Bacterial and Antibiotic Sensitivity Patterns in Patient Urine after Percutaneous Nephrostomy

Steven, Ferry Safriadi
Department of Urology Faculty of Medicine Universitas Padjadjaran
Dr. Hasan Sadikin General Hospital Bandung, Indonesia

Abstract

Percutaneous nephrostomy (PN) is a urine diversion procedure using a tube, stent, or catheter. Knowledge of bacterial sensitivity to antibiotics can guide the establishment of an appropriate and safe treatment to reduce the incidence of percutaneous nephrostomy-related infection (PNCI). The purpose of this study was to determine the suitability of antibiotics medication based on the results of bacterial culture and bacterial sensitivity test. This study was a retrospective descriptive observational study on medical records of patient diagnosed with obstructive uropathy who underwent PN in the period January 2017 to December 2019. A total of 20 bacterial isolates were classified as gram-positive bacteria isolates (16.5%) and 101 isolates presented gram-negative bacteria (83.5%). The most frequent gram-negative bacteria identified in these isolates were \textit{E. coli} (n=42), \textit{Pseudomonas aeruginosa} (n=22), and \textit{Klebsiella pneumoniae} (n=20). Meanwhile, \textit{Staphylococcus aureus} was seen in ten isolates with gram-positive bacteria. Vancomycin antibiotics had the best sensitivity to gram-positive bacteria based on the antibiotic sensitivity tests. On the other hand, meropenem and amikacin had the best sensitivity to gram-negative bacteria (83.2%). This study showed that the most common bacteria identified from nephrostomy patients is \textit{E. coli} with meropenem and amikacin as the most sensitive antibiotic for these patients. Thus, antibiotic therapy before and after PN procedure should be considered wisely to prevent resistant PNCI.

Keywords: Antibiotic, bacterial, percutaneous nephrostomy, sensitivity

Pola Sensitivitas Bakteri dan Antibiotik pada Urin Pasien Setelah Nefrostomi Perkutan

Abstrak

Nefrostomi Perkutan (PN) adalah prosedur pengalihan urin menggunakan selang, stent, atau kateter. Mengetahui sensitivitas bakteri terhadap antibiotik dapat memandu untuk menetapkan pengobatan yang tepat dan aman untuk mengurangi kejadian infeksi terkait nefrostomi perkutan (PNCI). Penelitian ini bertujuan menentukan kesesuaian pengobatan antibiotik berdasar atas hasil kultur dan sensitivitas bakteri. Jenis penelitian observasional deskriptif. Penelitian ini meninjau secara retrospektif rekam medis pasien yang didiagnosis uropati obstruktif yang menjalani PN pada periode Januari 2017 hingga Desember 2019. Sebanyak 20 isolat bakteri tergolong bakteri gram positif (16,5%) dan 101 isolat bakteri gram negatif (83,5%). Isolat bakteri terbanyak adalah \textit{E. coli} dengan 42 isolat, 22 isolat \textit{Pseudomonas aeruginosa}, dan 20 isolat \textit{Klebsiella pneumoniae} untuk bakteri gram negatif. Sepuluh isolat bakteri gram positif adalah \textit{Staphylococcus aureus}. Antibiotik vankomisin memiliki sensitivitas terbaik terhadap bakteri gram positif berdasar atas uji sensitivitas antibiotik. Sedangkan antibiotik meropenem dan amikasin memiliki sensitivitas paling baik terhadap bakteri gram negatif sebanyak 83,2%. Penelitian ini menunjukkan bahwa bakteri yang paling banyak ditemukan pada urine pasien pasca PN adalah \textit{E. coli} dengan meropenem dan amikacin adalah antibiotik paling sensitif. Walau demikian, terapi antibiotik pada pasien sebelum dan sesudah prosedur PN memerlukan pertimbangan bijak untuk mencegah resistensi PNCI.

Kata kunci: Antibiotik, bakterial, nefrostomi perkutan, sensitivitas

Corresponding Author: Steven, Department of Urology Faculty of Medicine Universitas Padjadjaran/Dr. Hasan Sadikin General Hospital Bandung, Jalan Pasteur No 38 Bandung, Indonesia, Email: steven14002@mail.unpad.ac.id
**Introduction**

Nephrostomy is a urine diversion procedure using a tube, stent, or catheter. The instrument used will be inserted through the skin incision, into the renal parenchyma and end in the renal pelvis or calix. Nephrostomy is performed in patients with acute urinary obstruction that occurs in the upper urinary system. Currently, there are two types of nephrostomy techniques used, namely percutaneous nephrostomy and open nephrostomy. Open nephrostomy was done by inserting a catheter tube into the pyelum through the renal pelvis. Percutaneous nephrostomy involves the insertion of a tube through the skin into the renal pelvis using ultrasonography (USG) or fluoroscopy. The target goal of percutaneous nephrostomy is urinary diversion in obstructive conditions and to prevent acute renal impairment, especially in patients with malignancy around the urinary tract.

Nephrostomy is a relatively safe and effective technique. Although relatively safe, but just like all other invasive procedures, it has potential complications. Bacteriuria is an almost inevitable consequence of percutaneous nephrostomy, such as pyelonephritis which, if left untreated, can lead to urosepsis. The occurrence of infection or percutaneous nephrostomy related infection (PCNI) is often predisposed by the decreasing of body's immune system in patients with malignancy or in systemic treatment. Urinary tract infections (UTIs) are closely related to urological procedures, included nephrostomy. Several studies have found an incidence of UTI up to 20%, infection associated with percutaneous nephrostomy up to 19% and sepsis 1.3 to 1.8%.

The occurrence of infection is influenced by the presence of bacterial virulence factors and host defense. Germ virulence is strongly influenced by the type of germ and the environment for colonization, adhesion and invasion. One of the things that must be kept in mind is the host defense mechanisms such as hydrodynamic factors, dilution, washing and elimination of germs that pass with urine. The response to broad-spectrum antibiotics depends on the pattern of resistance and effectiveness of these antibiotics. Knowing the bacterial sensitivity to antibiotics can guide to provide an appropriate and safe treatment to reduce the incidence of infectious diseases. The use of antibiotics that are not in accordance with existing resistance patterns can lead to bacterial resistance to antibiotic. One of the principles behind the emergence and spread of resistance between bacteria is the prevalence of resistance which is directly proportional to the number of antibiotics used in various treatments. This was illustrated by the increasing in antibiotic resistance in some countries that do not limit the use of antibiotics. Although the emergence of antibiotic resistance is not a new problem, due to the influence of various factors it causes bacterial resistance to antibiotics to become a complex health problem. The number of resistant bacteria is increasing rapidly, and some pathogenic bacteria have resistance to some antibiotics, even resistant to all antibiotics. Some bacteria that have become resistant to first-line antibiotics require more expensive second or third line antibiotics. Many factors influence the emergence of antibiotic-resistant bacteria. The important factors are the use of antibiotics and infection control. Therefore, the use of antibiotics wisely is very important in addition to implementing good infection control to prevent the development of these resistant bacteria into the community.

Therefore, this study was aimed to determine the suitability of antibiotics based on the results of culture and bacterial sensitivity. The researchers intend to examine the description of bacterial patterns and antibiotic sensitivity tested on urine cultures of patients who have undergone percutaneous nephrostomy at Hasan Sadikin Hospital Bandung in the last 3 years.

**Methods**

This study used a retrospective descriptive observational design. The data was taken from the medical record installation of Hasan Sadikin Bandung general hospital as well as specialized status from the Urology department of Hasan Sadikin Bandung general hospital. The data were taken from patients diagnosed with obstructive uropathy who underwent percutaneous nephrostomy in the period January 2017 to December 2019. Then data were recapitulated including age, gender, diagnosis, culture result data, and bacterial sensitivity test to antibiotics according to the inclusion criteria. To avoid sample BIAS, the urine sample was all taken from nephrostomy production as the urine pass down to urethral could be colonized with different bacteria along the urinary tract than from nephrostomy alone.

The inclusion criteria were including patients diagnosed with obstructive uropathy
who underwent percutaneous nephrostomy at the Urology Department of Hasan Sadikin Hospital Bandung general hospital from January 2017 to December 2019; the availability of laboratory data, including the results of bacterial culture tests, bacterial sensitivity tests, and antibiotic resistance test results of bacteria found in the culture; the availability of complete demographic data in medical records which includes medical record number, patient name, patient age, patient gender, and medical history. The exclusion criteria were patients who have been diagnosed with urinary tract infections including pyonephrosis prior to percutaneous nephrostomy at the Urology Department of Hasan Sadikin Hospital Bandung. The ethical clearance for this study was not required.

Result

A total of 121 patients from January 2017 to December 2019 underwent percutaneous nephrostomy and had their culture and bacterial resistance tested after the nephrostomy. Based on the facts, the age of patients who underwent percutaneous nephrostomy at RSHS was 52.80 ± 14.541 years with the range of 1 to 85 years. Most of the subjects who underwent percutaneous nephrostomy were patients with enlarged kidneys due to the obstruction by urinary tract stones as much as 28.7%, 12.3% due to cervical cancer and 16.4% due to bladder cancer. The remainders are due to chronic obstruction due to prostate disorders, urethral strictures and other conditions causing urinary tract obstruction.

The general characteristic of the subject in this research was shown in Table 1.

From 122 research subjects, 121 bacterial isolates were obtained. The isolation characteristics of bacteria from urine culture in this study are shown in Table 2.

Table 2 shows the isolation characteristics of bacteria from the urine samples of the subjects. A total of 20 bacterial isolates were classified as gram-positive bacteria (16.5%) and 101 isolates were gram-negative bacteria (83.5%). The most bacterial isolates were E. coli with 42 isolates, 22 isolates of Pseudomonas aeruginosa and 20 isolates of Klebsiella pneumoniae for gram-

---

**Table 1 Subject Characteristic**

| Variable                  | (n=121) (%) |
|---------------------------|-------------|
| Age (years)               |             |
| Average ± Standard deviation | 52.80±14.541|
| Median                    | 54          |
| Gender n (%)              |             |
| Male                      | 65 (53.3%)  |
| Female                    | 57 (46.7%)  |
| Comorbidity n (%)         |             |
| Cervical cancer           | 15 (12.3%)  |
| Urolithiasis              | 35 (28.7%)  |
| Bladder cancer            | 20 (16.4%)  |
| Prostate disorder         | 3 (2.5%)    |
| Urethral strictures       | 3 (2.5%)    |
| Others                    | 46 (37.7%)  |

**Table 2 Bacterial Isolation Characteristic of Urine Sample**

| Bacteria                     | Gram  | (N=121) (%) |
|------------------------------|-------|-------------|
| Enterococcus faecalis        | Positive | 2 (10%) |
| Streptococcus agalactiae     | 2 (10%) |
| Streptococcus dysgalactiae   | 2 (10%) |
| Staphylococcus epidermidis   | 4 (20%) |
| Staphylococcus aureus        | 10 (50%) |
| Acinetobacter baumanii       | 2 (20%) |
| Escherichia coli             | 42 (41.6%) |
| Klebsiella pneumoniae        | 20 (19.8%) |
| Morganella spp               | 6 (5.9%) |
| Proteus mirabilis            | 2 (5.9%) |
| Providencia struartii        | 2 (2%) |
| Pseudomonas aeruginosa       | 22 (21.8%) |
| Salmonella spp               | 5 (5%) |
Table 3 Sensitivity Pattern of Gram-Positive Bacteria to Antimicrobials

| Antibiotic       | Enterococcus faecalis n=2 | Staphylococcus aureus n=10 | Staphylococcus epidermidis n=4 | Streptococcus agalactiae n=2 | Streptococcus dysgalactiae n=2 | Total n=20 |
|------------------|---------------------------|-----------------------------|-------------------------------|-----------------------------|-------------------------------|------------|
| Vancomycin (VAN) | 2 (100%)                  | 10 (100%)                   | 4 (100%)                      | 2 (100%)                    | 2 (100%)                      | 20 (100%)  |
| Ceftriaxone (CRO)| 10 (100%)                 | 10 (100%)                   | 4 (100%)                      | 2 (100%)                    | 2 (100%)                      | 18 (90%)   |
| Cefoperazone (CFP)| 10 (100%)                | 10 (100%)                   | 4 (100%)                      | 2 (100%)                    | 2 (100%)                      | 18 (90%)   |
| Clindamycin (CLI)| 0 (0%)                    | 10 (100%)                   | 4 (100%)                      | 2 (100%)                    | 2 (100%)                      | 18 (90%)   |
| Erythromycin (ERY)| 0 (0%)                  | 10 (100%)                   | 4 (100%)                      | 2 (100%)                    | 2 (100%)                      | 18 (90%)   |
| Meropenem (MEM)  | 0 (0%)                    | 10 (100%)                   | 4 (100%)                      | 2 (100%)                    | 2 (100%)                      | 18 (90%)   |
| Amoxiclav (AMC)  | 2 (100%)                  | 10 (100%)                   | 4 (100%)                      | 0 (0%)                      | 0 (0%)                        | 16 (80%)   |
| Ampicillin (AMP) | 2 (100%)                  | 10 (100%)                   | 4 (100%)                      | 0 (0%)                      | 0 (0%)                        | 14 (70%)   |
| Cefotaxime (CTX) | 10 (100%)                 | 10 (100%)                   | 4 (100%)                      | 0 (0%)                      | 0 (0%)                        | 14 (70%)   |
| Ceftazidime (CAZ)| 10 (100%)                 | 10 (100%)                   | 4 (100%)                      | 0 (0%)                      | 0 (0%)                        | 14 (70%)   |
| Ciprofloxacin (CIP)| 8 (80%)                 | 8 (80%)                      | 0 (0%)                        | 0 (0%)                      | 0 (0%)                        | 8 (40%)    |
| Levofoxacine (LVX)| 8 (80%)                   | 8 (80%)                      | 0 (0%)                        | 0 (0%)                      | 0 (0%)                        | 8 (40%)    |
| Amikacin (AMK)   | 0 (0%)                    | 0 (0%)                      | 2 (100%)                      | 2 (100%)                    | 4 (20%)                       | 0 (0%)     |
| Gentamicin (GEN) | 0 (0%)                    | 0 (0%)                      | 0 (0%)                        | 0 (0%)                      | 0 (0%)                        | 0 (0%)     |
### Table 4: Sensitivity Pattern of Gram-Negative Bacteria to Antimicrobials

| Antibiotic | Acinetobacter baumannii n=2 | Escherichia coli n=42 | Klebsiella pneumoniae n=20 | Morganella spp n=6 | Proteus mirabilis n=2 | Providencia stuartii n=2 | Pseudomonas aeruginosa n=22 | Salmonella spp n=5 | Total n=101 |
|------------|-----------------------------|-----------------------|---------------------------|-------------------|----------------------|------------------------|---------------------------|----------------|-------------|
| MEM        | 0 (0%)                      | 38 (90.5%)            | 18 (90%)                  | 6 (100%)          | 2 (100%)             | 0 (0%)                 | 15 (68.1%)                | 5 (100%)        | 84 (83.2%)  |
| AMK        | 0 (0%)                      | 37 (88.1%)            | 18 (90%)                  | 6 (100%)          | 2 (100%)             | 0 (0%)                 | 18 (81.8%)                | 0 (0%)          | 83 (82.2%)  |
| GEN        | 0 (0%)                      | 33 (78.6%)            | 9 (45%)                   | 0 (0%)            | 2 (100%)             | 0 (0%)                 | 16 (72.7%)                | 0 (0%)          | 60 (59.4%)  |
| CAZ        | 0 (0%)                      | 24 (57.1%)            | 5 (25%)                   | 2 (33.3%)         | 0 (0%)               | 0 (0%)                 | 14 (63.6%)                | 5 (100%)        | 50 (49.5%)  |
| CRO        | 0 (0%)                      | 32 (76.1%)            | 5 (25%)                   | 0 (0%)            | 2 (100%)             | 0 (0%)                 | 16 (72.7%)                | 0 (0%)          | 41 (40.6%)  |
| SXT        | 2 (100%)                    | 19 (45.2%)            | 9 (45%)                   | 0 (0%)            | 0 (0%)               | 2 (100%)               | 0 (0%)                   | 5 (100%)        | 37 (36.6%)  |
| AMP        | 2 (100%)                    | 16 (38.1%)            | 3 (15%)                   | 0 (0%)            | 2 (100%)             | 0 (0%)                 | 0 (0%)                   | 5 (100%)        | 28 (27.7%)  |
| CTX        | 16 (38.1%)                  | 16 (38.1%)            | 3 (15%)                   | 2 (33.3%)         | 2 (100%)             | 0 (0%)                 | 0 (0%)                   | 2 (40%)         | 25 (23.8%)  |
| CIP        | 0 (0%)                      | 7 (16.8%)             | 5 (25%)                   | 0 (0%)            | 0 (0%)               | 0 (0%)                 | 8 (36.4%)                 | 0 (0%)          | 20 (19.8%)  |
negative bacteria. Ten isolates for gram-positive bacteria were *Staphylococcus aureus*. The least bacterial isolates were *Salmonella spp*, which was only 5 isolates from all isolates of gram-negative bacteria.

The number of sensitivity test results for gram-positive and gram-negative bacteria isolates to antibiotics could be seen in tables 3 and 4. Based on table 3, it was revealed that vancomycin antibiotics have the best sensitivity to gram-positive bacteria based on antibiotic sensitivity tests to bacteria from urine culture of patients who underwent nephrostomy. Other antibiotics such as ceftriaxone, cefoperasone, clindamycin, erythromycin, and Meropenem appeared to have good sensitivity in urine culture isolates of patients who have undergone percutaneous nephrostomy. Ciprofloxacin and levofloxacin have 40% susceptibility to gram-positive bacteria in urine culture, whereas amikacin and gentamicin have 20% and 0% susceptibility to gram-positive bacteria found in urine cultures of patients who have undergone percutaneous nephrostomy, respectively.

On culture and antibiotic sensitivity to gram-negative bacteria examination, as seen in table 4, shown that meropenem and amikacin antibiotics have the best sensitivity to gram-negative bacteria as much as 83.2%. Gentamicin and ceftazidime had a fairly good sensitivity, reaching 59.4% and 49.5%, respectively. The antibiotic that was least sensitive to gram-negative bacteria was ceftriaxocin, which was only 19.8% sensitive to gram-negative bacteria based on the results of the urine culture of patients who had percutaneous nephrostomy.

**Discussion**

Nephrostomy is a procedure that is often performed as a diversion option in various urological cases such as malignancy or ureteral obstruction. Percutaneous nephrostomy is a primary diversion method as a preventive measure for renal failure in high-risk patients, especially cancer patients.1 In this study, percutaneous nephrostomy was mostly performed in patients with obstruction due to urinary tract stones, followed by blockages due to malignancies such as cervical cancer and bladder cancer patients. This is in line with the most indications for percutaneous nephrostomy in patients with obstructing urinary tract stones and cases of malignancy.2

A systematic review conducted by Batura and Rao outlined some of the benefits of performing urine culture for nephrostomy. Most studies mention the use of urine culture to assist the selection of antibiotics for empiric therapy in sepsis.10 Research by Watson et al. mentioned that there were differences in bacteria found in kidneys urine cultures which was obtained through the nephrostomy tube compared to those taken from the bladder. In the urine collected directly by nephrostomy, 116 (36.8%) additional pathogens were found which allowed for the addition of the type of antibiotic that needed to be given to the patient.11

One of the complications that might be found in nephrostomy is the occurrence of infections such as pyelonephritis, which was a risk for urosepsis. Several studies have shown that the incidence of urinary tract infections is up to 20% and the incidence of PCNI as high as 19%.1 Infectious complications often occur related to the patient’s immune condition. In patients with impaired immunity, especially in patients with malignancy and patients on systemic treatment.12 The incidence of PCNI increases within the period of intervening nephrostomy placement for up to 90 days, which is the mean time to replace the conduit due to intraluminal obstruction and encrustation by debris.13

Percutaneous nephrostomy related infection (PCNI) was found in 14% cases of chronic obstruction.3 A study by Dienstmann et al. reported 20% incidence of urinary tract infection in cervical cancer patients undergoing nephrostomy.4 Another study by Bahu et al. examined the risk of PCNI in cancer patients. It was found that pyelonephritis occurred within 3 months and nearly 1 in 5 cancer patients who underwent nephrostomy.3 Research by Maramara et al. stated that out of 71 patients with pyelonephritis, 17 of them were asymptomatic.14

Percutaneous nephrostomy related infection (PCNI) is a risk of complications that often occurs in patients undergoing nephrostomy procedures. In this study, most of the bacteria found in the urine culture of patients undergoing nephrostomy were classified as gram-negative bacteria, namely *E. coli* and *Pseudomonas spp*. This finding is in line with research by Maramara et al., which found that in pyelonephritis conditions, *Pseudomonas aeruginosa* and *Enterococcus faecalis* were the most bacteria found in culture. This result is different from the study conducted by Bahu et al. who found that most of the incidence of pyelonephritis (48%) was caused by gram-positive bacteria and was similar to the culture findings of central line
associated blood stream infection (CLABSI). The bacteria that cause percutaneous nephrostomy tube related infection and CLABSI are similar in that they are both commercial bacteria on the skin that gain access to the urinary tract and blood vessels through percutaneous catheters. Staphylococcus aureus, Pseudomonas aeruginosa, and Escherichia coli found in this study are known as device-related biofilm infection.13

Percutaneous nephrostomy is a clean contaminated procedure, so prophylactic antibiotics were highly recommended.15 Bahu et al. revealed that the most risk factor for PNCI was a history of previous urinary tract infections. More than half of PNCI events occur within 40 days after insertion of percutaneous nephrostomy.3 According to research by Batura and Rao, there are currently no specific guidelines that recommend antibiotic administration at the time of nephrostomy tube replacement.10 The antibiotics commonly used are cefazolin, ceftriaxone, ampicillin sulbactam, gentamicin, vancomycin, clindamycin, and the penicillin class.15 The fluoroculonilone class of antibiotics (ciprofloxacin) had poor sensitivity in this study. This is in line with other studies and is probably due to the number of prescribing this antibiotic to patients without following good guidelines and being a contributing factor to the development of resistance.16

In the gram-positive group, the most sensitive antibiotic is vancomycin, which is a glycopeptide class of antibiotics and is indicated as a treatment for methicillin-resistant (beta-lactam-resistant) staphylococci. In addition, ceftriaxone and cefoperazone are two antibiotics that are commonly administered at Hasan Sadikin Bandung general hospital as an empirical treatment in post-nephrostomy patients. Both of these antibiotics were found to have 90% sensitivity to the gram-positive bacteria found in the patient’s urine culture results. In accordance with the therapeutic recommendations of UAE, the administration of empiric therapy has good effectiveness in complicated urinary tract infections associated with catheter placement. Ceftriaxone and cefoperazone are third generation cephalosporin class antibiotics. Both are semisynthetic broad-spectrum bacteria that are effective in the treatment of pseudomonas. Antibiotics of this class are well known and sensitive to various types of bacteria commonly found in respiratory infections, peritonitis, and skin infections.17

In the gram-negative group, the antibiotics with the best sensitivity were meropenem and amikacin. Meropenem is a broad-spectrum antibiotic belonging to the carbapenem (beta-lactamase inhibitor) class. This class is a broad spectrum antibiotic that has good effectiveness on gram-negative rods including P. aeruginosa, gram-positive, and anaerobic bacteria. Amikacin is an aminoglycoside class of antibiotics that is well known for use in combination in infections that have broad spectrum resistance.17

Since this was a retrospective study, the limitation of this study is that it only covered one health service location and no follow-up on subjects regarding culture-appropriate antibiotics.

In conclusion, Escherica coli is a bacterial isolate that is most commonly found in urine cultures of patients undergoing percutaneous nephrostomy at the Hasan Sadikin Hospital Bandung general hospital from the period of January 2017 to December 2019. Most of the bacterial isolates are bacteria commonly found in the urinary tract and digestive tract with the addition of gram-positive bacteria which are normal flora on the skin such as Staphylococcus aureus. The antibiotic therapy that is most widely used in post-nephrostomy patients is cefoperazone. This therapy is sensitive for handling gram-positive bacteria and is combined with the administration of amikacin which is sensitive to gram-negative bacteria. Antibiotic therapy in patients who were about and have undergone percutaneous nephrostomy required wise consideration to prevent resistance and percutaneous nephrostomy related infection (PNCI).

References

1. Cruz NV, Reitzel RA, Rosenblatt J, Jamal M, Szvalb AD, Chaftari A-M, et al. In vitro study of antimicrobial percutaneous nephrostomy catheters for prevention of renal infections. Antimicrobial agents and chemotherapy. 2017;61(6):e02596–16.
2. Dietrich C, Lorentzen T, Appelbaum L, Buscarini E, Cantisani V, Correas J, et al. EFSUMB guidelines on interventional ultrasound (INVUS), part III–abdominal treatment procedures (long version). Ultraschall in der Medizin-European Journal of Ultrasound. 2016;37(01):E1–E32.
3. Bahu R, Chaftari A-M, Hachem RV, Ahrar K, Shomali W, El Zakhem A, et al. Nephrostomy tube related pyelonephritis in patients with
cancer: epidemiology, infection rate and risk factors. J Urol. 2013;189(1):130–5.
4. Lapitan MCM, Buckley BS. Impact of palliative urinary diversion by percutaneous nephrostomy drainage and ureteral stenting among patients with advanced cervical cancer and obstructive uropathy: a prospective cohort. J Obstet Gynaecol Res. 2011;37(8):1061–70.
5. Hausegger KA, Portugaller HR. Percutaneous nephrostomy and antegrade ureteral stenting: technique—indications—complications. Eur Radiol. 2006;16(9):2016–30.
6. Hsu L, Li H, Pucheril D, Hansen M, Littleton R, Peabody J, et al. Use of percutaneous nephrostomy and ureteral stenting in management of ureteral obstruction. World J Nephrol. 2016;5(2):172–81.
7. Schaeffer AJ, Matulewicz RS, Klumpp DJ. Infections of the Urinary Tract. In: Wein AJ, Partin AW, Peters CA, editors. Campbell-Walsh Urology 11th ed. Philadelphia: Elsevier; 2016. p. 237–303.
8. Nace DA, Drinka PJ, Crnich CJ. Clinical uncertainties in the approach to long term care residents with possible urinary tract infection. J Am Med Dir Assoc. 2014;15(2):133–9.
9. Young M, Leslie SW. Percutaneous Nephrostomy. [Updated 2021 Aug 13]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan. Available from: https://www.ncbi.nlm.nih.gov/books/NBK493205/.
10. Batura D, Rao GG. A systematic review of the clinical significance of nephrostomy urine cultures. World J Urol. 2020;38(1):45–55.
11. Hamasuna R, Takahashi S, Nagae H, Kubo T, Yamamoto S, Arakawa S, et al. Obstructive pyelonephritis as a result of urolithiasis in Japan: Diagnosis, treatment and prognosis. J Int J Urol. 2015;22(3):294–300.
12. Cruz NV, Reitzel RA, Rosenblatt J, Jamal M, Szvalb AD, Chaftari A-M, et al. Antimicrobial percutaneous nephrostomy catheters for the prevention of renal infections: in vitro studies. Antimicrob Agents Chemother. 2017;61(6):e02596–16.
13. Szvalb AD, El Haddad H, Rolston KV, Sabir SH, Jiang Y, Raad II, et al. Risk factors for recurrent percutaneous nephrostomy catheter-related infections. Infection. 2019;47(2):239–45.
14. Maramara B, Psevdos G, Lobo Z, editors. A Ten-Year review of urinary tract infections in patients with indwelling nephrostomy tubes. Open Forum Infectious Diseases; Oxford University Press; 2016:
15. Pabon-Ramos WM, Dariushnia SR, Walker TG, d’Othée BJ, Ganguli S, Midia M, et al. Quality improvement guidelines for percutaneous nephrostomy. J Vasc Interv Radiol. 2016;27(3):410–4.
16. Shrestha LB, Baral R, Khanal B. Comparative study of antimicrobial resistance and biofilm formation among Gram-positive uropathogens isolated from community-acquired urinary tract infections and catheter-associated urinary tract infections. Infection drug resistance. 2019;12:957.
17. Katzung BG. Basic and Clinical Pharmacology 14th ed. New York: McGraw-Hill Education; 2017.