Eternal dilemma between percutaneous nephrostomy and double J stenting in the management of patients with ureteral obstruction: A single center study

RAFFAELE BAIO[1], GIOVANNI MOLISSO[2], DAVID PERPETUINI[3], EDMONDO BATTISTA[4], UMBERTO DI MAURO[1], OLIVIER INTILLA[1], UMBERTO PANE[1], VITTORIO FERSINI[1], RITA CITARELLA[5], ROSANNA D'ANTUONO[1], MARIANGELA BELLANGINO[1] and ROBERTO SANSEVERINO[1]

[1]Department of Urology, 'Umberto I' Hospital of Nocera Inferiore, Nocera Inferiore, I-84014 Salerno, Italy; [2]Department of Urology, 'Villa del Sole' Clinic, Caserta, I-81100 Caserta, Italy; [3]Department of Engineering and Geology, University G. D'Annunzio of Chieti-Pescara, I-65127 Pescara, Italy; [4]Department of Innovative Technologies in Medicine and Dentistry, University 'G. D'Annunzio' of Chieti-Pescara, I-66100 Chieti, Italy; [5]Department of Surgery and Anesthesia, 'Umberto I' Hospital of Nocera Inferiore, Nocera Inferiore, I-84014 Salerno, Italy

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Abstract. Ureteral obstruction is one of the most common urological emergencies, the etiology of which can be benign (in case of ureteral stones or strictures secondary to surgery) or malign (when a urothelial cancer affects the ureteral lumen or when an abdominal advanced neoplastic disease compresses the ureter '*ab estrinseco*'). To date, the most commonly used existing surgical methods for ureteral obstruction include percutaneous nephrostomy (PCN) and Double J stenting (DJS). The choose of the drainage method is multifactorial and, currently, no existing guidelines suggest to the urologist the ideal treatment for ureteral obstruction. Therefore, it was assessed which of the two main methods is superior in patients with ureteral obstruction according to normalization of renal function indices, post-operative complication and the perception of the quality of life (QoL) by the patient's point of view. In a period between 2019 and 2023, a total of 317 consecutive patients (198 males and 119 females) presenting to the emergency room of our hospital with a ureteral obstruction, which was resolved surgically by DJS or nephrostomy tube, were enrolled in the present study. All the patients signed written informed consent. Patients underwent surgical drainage when definitive treatment was not possible immediately or when a two-stage procedure was considered a safer approach. Inclusion criteria were: ureteral obstruction with fever (>38˚C), acute renal failure (indicated by an increase in creatinine and urea nitrogen blood values), risk of sepsis [suspected based on an increase in white blood cell (WBC) count] or intractable pain. Diagnosis of the ureteral obstruction was made by either a non-contrast CT and/or renal ultrasound. Specifically, 155 patients of the study sample were treated with nephrostomy, whereas 217 individuals underwent to stenting procedure. For each participant, data concerning the creatinine (mg/dl), azotemia (mg/dl), potassium (mEq/l), WBC count (10^3/mm^3), core temperature (˚C), pain in the side (yes or not), anti-inflammatory therapy (yes or not) and ASA score were evaluated. A Chi-square test was used to evaluate the difference in the incidence of complications according to sex and to the type of intervention. Moreover, 2-way ANOVA, considering the time (that is, pre-intervention, 2, 3, and 4 days after the intervention) as within factor and the groups as between factor, was implemented separately for the creatinine, azotemia, WBC, and body temperature values to assess differences between the PCN and DJS groups. Multiple comparisons were performed through t-tests comparing the values pre-operation and the values at two, three and four days after the intervention for each group. Moreover, independent samples t-tests were computed to identify differences between the two groups. Importantly, the multiple comparisons results were Bonferroni corrected. Finally, in order to assess a possible effect of the age on the variations of the creatinine, azotemia, WBC and body temperature for the two groups considered, a MANCOVA was performed, considering the age as a covariate. Finally, an independent sample t-test was performed between the hospitalization time of the two groups. According to our results, PCN is an improved method compared with DJS for management of ureteral obstruction in terms of renal function preservation, also ensuring an improved QoL. Moreover, PCN patients have a higher rate of post-operative complications. Then, concerning the prediction of the hospitalization time (according to the two-class classification: hospitalization time lower or higher than 3 days), the accuracy of the prediction was 61.9% for DJS and 60.2 for PCN. These results demonstrate the feasibility

Correspondence to: Dr Raffaele Baio, Department of Urology, 'Umberto I' Hospital of Nocera Inferiore, Nocera Inferiore, I-84014 Salerno, Italy
Email: dott.rbaio@gmail.com

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of predicting the hospitalization time for the patients based on their pre-drained condition. Although the results are preliminary and the accuracies are not high, this approach could help the surgeon choose the right kind of intervention for each patient.

Introduction

Ureteral obstruction is one of the most common urological emergencies, the etiology of which can be benign (in case of ureteral stones or strictures secondary to surgery or radiotherapy) or malign (when a urothelial cancer affects the ureteral lumen or when an abdominal advanced neoplastic disease compresses the ureter '*ab estrinseco*') (1). Effective treatment should be immediately carried out, in order to avoid the complications of long-term obstruction (such as pain, infection and ultimately renal failure). The scope of this treatment is to alleviate the patient pain and to protect its renal function (2). To date, the most commonly used existing surgical methods for ureteral obstruction include percutaneous nephrostomy (PCN) and Double J stenting (DJS) (3,4). PCN is performed under both sonographic and fluoroscopy guidance. This procedure requires the patient to be in the prone position and moderate sedation is needed. PCN placement is associated with a risk of hemorrhage, urinary tract infection and catheter dislodgement. On the other hand, DJS placement is performed concomitantly with cystoscopy for the visualization of the ureteral orifice, with the patient who is in the supine position during the procedure. Early complications of DJS placement include irritative bladder symptoms, hematuria and stent discomfort; meanwhile, stent migration and encrustation are among the common complications in the late period. The selection of the drainage method is multifactorial and may be influenced by the nature of each case, considering different factors such as complexity, local technique expertise, availability of medical equipment and patient features. For example, the classical ureteral obstruction is due to stones; about this, we have to consider that in certain health systems the waiting time for stone removal surgery is long. For this reason, it was observed that an expected long period time for definitive treatment biased the treating urologist to prefer a ureteral stent over nephrostomy tube, assuming the patient would be less bothered by the stent during the waiting period. Currently, no existing guidelines suggest to the urologist the ideal treatment for the obstructive uropathy. On one hand, DJS placement is commonly considered as the best surgical method, but it can occasionally be difficult to apply in patients with cancer. On the other hand, the numerous complications associated with the PCN procedure must be considered. The treatment choice for patients with obstructive uropathy is, therefore, still an open question. Both procedures have advantages and disadvantages in regard to complications, costs and post-operative management. Therefore, it is important to select the appropriate technique, as each has its own unique impact on the patients' outcomes. For this reason, it was assessed which of the two main methods is superior in this type of patients according to normalization of renal function indices, post-operative complication and the perception of the quality of life by the patient's point of view.

Materials and methods

In a period between 2019 and 2023, a total of 317 consecutive patients (198 males and 119 females) presenting to the emergency room of our hospital with a ureteral obstruction, which was resolved surgically by DJ stent placement or nephrostomy tube, were enrolled in the present study. All patients signed a written informed consent. All data analyzed were collected as part of routine diagnosis and treatment. Patients were treated according to national and international guidelines and agreements. Surgical drainage was performed when definitive treatment was not possible immediately or when a two-stage procedure was considered a safer approach. Inclusion criteria were: Ureteral obstruction with fever (>38˚C), acute renal failure (indicated by an increase in creatinine and urea nitrogen blood values), risk of sepsis (suspected based on an increase in WBC count) or intractable pain. Diagnosis of the ureteral obstruction was made by either a non-contrast CT and/or renal ultrasound. Pregnant women and patients with a contraindication to either form of drainage (for example uncorrected coagulopathy excluding percutaneous tube, hemodynamic instability precluding anesthesia for DJS placement or abnormalities of the urinary tract) were excluded from the analysis. Patients received either a DJS or a PCN according to the surgeon's preference and to the availability of anesthetic support. PCN was routinely performed in local anesthesia (1% Lidocaine, 10 cc), positioning a percutaneous pigtail polyurethane 8 or 10-French catheter (Cook medical). Ureteral stents were placed under loco-regional anesthesia and according to the commonly validated technique; a 6 or 7 FR, Percuflex (Boston Scientific) stent of the appropriate length (most commonly from to 24-28 cm) was used. Specifically, 155 patients of the study sample were treated with nephrostomy, whereas 217 individuals underwent to stenting procedure. The standardized Clavien-Dindo classification of surgical complications was used to assess and report post-operative complications (5). According to Clavien classification, post-operative complications were subdivided in three grades as shown in Table I. The PCN group was composed of 79 men (mean age ± standard deviation: 58.17±16.21 years, min-max: 39-92 years) and 76 women (mean age ± standard deviation: 60.18±14.34 years, min-max=29-90 years), whereas the DJS group constituted of 116 men (mean age ± standard deviation: 68.53±10.88 years, min-max=18-92 years) and 101 women (mean age ± standard deviation: 64.01±15.94 years, min-max=23-85 years). Notably, the legal age of adulthood in Italy is 18 years. For each participant, data concerning the creatinine (mg/dl), azotemia (mg/dl), potassium (mEq/l), WBC count (10^3/mm^3), core temperature (˚C), pain in the side (yes or not), anti-inflammatory therapy (yes or not) and ASA score were evaluated. The pre- and post-drainage data of creatinine, azotemia, potassium, WBC count and core temperature are reported in Table II. The distribution of the flank pain and of the anti-inflammatory therapy pre- and post-drainage until 4 days after the intervention separately for the DJS and PCN groups are reported in Fig. 1. In both groups the post-procedural pain was measured with VAS scale, suggesting a higher pain in patients with DJS. The VAS scale corresponds to the visual representation of the extent of

Table I. Clavien-Dindo classification of surgical complications.

GRADE I	Fever	Hematuria	Pain	Urgency	Urge incontinence
GRADE II	Septicemia	Bleeding	Encrustation	Pyelonephritis	Infection
GRADE III	Percutaneous nephrostomy dislodgement	Ureteral perforation	Migration	Slippage	Tube obstruction

Table II. The pre- and post-drainage data of creatinine, azotemia, potassium, WBC count and core temperature for the group of patients with DJS and the group of patients with PCN.

Group		Pre-renal drainage	Post renal drainage, Day 2	Post-renal drainage, Day 3	Post-renal drainage, Day 4
DJS	creatinine (mg/dl)	1.574±1.758	1.533±2.618	2.156±1.976	1.882±2.062
	azotemia (mg/dl)	56.019±38.291	49.973±33.565	65.230±44.827	54.814±43.686
	WBC (10^3/mm^3)	7.698±2.523	8.813±3.548	8.857±4.250	8.220±3.599
	Body temperature (˚C)	36.327±2.051	36.286±2.581	36.468±2.291	36.171±3.179
PCN	creatinine (mg/dl)	3.673±3.003	3.196±2.648	3.233±2.460	2.882±2.209
	azotemia (mg/dl)	102.540±69.099	100.383±67.741	104.50±67.891	100.539±64.899
	WBC (10^3/mm^3)	11.078±9.228	10.7498±7.174	10.576±8.745	9.783±6.061
	Body temperature (˚C)	36.479±0.290	36.467±0.244	36.467±0.177	36.463±0.178

DJS, Double J stenting; PCN, percutaneous nephrostomy; WBC, white blood cells.

the pain felt by the patient and is made up of a predetermined line 10 cm long, where the left end corresponds to 'no pain' while the right end corresponds to 'worst possible pain'. Patients in the present study were asked to draw a mark on the line representing the level of pain they felt. The scale line can be oriented horizontally or vertically, without this affecting its sensitivity; however, the horizontal orientation was preferred. The scale was administered to patients 24 h after the surgical procedure and in the following days, until discharge. Thereafter, measurement was performed weekly for a 6-month follow-up. The score was calculated in mm, measuring with a ruler the length of the line between the end corresponding to the minimum intensity and the mark placed by the patient. Based on several studies, the following cut-off values were used: 0 to 4 mm: 'no pain'; from 5 to 44 mm: 'mild pain'; from 45 to 74 mm: 'moderate pain'; and from 75 to 100 mm: 'severe pain'.

Consistently, patients with DJ stents reported values on the VAS scale, which oscillated between moderate pain and severe pain. By contrast, a greater number of patients with PCN reported not complaining of any pain. Furthermore, quality of life (QoL) was assessed weekly after the surgical procedure for a 6-month follow-up period. Patients were requested to fill out the 'Tube symptoms' questionnaire' which included six questions regarding pain, analgesics use, hematuria, urinary discomfort, discomfort associated with movement and discomfort associated with personal hygiene. Answers to these questions were based on a four-point rating scale; a higher score is associated with worse symptoms. At each measurement, the DJS group more frequently reported pain, analgesics use and presence of hematuria. Furthermore, the severity of these symptoms increased over time in the DJS group, while patients with PCN showed greater adaptation to the surgical device, which did not impede their personal hygiene or carrying out their daily activities.

The medial length to defervescence was 2.06 days, while the median length of white blood count (WBC) normalization was 1 day. After discharge, none of the patients undergoing DJS placement required readmission to the hospital; conversely, 10 patients (6,4%) required readmission to the hospital due to PCN dislocation. More patients with DJS presented to the emergency room with complaints related to their procedure compared with patients with PCN, mostly due to flank pain and dysuria. The post-drainage complication rate was not similar, being higher in PCN group. The majority of patients in both groups underwent ureteroscopy as the definitive treatment. The length of time between the urgent drainage and the definitive treatment was higher in the DJS group compared with the PCN group; this meant that a greater number of patients with DJS were admitted to the emergency room due to infection, malfunction of the stent or calcification of the same in both the bladder and the kidney (with the consequent need for a double operation, percutaneous nephrolithotomy and laser cysto-lithotripsy, to remove the stent in those patients).

Inferential statistical analysis. A Chi-square test was used to evaluate the difference in the incidence of complications according to sex and to the type of intervention. Moreover, 2-way ANOVA, considering the time (that is, pre-intervention,

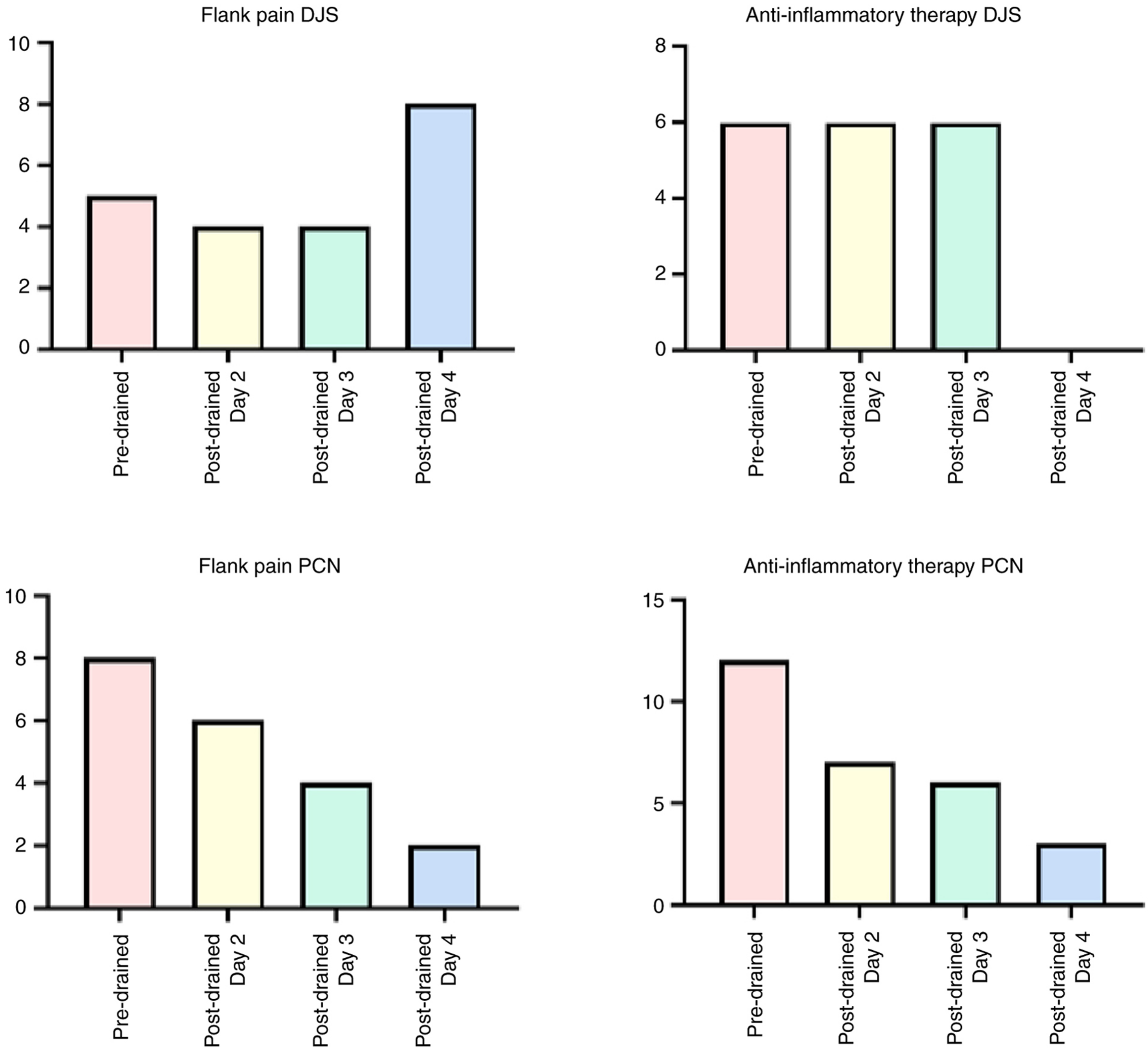

Figure 1. Distribution of the flank pain and of the anti-inflammatory therapy pre-drainage and until 4 days after the intervention separately for the DJS and PCN groups. The orange bar represents the pre-drained condition, the yellow bar shows the condition after 2 days from the draining, the green one represents the condition after 3 days from the draining, and the blue one shows the condition after 4 days from the draining. DJS, Double J stenting; PCN, percutaneous nephrostomy.

2, 3, and 4 days after the intervention) as within factor and the groups as between factor, was implemented separately for the creatinine, azotemia, WBC and body temperature values to assess differences between the PCN and DJS groups. Multiple comparisons were performed through t-tests comparing the values pre-operation and the values at 2, 3 and 4 days after the intervention for each group. Moreover, independent samples t-tests were computed to identify differences between the two groups. Importantly, the multiple comparisons results were Bonferroni corrected. Finally, in order to assess a possible effect of the age on the variations of the creatinine, azotemia, WBC and body temperature for the two groups considered, a MANCOVA was performed, considering the age as a covariate. Finally, an independent sample t-test was performed between the hospitalization time of the two groups; differences between the two sides were also investigated with a preliminary analysis, not proving any difference between the two sides; for this reason, the side of the intervention was not considered as a regressor for the ML algorithms.

Machine learning analysis. A Support Vector Regressor was employed to estimate the values of the creatinine and azotemia until to 4 days after the interventions for both the PCN and DJS groups. The input features were age, creatinine, azotemia, potassium, WBC, body temperature, flank pain and anti-inflammatory therapy before the intervention. Specifically, three different models were developed by splitting the study sample in three classes of age: patients with age <55 years, patients between 55-70 years-old, and patients aged >70 years. Moreover, a Support Vector Machine classifier was fed using the same regressors to estimate whether the hospitalization time of the patients is lower or higher than 3 days. Importantly, the input features were normalized (z-score) and, in order to assess the generalizability of the models' performance, a nested cross-validation (nCV) was implemented. In the nCV approach, the dataset is partitioned into numerous folds. The model is then trained repeatedly and in a nested manner, excluding 1-fold at a time, on the remaining data. In contrast to the outer loop, which assesses the model's performance over iterations (test), the inner loop is responsible

Table III. Results of the comparison between the values of the creatinine, azotemia, WBC count, and body temperature before and until four days after the intervention. The comparisons have been performed for both nephrostomy and stenting.

		Day 2		Day 3		Day 4	
Intervention	Metric	T-stat	P-value	T-stat	P-value	T-stat	P-value
Nephrostomy	creatinine	4.778	$4.088x10^{-6}$	6.468	$1.244x10^{-9}$	7.41	$7.812x10^{-12}$
	azotemia	3.031	0.003	4.711	$5.49x10^{-6}$	5.808	$3.537x10^{-8}$
	WBC count	0.147	0.883	1.004	0.316	1.952	0.053
	Body temperature	1.077	0.282	1.203	0.231	1.263	0.208
Stenting	creatinine	0.313	$0.754 \cdot 10^{-7}$	0.454	0.650	0.330	0.7411
	azotemia	5.353	2.201	6.225	$2.470x10^{-9}$	5.991	$8.620x10^{-9}$
	WBC count	-4.594	$7.396x10^{-6}$	-4.523	$1.007x10^{-5}$	-3.112	0.002
	Body temperature	-0.947	0.344	-0.903	0.367	0.074	0.941

WBC, white blood cells.

Table IV. Results of the comparison between the variations of the values of the creatinine, azotemia, WBC count, and body temperature in response to nephrostomy and stenting until four days after the intervention.

	Day 2		Day 3		Day 4	
Metric	T-stat	P-value	T-stat	P-value	T-stat	P-value
Creatinine	3.767	0.003	3.968	$2.17x10^{-5}$	4.091	$6.696x10^{-7}$
Azotemia	0.516	0.606	1.947	0.052	2.508	0.012
WBC count	2.361	0.018	3.093	0.002	3.39	$7.748x10^{-4}$
Body temperature	1.44	0.151	1.508	0.132	0.714	0.475

for identifying the ideal hyperparameter (validation). In the present study, the 5-fold CV was utilized and, in addition, a portion of the study sample (10%) was used as test set to further confirm the generalization performance of the models and to reduce overfitting effects. The data analysis was conducted using the MATLAB 2023b software (MathWorks, Inc.).

Results

Inferential statistical results. The chi-square test showed a not significant difference in the incidence of complications according to sex (Chi-squared=0.692; P=0.4054), whereas a significant difference was assessed regarding the incidence of the complications according to the type of intervention (Chi-squared=13.000; P=3x10^{-4}), highlighting a higher incidence of complications in the nephrostomy group. Concerning the creatinine, the ANOVA showed significant differences for the groups [F(1,370)=42.39, P<0.0001], the time [F(1.203,445,3)=23.52; P<0.0001] and their interaction [F(3,1110)=19.26, P<0.0001]. Regarding the azotemia no significant differences were assessed for the groups [F(1,370)=0.5853, P=0.4447], for the time [F(1,369.7)=0.3574, P=0.5503], and for their interaction [F(3,1109)=1.116, P=0.3415]. As far as it concerns the WBC, significant differences were identified for the groups [F(1,370)=14.42, P=0.0002], for the time [F(1.716,630)=4.383, P=0.173] and for their interaction [F(3,1101)=7.310, P<0.0001]. Regarding the body temperature, no significant differences were assessed for the groups [F(1,370)=0.7451, P=0.3886], time [F(1.375,507.8)=1.003, P=0.3418] and for their interaction [F(3,1108)=0.2213, P=0.8817]. The paired t-tests demonstrated a statistically significant improvement of the patients' condition after the intervention for both nephrostomy and stenting, as reported in Table III. Moreover, the independent samples t-test showed a significant difference between the variations of the several metrics considered when comparing the nephrostomy and the DJS operations, highlighting a higher effect of the nephrostomy (Table IV). The MANCOVA showed a significant interaction between the group and the age of the participant regarding the creatinine (P=0.0021) and the azotemia (P=0.0089), whereas no significant interaction was found for the WBC (P=0.0611) and for the body temperature (P=0.1354). The t-test between PCN and DJS demonstrated a greater hospitalization time for the PCN group with respect to the DJS (t-stat=7.3075, d.f.=394, P<0.0001).

Machine learning results. The prediction results of the values of creatinine and azotemia until day 4 are reported in Table V. Specifically, the correlation coefficient between the measured value of the metrics considered and the predicted one is reported. The results reported in Table V refers to the test set.

Table V. Results of the Support Vector Regressor based prediction of the values of creatinine and azotemia until day 4 relying on age, creatinine, azotemia, potassium, white blood cell count, body temperature, flank pain, and anti-inflammatory therapy before the intervention, for both nephrostomy and stenting. In the table, the correlation coefficients obtained between the measured and predicted values for each metric considered.

Age class	Metric	Intervention	Day 2	Day 3	Day 4
<55	Creatinine	Stenting	0.89	0.92	0.94
	Creatinine	Nephrostomy	0.69	0.68	0.72
	Azotemia	Stenting	0.76	0.63	0.63
	Azotemia	Nephrostomy	0.82	0.82	0.81
>55 and <70	Creatinine	Stenting	0.51	0.35	0.36
	Creatinine	Nephrostomy	0.66	0.65	0.41
	Azotemia	Stenting	0.51	0.69	0.33
	Azotemia	Nephrostomy	0.77	0.64	0.53
>70	Creatinine	Stenting	0.87	0.85	0.90
	Creatinine	Nephrostomy	0.52	0.50	0.48
	Azotemia	Stenting	0.69	0.65	0.37
	Azotemia	Nephrostomy	0.66	0.58	0.49

In fact, in the present study, together with a 5-fold cross validation, the 10% of the study sample was used as test set to further investigate the generalization performance of the models and to reduce the overfitting. Concerning the prediction of the hospitalization time, the results of the two-class classification (that is, hospitalization time lower or higher than 3 days) for both DJS and PCN are reported in Fig. 2. Specifically, the confusion matrices associated to the test set are reported in Fig. 2, demonstrating the correct classification in the main diagonal (blue background) and the wrong classification in the secondary diagonal (orange background). The test accuracy of the prediction was 61.9% for DJS and 60.2% for PCN, whereas the validation accuracy of the prediction was 62.4% for DJS and 61.6% for PCN. These results demonstrate the feasibility of predicting the hospitalization time for the patients based on their pre-drained condition. Although the results are preliminary and the accuracies are not high, this approach could help the surgeon choose the right kind of intervention for each patient.

Discussion

The incidence of ureteral obstruction has risen in last decades for causes that differ depending on the age group of the patients: Ureteral stones in young and middle age (6) while, for the elderly, advanced urological malignant diseases (such as bladder cancer which involves ureteral orifice or ureteral neoplasms) or non-urological abdominal cancer with compression of the ureter are more common (7). Those patients require emergency treatment in order to avoid different adverse events such as pain unresponsive to medical therapy, urinary infections, acute renal failure, urosepsis and even death (1). Despite the commonness of these situations, only few studies compared renal drainage methods (8-12). The placement of PCN or DJS represents the mainstream surgical drainage method for temporary relief of obstruction (13). However, the dilemma of choosing between these two drainage methods remains extremely relevant and current in urological daily practice; this is where the idea of our research was born. In the present study, all patients were potential candidates for both procedures and they showed similar characteristics. The goal of the aforementioned systems is to obtain ureteral drainage, in order to maintain renal function, waiting for the resolution surgery. Regarding this, some studies reported a difference in time to second procedure (9), which was 2-fold longer in DJS patients compared with those with PCN (probably because a patient with a DJS is mistakenly considered less debilitated compared with a patient with a PCN). Furthermore, both PCN and DJS placements have some complications such as the risk of infection and displacement, as well as the discomfort of nephrostomy catheter and stent. Moreover, ureteral stents should be exchanged every 6 to 8 weeks in order to avoid the risk of encrustation and bacterial colonization (14). Generally, stent placement has a high success rate and it is minimally traumatic using the natural ureteral orifice. In addition, it does not require an external tube, resulting in no effect on the aesthetic appearance of patients. However, the review of Ramsey *et al* (15) suggested that retrograde stent placement leads to increased bacteremia. PCN placement reduces renal pelvis pressure and the risk of bacteremia (16). It is commonly performed under local anesthesia by a urologist using ultrasonographic guidance (16) and, in part for this reason, urologists consider PCN to be superior to DJS (17). Likewise, oncologists were more likely to recommend PCN as the next step after stent failure in unilateral obstruction (18). In another study a more rapid return of serum creatinine to normal levels with PCN tubes than DJS was also reported (19). Moreover, unstable patients with larger stones being severely ill should be treated with PCN under local anesthesia (12). Despite this, in clinical practice, the proper surgical option is affected by numerous factors. In recent decades, studies (evaluating the superiority of one drainage method over the other) reported

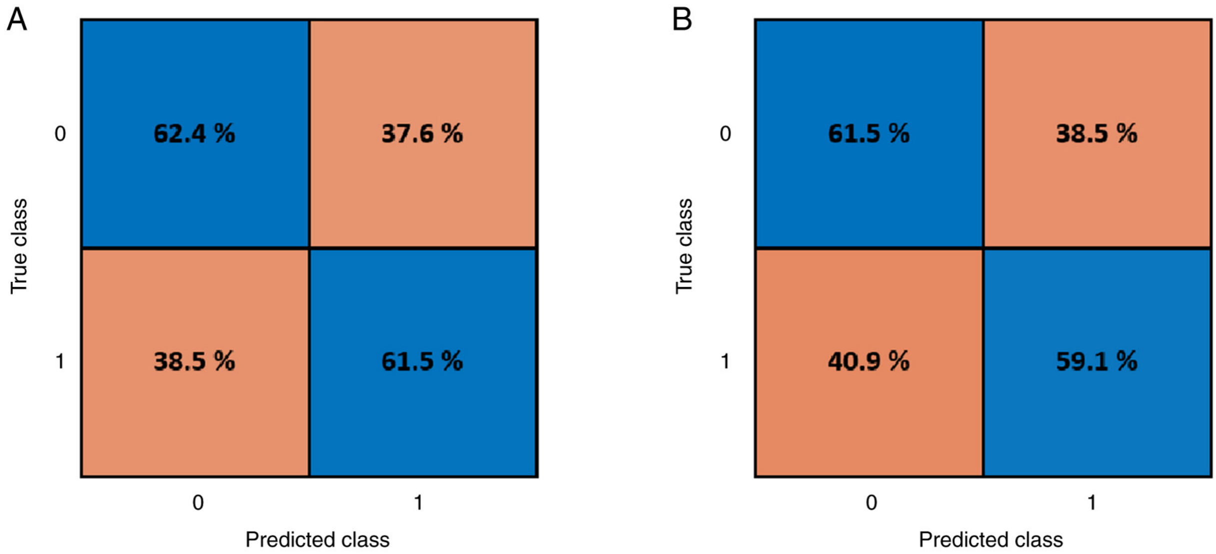

Figure 2. Confusion matrices for the hospitalization time classification (that is, hospitalization time lower or higher than 3 days) obtained through Support Vector Machine applied to (A) DJS and (B) PCN. The blue and orange colors used for the background of the confusion matrices are related to the correct or wrong classification of the hospitalization time (that is, hospitalization time lower than 3 days and hospitalization time higher than 3 days). Specifically, in the main diagonal are reported the correct classification for both the classes (that is, sensitivity and specificity) and the background of the cells is blue, whereas the wrong classifications performance is reported in the secondary diagonal, with an orange background. The intensity of the colors is related with the percentage reported in the cell of the confusion matrices. DJS, Double J stenting; PCN, percutaneous nephrostomy.

inconclusive results, probably due to too small study samples. Thus, PCN and DJS were compared to understand which of the two was the best drainage method for resolving urinary tract obstruction. The Chi-square test showed a not significant difference in the incidence of complications according to sex (Chi-square=0.692; P=0.4054), whereas a significant difference was assessed regarding the incidence of the complications according to the type of intervention (Chi-square=13.000; P=3x10^{-4}), highlighting a higher incidence of complications in the nephrostomy group. The paired t-tests demonstrated a statistically significant improvement of the patients' condition after the intervention for both nephrostomy and stenting, as reported in Table I. Moreover, the independent samples t-test showed a significant difference between the variations of the several metrics considered (values of the creatinine, azotemia, WBC count and body temperature) when comparing the nephrostomy and the stenting operations, highlighting a higher effect of the nephrostomy, as showed in Table II. On the other hand, compared with DJS, PCN showed a relatively higher rate of post-operative complications. Another aspect that was evaluated is the QoL of patients undergoing DJS placement or nephrostomy tube. Both surgical methods caused pain or discomfort to a significant number of patients. Generally, while the number of patients with PCN complaining of pain remain similar over time and with an ever-decreasing use of analgesics, more patients with DJS report of pain, requiring greater and more frequent use of painkillers (20). The most troublesome symptoms in the DJS group are irritative symptoms of the lower urinary tract (10,21), inflicting ~70% of these patients who require over time a higher number of emergency room visit due to the unchanged frequency and severity of the bother symptoms. In distinct opposition, patients with PCN suffered at first mostly from discomfort during daily activities and personal hygiene but, over time, they adjusted to this condition. This result is corroborated by the study of de Sousa Morais *et al* (10) and in other studies which compared PCN drainage vs. DJS in other clinical scenarios (22,23). Although according to the current results PCN is superior to DJS for temporary urinary diversion in terms of renal function preservation (with also an improved QoL for the patients, as demonstrated by the results of the VAS scale and of the 'Tube symptoms' questionnaire'), the choice of treatment depends on the individual situation. For example, PCN represents the choice treatment in case of advanced malignancies, after failed retrograde stent placement (24) and in patients who might not be able to tolerate general anesthesia (25). Thus, the decision on the appropriate method of drainage is multifactorial; furthermore, a discussion with the patient is extremely important because the urologist might explain the clinical advantages and the complications of each procedure, not forgetting what is expected regarding tube symptoms and their impact on QoL. To quote Dr Louis R Kavoussi (26), 'traditionally, urologists have placed stents because … that's what we do', but his experience is that 'patients are more comfortable with a nephrostomy than a stent'. The results of the present study support superior QoL of nephrostomy tube over time, inducing some urologists to reconsider their choice of renal drainage, especially in health systems in which definitive treatment might be delayed. There are several limitations to the present study. Selection bias may have been introduced through choice of drainage procedure according to surgeon's preference, with a higher probability of performing PCN in patients suspected of long-standing obstruction. Furthermore, as different imaging modalities were used (CT scan and/or ultrasonography exam), hydronephrosis severity could not be assessed as a possible confounder. Nevertheless, the authors consider that the present study has a fundamental strength. To the best of our knowledge, the current research represents the first single-center study with the highest number of patients enrolled, which allows for a more accurate assessment of the problem of ureteral obstruction.

In conclusion, according to the present results, PCN is an improved method compared with DJS for management of ureteral obstruction in terms of renal function preservation, also ensuring an improved QoL (as demonstrated by the results of the VAS scale and of the 'Tube symptoms' questionnaire'). Moreover, patients with PCN have a higher rate of postoperative complications. Then, concerning the prediction of the hospitalization time (according to the two-class classification: hospitalization time lower or higher than 3 days), the test accuracy of the prediction was 61.9% for DJS and 60.2 for PCN. These results demonstrate the feasibility of predicting the hospitalization time for the patients based on their pre-drained condition. Although the results are preliminary and the accuracies are not high, this approach could help the surgeon choose the right kind of intervention for each patient. In fact, predicting hospitalization time is directly related to post-surgery complications, which can significantly impact patient outcomes and healthcare resource management. To improve the accuracies obtained, it could be possible to include more regressors for the machineries (for example, detailed patient demographics, comorbidities, lab results, imaging findings and intraoperative details). Furthermore, increasing the sample size can enable models to learn improved patterns and generalize well to unseen data. Additionally, increasing the sample size would allow to employ more sophisticated ML algorithms or ensemble methods that can capture more complex patterns in the data.

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Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Authors' contributions

RB was the major contributor in writing the manuscript. RB and GM performed the DJS placement and nephrostomy tube. DP and EB performed the statistical analysis of the data. RC, VF and RDA performed the data collection. RB and GM confirm the authenticity of all the raw data. RS, UDM, OI, UP and MB interpreted the patient data regarding urological disease. All authors read and approved the final version of the manuscript.

Ethics approval and consent to participate

The present study was conducted according to the guidelines of the Declaration of Helsinki. The present study is part of the checks that patients routinely carry out as part of pre-operative screening programs when they enter the emergency room and is not a clinical study. The data presented in this manuscript were produced by the Umberto I Hospital of Nocera Inferiore, belonging to the ASL Salerno, as part of the routine emergency medicine program for the monitoring of patients referred to the emergency room, according to good practices laboratory municipalities. No further sampling was performed for the analyses reported. For this reason, the opinion of the Ethics Committee was not necessary as it is not a clinical study or a pharmacological treatment. Patients had already been informed by written communication that these analyses were part of normal emergency medicine evaluation practice. Patient data has been processed in accordance with current privacy protection laws and in accordance with the procedures of the General Data Protection Regulation (GDPR) n. 2016/679; the patients' informed consent was acquired for the processing of their data, both personal and medical.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Use of artificial intelligence tools

During the preparation of this work, artificial intelligence tools were used to improve the readability and language of the manuscript or to generate images, and subsequently, the authors revised and edited the content produced by the artificial intelligence tools as necessary, taking full responsibility for the ultimate content of the present manuscript.

References

1. Tabib C, Nethala D, Kozel Z and Okeke Z: Management and treatment options when facing malignant ureteral obstruction. Int J Urol 27: 591-598, 2020.
2. Yoon JH, Park S, Park S, Park S, Moon KH, Cheon SH and Kwon T: Renal function is associated with prognosis in stent-change therapy for malignant ureteral obstruction. Investig Clin Urol 59: 376-382, 2018.
3. Netsch C, Becker B and Gross AJ: Management of ureteral obstruction: Value of percutaneous nephrostomy and ureteral stents. Urologe A 55: 1497-1510, 2016 (In German).
4. Hardie EM and Kyles AE: Management of ureteral obstruction. Vet Clin North Am Small Anim Pract 34: 989-1010, 2004.
5. Clavien PA, Sanabria JR and Strasberg SM: Proposed classification of complications of surgery with examples of utility in cholecystectomy. Surgery 111: 518-526, 1992.
6. Zhang Z, Wang X, Chen D, Peng N, Chen J, Wang Q, Yang M and Zhang Y: Minimally invasive management of acute ureteral obstruction and severe infection caused by upper urinary tract calculi. J Xray Sci Technol 28: 125-135, 2020.
7. Kumar A, Mynderse L, Patel K, Grudem M, Bakkum-Gamez J, Longenbach S, Block MS, Pitot HC, Garovic V, Weroha SJ and Jatoi A: Ureteral obstruction in cancer patients: A qualitative study. Psychooncology 25: 605-609, 2016.
8. Joshi HB, Adams S, Obadeyi OO and Rao PN: Nephrostomy tube or 'JJ' ureteric stent in ureteric obstruction: Assessment of patient perspectives using quality-of-life survey and utility analysis. Eur Urol 39: 695-701, 2001.

9. Mokhmalji H, Braun PM, Martinez Portillo FJ, Siegsmund M, Alken P and Köhrmann KU: Percutaneous nephrostomy versus ureteral stents for diversion of hydronephrosis caused by stones: A prospective, randomized clinical trial. J Urol 165: 1088-1092, 2001.
10. de Sousa Morais N, Pereira JP, Mota P, Carvalho-Dias E, Torres JN and Lima E: Percutaneous nephrostomy vs ureteral stent for hydronephrosis secondary to ureteric calculi: Impact on spontaneous stone passage and health-related quality of life-a prospective study. Urolithiasis 47: 567-573, 2019.
11. Pearle MS, Pierce HL, Miller GL, Summa JA, Mutz JM, Petty BA, Roehrborn CG, Kryger JV and Nakada SY: Optimal method of urgent decompression of the collecting system for obstruction and infection due to ureteral calculi. J Urol 160: 1260-1264, 1998.
12. Goldsmith ZG, Oredein-McCoy O, Gerber L, Bañez LL, Sopko DR, Miller MJ, Preminger GM and Lipkin ME: Emergent ureteric stent vs percutaneous nephrostomy for obstructive urolithiasis with sepsis: Patterns of use and outcomes from a 15-year experience. BJU Int 112: E122-E128, 2013.
13. Hsu L, Li H, Pucheril D, Hansen M, Littleton R, Peabody J and Sammon J: Use of percutaneous nephrostomy and ureteral stenting in management of ureteral obstruction. World J Nephrol 5: 172-181, 2016.
14. Loughlin KR and Bailey RB Jr: Internal ureteral stents for conservative management of ureteral calculi during pregnancy. N Engl J Med 315: 1647-1679, 1986.
15. Ramsey S, Robertson A, Ablett MJ, Meddings RN, Hollins GW and Little B: Evidence-based drainage of infected hydronephrosis secondary to ureteric calculi. J Endourol 24: 185-189, 2010.
16. Xu ZH, Yang YH, Zhou S and Lv JL: Percutaneous nephrostomy versus retrograde ureteral stent for acute upper urinary tract obstruction with urosepsis. J Infect Chemother 27: 323-328, 2021.
17. Lynch MF, Anson KM and Patel U: Percutaneous nephrostomy and ureteric stent insertion for acute renal deobstruction: Consensus-based guidance. Br J Med Surg Urol 1: 120-125, 2008.
18. Hyams ES and Shah O: Malignant extrinsic ureteral obstruction: A survey of urologists and medical oncologists regarding treatment patterns and preferences. Urology 72: 51-56, 2008.
19. Elgammal MA, Abdel-Kader MS, Kurkar A, Mohammed OA and Hammouda HM: Management of calculus anuria in children: Experience of 54 cases. J Pediatr Urol 5: 462-465, 2009.
20. Shoshany O, Erlich T, Golan S, Kleinmann N, Bensel J, Rosenzweig B, Eisner A, Mor Y, Ramon J, Winkler H and Lifshitz D: Ureteric stent versus percutaneous nephrostomy for acute ureteral obstruction-clinical outcome and quality of life: A bi-center prospective study. BMC Urol 19: 79, 2019.
21. Dellis A, Joshi HB, Timoney AG and Keeley FX Jr: Relief of stent related symptoms: Review of engineering and pharmacological solutions. J Urol 184: 1267-1272, 2010.
22. Zhao PT, Hoenig DM, Smith AD and Okeke Z: A randomized controlled comparison of nephrostomy drainage vs ureteral stent following percutaneous Nephrolithotomy using the wisconsin StoneQOL. J Endourol 30: 1275-1284, 2016.
23. Jiang H, Huang D, Yao S and Liu S: Improving drainage after percutaneous Nephrolithotomy based on health-related quality of life: A prospective randomized study. J Endourol 31: 1131-1138, 2017.
24. Lau MW, Temperley DE, Mehta S, Johnson RJ, Barnard RJ and Clarke NW: Urinary tract obstruction and nephrostomy drainage in pelvic malignant disease. Br J Urol 76: 565-569, 1995.
25. Bres-Niewada E: Ureteral obstruction in pregnancy-the 'stone mountain' for the urologist. Cent European J Urol 70: 101-102, 2017.
26. Practice update, comment by Kavoussi LR, 2016: http://www.practiceupdate.com/content/inferior-wisconsin-stoneqol-results-observed-with-ureteral-stent-vs-nephrostomy-drainage-following-percutaneous-nephrolithotomy/47216. Accessed at 21 July 2018.