing urogenital plastic procedures was 4396 in the same period. The urethral repairs and lump resection were the surgery with the most cases of infection. After mass resection, *S. aureus* was the most common infective agent. *E. coli* was the main infective agent in all of the other surgical procedures. No *S. aureus* or *CoNS* infections occurred in patients undergoing urethral reconstruction or vaginal tightening. The main infective agents following urethral repair surgery were *E. coli*, *Streptococcus*, and *Enterococcus*, whereas that following urethral reconstruction was *E. coli* alone, as shown in Table 3.

Time of Occurrence of Postoperative Infection

The number of available cases with clear records was 40; of these, 32 developed infection within 15 days of surgery, with a probability of 80%, and 10 developed late infection. The 32 cases of early infection included 14 urethral repairs, six urethral reconstructions, six lump resections, two penile reconstructions, two vaginal tightenings, and two other procedures. The probability of early postoperative infection after urethral repair, urethral reconstruction, vaginal tightening, and lump resection was greater than 50%. *E. coli* was the major agent causing early infection following urethral repair, urethral reconstruction, penile reconstruction, and vaginal tightening. The predominant agents causing early infection after penile reconstruction and vaginal tightening were *E. coli* and *Enterobacter cloacae*, whereas the infective agent following lump resection was *S. aureus*, as shown in Table 4.

Table 3. The Distribution of the Bacteria Involved in Postoperative Infection of Urogenital Plastic Procedures

	S. aureus	*CoNS*	*E. coli*	*P. aeruginosa*	*E. cloacae*	*Streptococcus*	*Enterococcus*	*K. pneumoniae*	*A. Baumannii*	Other Pathogenic Bacteria	No. Cases
Urethral repair	4.8%	9.5%	14.3%	4.8%	9.5%	14.3%	14.3%	4.8%	4.8%	19.0%	21
Urethral reconstruction	0%	0%	42.9%	0%	0%	0%	0%	0%	0%	57.1%	7
Penile reconstruction	14.3%	0	42.9%	0	14.3%	0	14.3%	14.3%	0%	0%	7
Vaginal tightening	0%	0%	50.0%	0%	50.0%	0%	0%	0%	0%	0%	2
Lump resection	40.0%	0%	30.0%	10.0%	10.0%	0%	0%	0%	0%	10.0%	10
Other procedures	0%	8.3%	25.0%	16.7%	0%	0%	0%	0%	0%	50.0%	12

Table 4. Number of Surgical Procedures Followed by Early Infection and Species Causing Early Infection

	Cases of Early Infection	Species
Urethral repair	14	*E. coli*
Urethral reconstruction	6	*E. coli*
Penile reconstruction	2	*E. coli, E. cloacae*
Vaginal tightening	2	*E. coli, E. cloacae*
Lump resection	6	*S. aureus*
Other procedures	2	*P. aeruginosa, E. cloacae*

DISCUSSION

The normal appearance and function of the genitourinary tract is essential to the individual's physical wellness and mental health. It also has a significant impact on their social interactions and quality of life. With economic prosperity, people's expectations in terms of personal appearance are growing, and the demand for various types of plastic surgery is growing as well. In the field of genitourinary plastic surgery, patients' main complaints generally involve congenital malformations and acquired defects. Although congenital malformations are relatively common, there are also many acquired defects due to diseases or accidents.[7,8] Therefore, genitourinary plastic surgery has gradually been receiving greater attention. Infection, which is a common complication of such surgery, affects the surgical result and the patient's prognosis. Therefore, a profound understanding of the causes of infection, the distribution of pathogenic bacteria, and their susceptibility to antibiotics is vitally important, helping to guide drug use and to prevent and control infection.

Our study shows that a total of 76 strains of pathogenic bacteria were isolated after plastic surgery of the urogenital system; 53 strains of Gram-negative bacteria accounted for 69.7% of these. Among the latter, *E. coli* and *P. aeruginosa* were the most prominent; 23 strains were Gram-positive bacteria, comprising mainly *S. aureus*. In the research of Zhao et al, infections of the scrotum and penis were mainly associated with *P. aeruginosa* and *E. cloacae*.[9] Yang et al proposed that *E. coli, K. pneumoniae*, and *P. aeruginosa* were the most prominent Gram-negative bacteria for urinary tract infections.[10] Our study collected statistics on the distribution of pathogens in the urogenital system, including the penis, perineum, and urethra. The results differed from the distribution of pathogens in a single site, but there were still many aspects in common. For instance, *E. coli* was always included as the major pathogen. Another study found that the main pathogens in male and female urinary tract infections were Gram-negative bacilli, which arise from airborne pathogens contaminating instruments and retrograde infection due to perineal surface pathogens.[11] Thus, the fact that *E. coli* was the major Gram-negative bacterium in postoperative urethral infections may be explained by two observations: (1) pathogenic bacteria in the perineal area enter the urethra and cause retrograde infection and (2) airborne pathogens may contaminate instruments.

We found that *E. coli* was highly sensitive to amikacin, piperacillin/tazobactam, cefoxitin, and imipenem, whereas *P. aeruginosa* was highly sensitive to gentamicin, amikacin, cefepime, piperacillin/tazobactam, imipenem, ceftazidime, and ciprofloxacin. Both were highly sensitive to amikacin, imipenem, and piperacillin/tazobactam. The findings of a study on urinary tract infection with a sample size of 4332[10] were highly consistent with those of our study, particularly regarding the drugs used against *P. aeruginosa*. The study by Guan et al showed that their isolated Gram-negative bacteria had little resistance to amikacin, which was consistent with the results of our study (82.4% sensitivity of *E. coli* to amikacin and 100% sensitivity of *P. aeruginosa* to amikacin).[12] Zhao et al found through a network comprehensive analysis that *E. coli* in urinary tract infection was highly resistant to ampicillin, tetracycline, and cefotaxime,[13] similar to the resistance rate of *E. coli* to ampicillin and cefotaxime in our study. In summary, the main findings of our study have many similarities with those of previous studies on pathogens' resistance to common drugs; therefore, this study provides a reference for the empiric prescriptions of antimicrobials following genitourinary plastic surgery.

Most procedures in our study involved the urethra, and Yan et al have suggested that quinolones could be applied to the treatment of uncomplicated urinary tract infections.[14] Additionally, we found no carbapenem-resistant strains; therefore, carbapenems can be used to treat severe infections after genitourinary plastic surgery. Experts have also suggested treatment with imipenem/relebactam in China, especially for isolates that are not susceptible to carbapenems.[15]

As previously mentioned, we found that genitourinary plastic surgery is often followed by infection within 15 days after surgery, and *E. coli* is the major early infectious agent. It is speculated that this was related to the application of catheters and other contaminated hospital equipment during surgery. It has been reported that the formation of biofilm on catheters reduces the microorganisms' sensitivity to antibiotics and leads to microbial resistance, resulting in high rates of infection.[16] Relevant studies have indicated that by infusing the catheter with nitrofurazone and eluting an antiinfective agent into its lumen, infection due to Gram-negative organisms can be reduced. Furthermore, a novel silver-hydrogel-coated catheter can be used to reduce infection due to Gram-positive cocci.[11] Infection may also be related to the various techniques utilized by different surgeons as well as the different physiques and living habits of patients. Thus, clinicians are supposed to place more emphasis on the surgical technique, postoperative care, and the type and dosage of medication.

Two of our patients underwent vaginal tightening in this study, and both developed early infection (100%) after surgery. Because this is a very small sample, the results may be biased, but it also suggests a high possibility of early infection after this particular procedure. Therefore, infection prevention and control should be maximized in such cases and optimal treatment plans formulated with an eye to minimizing infection.

This study has limitations. It was a retrospective study, not a controlled one. The number of cases of infection associated with some urogenital plastic procedures were limited. Despite these drawbacks, the study has certain clinical significance. Earlier studies showed mainly the efficacy and prognosis of a single surgical procedure, without listing and comparing the distribution of pathogens and the early infection with different major bacteria on the dimension of the various plastic surgical procedures related to the urogenital system. Our team's future direction is analyzing the possible correlation factor of the infection and the bacteria after plastic surgery of the urogenital system.

CONCLUSIONS

We have summarized the distribution of infectious strains after genitourinary plastic surgery, reviewed the drug sensitivity of common pathogenic bacteria, and considered patients' prognoses regarding infectious complications. Thus, our results should benefit the targeted selection of antibiotics, contribute to the development of infection prevention and control measures, and help to slow the emergence of drug-resistant strains.

Sien Zhan, MD
Department of Medical Laboratory, Plastic Surgery Hospital
Chinese Academy of Medical Sciences and Peking Union Medical College
33 Badachu Road, Shijingshan District
Beijing, China
E-mail: zhansien81@163.com

DISCLOSURES

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