Renal Profile and Outcome of Patients With Post-Obstructive Diuresis at the UST Hospital: A Retrospective Study

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ABSTRACT

Background of the Study: Post-obstructive diuresis (POD) is a common diagnosis among urologic patients that is medically diagnosed and managed. It is defined as urine production exceeding 200 mL per hour for two consecutive hours or producing greater than 3 L of urine in 24 hours. There is limited data on the risk factors of developing POD, but the need to identify such is important to prevent its complications such as dehydration, electrolyte imbalance, acute renal failure and even death.

Objectives: The study aims to identify clinical and renal predictors of developing POD. It also seeks to show the outcome of patients diagnosed with POD and its correlation with medical management.

Method: This is a retrospective study of all patients diagnosed with POD centered in the University of Santo Tomas Hospital from January 2017 to December 2018. Renal parameters such as serum creatinine, sodium, potassium, urea and ionized calcium were analyzed. Urinalysis and arterial blood gases were also noted and correlated.

Results: Among a total of 106 patients with obstruction, 28.32% developed POD after decompression. The mean age is 58.2 ± 13.89, and most are male. Patients with POD have significantly longer days of obstruction (14 days, p = 0.049) compared to non-POD. Overweight patients comprise a significantly larger proportion of patients who had POD (p = <0.001). Those with baseline acute kidney injury (AKI) (elevated serum creatinine at an average of 1.93 and low eGFR at an average of 35.6) have a significantly higher risk of developing POD (p = 0.004). Serum sodium levels were also higher among patients with POD (140, p = 0.008). Renal predictors identified include obstruction from prostate cancer (p = 0.011), longer duration of obstruction (p = 0.042), low eGFR (p = 0.009) and AKI (p = 0.004). Intravenous fluid (IVF) did not differ in the type used and outcomes of POD. Fluid replacement per urine volume also did not alter the disease course (p = 801). Regarding outcome, all discharged patients improved but differed significantly from the non-POD group regarding prolonged hospital stay. There were no significant electrolyte imbalances, postoperatively.

Conclusion: POD occurs more likely among patients with a baseline AKI, low level of eGFR, longer duration of obstructions beyond 14 days and those with prostate cancer. Serum sodium and creatinine were higher among patients with POD. POD is associated with prolonged hospital stay, but obstruction relief leads to renal function improvement.

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Academic editor: Leilani B. Mercado-Asis

Submitted date: April 07, 2024

Accepted date: May 07, 2025

Keywords: *Post-obstructive diuresis, obstructive uropathy*

INTRODUCTION

Post-obstructive diuresis (POD) is a condition characterized by excessive urine output following the relief of urinary tract obstruction, typically after decompression of an obstructed bladder or ureter. The diagnostic criteria for POD include urine production exceeding 200 mL per hour for two consecutive hours or greater than 3 L within 24 hours.[1] It involves polyuria, where large amounts of water and salt are excreted after urinary obstruction relief. The incidence of POD is uncertain, with estimates ranging from 0.5% to 52%.[2]

POD typically occurs after alleviating bladder outlet obstruction, bilateral ureteral obstruction, or unilateral ureteral obstruction in a solitary kidney. Diuresis serves as a normal physiological response to eliminate excess volume and solutes accumulated due to obstruction. In most patients, diuresis resolves once the kidneys restore balance.[3] Polyuria is more common after bilateral ureteral or subvesical obstruction, while unilateral obstruction rarely causes POD. Thiel, et.al. reported an extreme case with 58,000 mL per day of diuresis (204 L in 10 days) following left ureteral obstruction relief.[3] The pathophysiology of POD is not fully understood, but it is believed to involve multiple factors. Treatment focuses on careful monitoring and fluid-electrolyte replacement.[3]

Despite its clinical significance, the risk factors for POD remain poorly defined. Factors like lower urinary tract symptoms, diabetes, prior urethral catheterizations, prostatic hyperplasia, fecal impaction and anticholinergic medication use have been identified as potential risk factors.[2] However, study results are inconsistent.[4,5] Several mechanisms have been proposed for POD's pathophysiology, including vascular washout, down-regulation of sodium transporters in the loop of Henle, GFR reduction and impaired antidiuretic hormone response. POD likely results from a combination of these factors.[2] A literature review by Shah, et.al. highlighted tubular dysfunction and recovery as key elements in POD's transient nature. Urinary output and electrolyte excretion peak within 24 hours and typically stabilize by day 14.[6]

Patients with POD are at risk for severe dehydration, electrolyte imbalances, hypovolemic shock and, in extreme cases, death.[7] Predicting which patients will develop POD after urinary tract decompression remains challenging. Hamdi, et.al. identified high serum creatinine levels, elevated sodium bicarbonate and urinary retention as independent risk factors for developing POD.[8] However, few markers predict whether POD will progress to a pathologic state. Some studies have linked renal insufficiency, heart failure, volume overload, dizziness and central nervous system (CNS) depression as risk factors for severe POD.[9]

Management of POD generally involves fluid replacement, tailored based on clinical parameters, diuresis and monitoring. High-risk patients should be closely observed, and nephrologist involvement may be necessary for prolonged diuresis.[6] While POD is common in urology, vigilant management is required. Understanding its pathophysiology, risks and management strategies is crucial for clinicians, particularly internists. No formal guidelines exist for diagnosing or managing POD, though further research could establish a clearer framework for clinical practice.

Literature on POD profiles and outcomes is limited. Bermeo, et.al. examined 88 patients with ureteropelvic junction obstruction who underwent open pyeloplasty between 2006 and 2016. About 30% developed POD, with younger age and tubular acidosis correlated with its development.[7] Despite analyzing serum electrolytes, they did not correlate with POD.[10]

Frohlich, et.al. assessed POD incidence in cats after urethral obstruction relief, finding 88% developed POD within 48 hours, with intravenous fluids (IVF) likely contributing to high polyuria.[11] Francis, et.al. explored the correlation between venous pH and POD, finding that POD was more likely in samples with venous pH <7.35.[12] Wilson, et.al. studied natriuretic factors in rats, showing that high blood and urine urea levels contributed to pronounced diuresis, explaining differences between bilateral and unilateral ureteral relief.[13]

Quinlan, et.al. (2010) compared gender-based renal responses in rats following unilateral obstruction and nephrectomy. They found increased renal injury and reduced glomerular filtration rate (GFR) in male rats but no significant differences in other parameters, although both sexes exhibited increased aquaporin-2 expression.[14] Gillenwater's 1975 study found no cases of POD after unilateral hydronephrosis relief, despite some obstructed kidneys showing impaired GFR and sodium reabsorption.[15]

A 2012 study by Hamdi, et.al. found that POD occurred more frequently in patients with AKI, even without chronic renal failure. Risk factors for POD in chronic renal failure patients included lower hemoglobin, serum bicarbonate levels, delayed relief and the absence of POD.[8]

This study aims to provide insights for patients with obstructive nephropathy or uropathy preparing for decompressive surgery, improving patient preparation, outcome prediction and complication management. It will also assist general practitioners and physicians in preoperative clearance and risk stratification.

The primary objective is to evaluate the renal profile, risk factors and outcomes of POD in patients treated at the University of Santo Tomas Hospital between January 2017 and December 2018. Specifically, the study aims to identify blood and urine parameters influencing or predicting POD, assess fluid therapy's role, determine POD incidence and explore correlations with serum creatinine levels, electrolyte imbalances and creatinine clearance. This analysis will enhance the understanding and management of POD in this patient population.

METHODS

This study retrospectively analyzed POD patients admitted to the University of Santo Tomas Hospital from January 2017 to December 2018. Patients who met the criteria for POD were included.

Study Population

Demographic, etiological and clinical data for hospitalized patients diagnosed with obstructive uropathy (bilateral or unilateral) at the UST Hospital were collected. Among these, cases diagnosed with POD were selected. The data came from inpatient charts at the UST Hospital Records Section.

Patients aged >18 diagnosed with POD were included. POD was defined as urine production exceeding 200 mL per hour for two consecutive hours or greater than 3 L of urine in 24 hours, based on Leslie's 2018 study. Patients had to be admitted and observed for more than 24 hours at the UST Hospital.

Patients with these findings before the operation or discharged in less than 24 hours were excluded, along with those with unilateral obstruction, except for those with a solitary kidney.

Study Procedure

The obstructive uropathy database from January 2017 to December 2018 was reviewed. Researchers identified patients who underwent procedures to relieve the obstruction. A chart review identified patients diagnosed with POD.

Necessary data were extracted and ethical considerations will be discussed in the Ethical Consideration section. Data were analyzed to identify risk factors and outcomes, including length of hospital stay, days to resolve POD and electrolyte imbalances. Included risk factors were age, gender, sodium, creatinine and Blood urea nitrogen (BUN) levels before surgery, ultrasound findings, urinalysis results (pH, specific gravity, urine chemistry and microscopy), IVF volume and use of antibiotics before surgery.

Data were encoded using a data-gathering instrument developed for this study and Microsoft Excel.

Sampling Design and Sample Size

The study identified all patients with POD from January 2017 to December 2018 in the UST Hospital, including all of them with approval from the Institutional Review Board (IRB) to review their charts and data.

Statistical Analysis

Clinical, biological and imaging characteristics on admission and post-obstruction release were analyzed using univariate and multivariate analysis to identify predictors of POD occurrence. Data were presented as percentages. A p-value <0.05 was considered statistically significant.

Descriptive statistics summarized the patients' demographic and clinical characteristics. Frequency and proportion were used for categorical variables

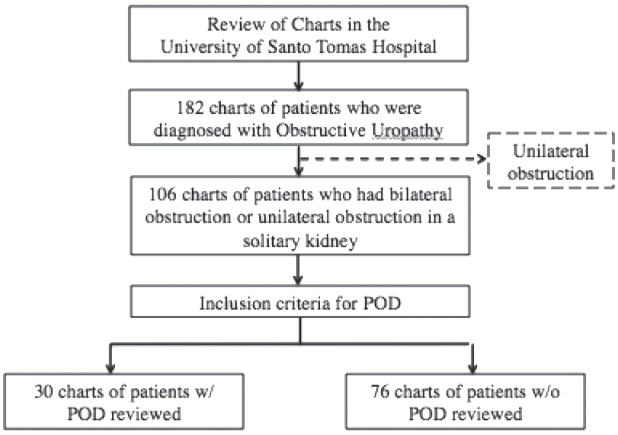

Figure 1: Schematic Diagram of the Research Paper

as well as median and interquartile range used for non-normally distributed continuous variables. For normally distributed variables, the mean and standard deviation (SD) were used. Independent Sample T-test, Mann-Whitney U test and Fisher's Exact/Chi-square tests were used to determine the mean, rank and frequency differences between patients with and without POD. Wilcoxon signed-rank test assessed changes from preoperative to postoperative serum creatinine, Na, K, eGFR and iCA. Odds ratios and 95% confidence intervals from binary logistic regression were calculated to determine factors associated with POD. All tests were two-tailed. Shapiro-Wilk was used for normality testing and missing variables were not estimated. Null hypotheses were rejected at a 0.05 significance level. Data analysis was performed using STATA 13.1.

Data Collection/Gathering Tools

A master table was made to be used for encoding data. An individual patient sheet/instrument with a checklist of risk factors and outcomes was also created for each chart. Terms found on the data gathering instrument were properly defined (including operational definitions for the coding process).

Ethical Consideration

The study received approval from the Research Ethics Committee (REC) of UST Hospital. The medical director was informed and the study followed the 2017 National Ethical Guidelines for Health and Health-Related Research (NEGHHRR).

Informed Consent

Since this study was a chart review, patient informed consent was not required for using data from records. According to the NEGHHRR, informed consent may be waived for specific research contexts such as archival research. Ethical principles outlined by Sakar in "Conducting Record Review Studies in Clinical Practice" were followed. This included obtaining only necessary information, ensuring confidentiality, removing identifying data and seeking approval from the IRB.

The study requested USTH-REC to waive the informed consent process based on these principles.

Compliance with the Data Privacy Act

The study ensured confidentiality. Only authorized researchers could access the data, and subjects were assigned alpha-numeric codes for anonymity. Coded data were sent to the statistician for analysis. The study adhered to the Data Privacy Act of 2012 and its Implementing Rules and Regulations of 2016.

Data Management

Data were used solely for research purposes and stored on a secure hard drive accessible only to researchers and statisticians. Data were processed fairly and retained as long as necessary for research. Records were to be retained for three

Table 1: Demographic Profile of Patients Diagnosed with Post-Obstructive Diuresis (POD)

	Total (n=106)	Without POD (n=76, 71.7%)	With POD (n=30, 28.3%)	P-value
	Frequency (%); Mean ± SD			
Age	58.30 ± 15.89	58.34 ± 16.70	58.2 ± 13.89	0.967
Sex				0.200
Male	56 (52.83)	37 (48.68)	19 (63.33)	
Female	50 (47.17)	39 (51.32)	11 (36.67)	
Case				0.131
Lithiasis[a]	49 (46.23)	39 (51.32)	10 (33.33)	
Benign Prostatic Hypertrophy	6 (5.66)	3 (3.95)	3 (10)	
Prostate CA	14 (13.21)	6 (7.89)	8 (26.67)	
Urinary Tract Infection	7 (6.60)	6 (7.89)	1 (3.33)	
Ureteral/Urethral Stricture	3 (2.82)	3 (3.95)	0	
Lymph Node Involvement	1 (0.94)	1 (1.32)	0	
Other causes of obstruction[b]	22 (20.75)	15 (19.74)	7 (23.33)	
Cancer Metastases	4 (3.77)	3 (3.95)	1 (3.33)	
Duration of obstruction (d)[c]	7 (3 to 21)	7 (3 to 14)	14 (4 to 30)	**0.049**
Polyuric state[d] (d)	0 (0 to 1)	0	4 (2 to 6)	**<0.001**
Co-Morbid Illnesses				
Hypertension	16 (15.09)	11 (14.47)	5 (16.67)	0.769
Diabetes Mellitus	15 (14.15)	9 (11.84)	6 (20)	0.354
Urinary Tract Infection	3 (2.83)	2 (2.63)	1 (3.33)	1.000
Benign Prostatic Hypertrophy	12 (11.32)	9 (11.84)	3 (10)	1.000
Smoking[e]	49 (46.23)	35 (46.05)	14 (46.67)	1.000
Acute Kidney Injury[f]	41 (38.68)	30 (39.47)	11 (36.67)	0.828
Chronic Kidney Disease[f]	31 (29.25)	21 (27.63)	10 (33.33)	0.637
Gout/Hyperuricemia	2 (1.89)	0	2 (6.67)	0.078
Solitary kidney	1 (0.94)	1 (1.32)	0	1.000
OR (h)[g]	1 (0–1)	0.3 (0–1)	1 (0–2)	**0.009**
OR				
No surgical intervention	12 (11.32)	11 (14.42)	1 (3.33)	0.172
PCN	6 (5.66)	3 (3.95)	3 (10)	0.348
DJ stent insertion, B	32 (30.19)	25 (32.89)	7 (23.33)	0.481
Cystostomy	2 (1.89)	0	2 (6.67)	0.078
TURP	8 (7.55)	3 (3.95)	5 (16.67)	**0.039**
Indwelling catheter	39 (36.79)	25 (32.89)	14 (46.67)	0.263
Lithotripsy	2 (1.89)	2 (2.63)	0	1.000
s/p DJ stent insertion, unilateral	3 (2.83)	0	3 (10)	**0.021**
Others	8 (7.55)	6 (7.89)	2 (6.67)	1.000
BMI[h]				**<0.001**
Underweight	5 (4.76)	4 (5.33)	1 (3.33)	
Normal	55 (52.38)	49 (65.33)	6 (20)	
Overweight	28 (26.67)	11 (14.67)	17 (56.67)	
Obese	17 (16.19)	11 (14.67)	6 (20)	

[a] *includes nephrolithiases (such as staghorn calculi), urolithiases in any part of the urinary tract.*
[b] *genitourinary tuberculosis, neurologic pathologies (such as neurogenic bladder, DM cystopathy), blood clots and pelvic inflammatory disease among females*
[c] *pertains to the number of days from the time of obstructive symptoms until any interventions to remove obstruction.*
[d] *pertains to the number of days with post-obstructive diuresis until resolution.*
[e] *any smoking history (not specific with pack years)*
[f] *defined by the KDIGO guidelines of Acute Kidney Injury and Chronic Kidney Injury*
[g] *type and duration of operation/surgery/intervention done to relieve the obstruction*
[h] *based on the Asia Pacific Classification of Body Mass Index (BMI).*
Acronyms: PCN—Percutaneous Nephrolithotomy, DJ—Double J, TURP—Transurethral Resection of Prostate, BMI—Body Mass Index

years, with proper disposal afterward: hard copies were shredded and soft copies were deleted. Flash drives would be reformatted.

Benefits

No direct benefits were given to patients. However, the study's results could advance the understanding and management of POD in similar patients.

Risks

Patients faced no direct risks except for potential breaches in confidentiality. However, the risk was minimized by following the Data Privacy Act of 2012.

Conflict of Interest

There was no conflict of interest.

RESULTS

After retrieving records of patients previously admitted at the University of Santo Tomas Hospital in 2018 using the search terms mentioned above, a total of 182 charts were retrospectively reviewed. Of these, only 106 had any of the following: bilateral ureteral obstruction, bladder outlet/urethral obstruction (including prostate pathologies), or unilateral obstruction on a patient with a solitary kidney. Among these patients, the incidence of POD was 28.3% (*n=30*).

Clinical Profile of Post-Obstructive Diuresis (POD)

The mean age of patients who had POD was 58 years old, ranging from 44 to 72 years. Those patients who did not have POD had an almost equal mean age of 58 years. There was no significant difference between these two groups with regard to age (p = 0.967). The majority of patients diagnosed with POD were male, comprising 63.33% (*n=19*) of the group. Female gender, on the other hand, predominates patients who did not develop POD at 51.32%.

Comorbid illnesses among patients who had POD were likewise identified. The three most common illnesses were smoking, AKI and chronic kidney disease (*n=14, 11, 10*, respectively). Less commonly, other comorbidities included hypertension, diabetes mellitus and urinary tract infection. Body mass index (BMI) was also calculated among POD patients. In the POD group, the majority belonged to the overweight classification (56.67%, *n=17*) as compared to those in the non-POD group, in which most have a normal BMI (65.33%, *n=49*) [p = <0.001].

Diagnoses identified from the data review include lithiasis, benign prostatic hypertrophy/enlargement (BPH), prostate cancer, urinary tract infection causing acute urinary retention, ureteral/urethral stricture, obstruction from lymph nodes and cancer infiltrations. The most common condition leading to POD after decompression is lithiasis in any part of the urinary tract (eg, bilateral staghorn calculi, bilateral ureteral lithiasis, unilateral lithiasis in a solitary kidney, and less commonly, bladder lithiasis). Thirty-three percent (33%) of patients developed POD after an intervention to relieve obstruction. The second most common diagnosis for POD patients was prostate cancer (26.67%, n=8). Obstructions in the ureters or urethra did not lead to POD after intervention, nor did lymph node obstruction. Most obstructions from lithiasis are nephrolithiasis, primarily bilateral staghorn calculi.

Ten percent (10%) of POD patients had obstruction secondary to BPH (n=3) and 3.33% (n=1) had acute urinary retention due to urinary tract infection that led to POD after Foley catheter insertion.

Other less common diagnoses associated with POD include genitourinary tuberculosis (GUTB), neurologic pathologies (eg, neurogenic bladder, DM cystopathy), retained blood clots and unspecified pelvic inflammatory disease in females. Decompressive interventions, such as indwelling Foley catheters, bilateral DJ stent insertion, or other invasive procedures, were used to relieve obstruction. The most common intervention was the insertion of an indwelling Foley catheter with hourly urine output monitoring (46.67%, n=25). This was followed by bilateral or unilateral DJ stents. There was a significant difference in DJ stent insertion rates between POD and non-POD groups (p = 0.021), with all unilateral kidney DJ stent insertions leading to POD (10%, n=3).

The duration of obstruction was analyzed, showing that POD patients had significantly longer obstruction durations than those without POD (p =

Table 2: Renal Profile of Patients Diagnosed with Post-Obstructive Diuresis (POD)

	Total (n=106)	Without POD (n=76, 71.7%)	With POD (n=30, 28.3%)	P-value
	Frequency (%); Mean ± SD			
Blood Urea Nitrogen	43.97 ± 31.13	46.06 ± 34.49	38.4 ± 24.86	0.736
Arterial pH	7.40 ± 0.06	7.39 ± 0.05	7.42 ± 0.08	0.468
Arterial HCO3 level	19.59 ± 5.62	20.81 ± 5.38	18.36 ± 6	0.434
Urine pH	6.38 ± 0.99	6.28 ± 1.02	6.58 ± 0.92	0.278
Urine specific gravity	1.01 ± 0.03	1.02 ± 0.04	1.01 ± 0.005	0.322
Urine albumin	1.18 ± 1.29	1.17 ± 1.36	1.2 ± 1.2	0.928
Acute Kidney Injury[a]				**0.004**
With	43 (40.57)	24 (31.58)	19 (63.33)	
Without	63 (59.43)	52 (68.42)	11 (36.67)	
Baseline[b]				
Creatinine	1.31 (0.95–2.45)	1.2 (0.87–2.29)	1.93 (1.28–3.1)	**0.003**
Sodium	138 (133–141)	136.5 (132–140)	140 (136–142)	**0.008**
Potassium	4.02 (3.6–4.56)	4.03 (3.60–4.62)	3.94 (3.7–4.4)	0.755
eGFR[c]	52.9 (22.4–78.4)	59.2 (23.9–83.3)	35.6 (15.7–58.6)	**0.008**
Ionized Calcium	1.24 (1.16–1.29)	1.24 (1.13–1.3)	1.23 (1.21–1.27)	0.879

[a] *based on the Acute Kidney Injury criteria of the KDIGO*
[b] *serum levels upon admission and prior to decompression*
[c] *creatinine clearance based on CKD-EPI (Expressed in mL/min/1.73m²)*

0.049). The average duration of obstruction before intervention in the POD group was 14 days (range: 4–30 days). Most patients who did not develop POD had less than seven days of obstruction.

Renal Profile of Post-Obstructive Diuresis (POD)

Serum creatinine, sodium, potassium, ionized calcium and urea nitrogen were analyzed and correlated among these patients. Arterial pH, arterial bicarbonate level and urine pH, specific gravity and albumin were also recorded.

In general, most patients with obstructive uropathy did not have baseline AKI (59.43%, n=63). However, a majority of those who developed POD after decompression had an initial AKI upon admission (63.33%, n=19). The incidence of AKI in the POD group was significantly higher compared to the non-POD group ($p = 0.004$). Similarly, serum creatinine levels were significantly higher in the POD group ($p = 0.003$), with a mean of 1.93 (range: 1.28–3.1). Consequently, those with lower eGFR levels had a significantly higher incidence of POD ($p = 0.008$), with the average eGFR in the POD group being 35.6 mL/min/1.73m^2 (range: 15.7–58.6).

Serum sodium levels also differed significantly between the POD and non-POD groups ($p = 0.008$). Although still within normal range, baseline sodium levels were higher in the POD group (mean: 140 mmol/L, range: 136–142) compared to the non-POD group (mean: 136.5 mmol/L). There was no significant difference in serum potassium levels between the two groups, with mean values of 3.94 in the POD group and 4.03 in the non-POD group. Ionized calcium levels were similar in both groups, though only 20 records had baseline ionized calcium levels.

BUN was not routinely measured at baseline in obstructive uropathy patients, with only 11 patients having reference BUN levels upon admission. Among those with available results, BUN levels were not significantly different between the POD and non-POD groups ($p = 0.736$).

For a limited number of patients with arterial blood gas on admission, no significant differences in pH ($p = 0.468$) or bicarbonate levels ($p = 0.434$) were observed. The average arterial pH for POD patients was 7.42 ± 0.08, while the POD group had lower serum bicarbonate levels (18.36 ± 6), though this was not statistically significant ($p = 0.434$).

Urine pH and specific gravity were also assessed. Urine pH was more alkaline in those who developed POD (mean: 6.58 ± 0.92), but this was not statistically significant ($p = 0.278$). No significant differences in urine specific gravity (p = 0.322) or urine albumin (p = 0.928) were found between the groups.

Predictors of Post-Obstructive Diuresis (POD)

To identify potential predictors of POD, associations between clinical and renal profiles were analyzed. Age did not significantly correlate with POD risk (OR 0.99, 0.97–1.03; p = 0.967). Gender was also not a significant risk factor for developing POD (p = 0.176).

Among various diagnoses, only obstruction secondary to prostate cancer was significantly associated with POD. Patients with prostate cancer who had obstruction were 5.2 times more likely to develop POD after an intervention (p = 0.011). Other diagnoses, such as benign prostatic hypertrophy, lithiasis and ureteral stricture were not significantly associated with POD.

The number of days of obstruction was also a significant predictor of POD. For each additional day of obstruction, the odds of developing POD after obstruction relief increased by 1% (p = 0.042). No specific comorbid conditions or body mass index (BMI) classifications were found to be significantly associated with increased POD risk.

This analysis suggests that AKI, lower eGFR, higher serum sodium levels, longer duration of obstruction and prostate cancer are important factors in predicting POD. However, other clinical and biochemical markers, such as potassium, calcium and BUN levels were not found to be significant predictors in this cohort.

The renal profile was analyzed for possible predictors of POD. Table 3 shows different renal parameters and their association with the development of POD.

The study showed that for every unit that rises in the level of eGFR, the odds of having POD decreased by 2% (p,= 0.009). The levels of serum sodium, potassium, ionized calcium and urea, although significantly higher in POD, could not be used to predict the development of POD. Arterial blood gas and urinalysis could not be used to determine any risk factors for having POD.

A baseline AKI was significantly associated with subsequent POD after a decompression (p = 0.004). Obstructive uropathy/nephropathy patients without AKI had 73% odds of not having POD compared to patients with AKI. Hence, an AKI increases likelihood of the patient consequently developing POD. On the other hand, no significant association was determined between chronic kidney disease and POD.

Table 3: Risk Factors Associated with Post-Obstructive Diuresis (POD)

Factors	Odds ratio (95% CI)	P-value
Age	0.99 (0.97 to 1.03)	0.967
Sex		
Male	(reference)	-
Female	0.55 (0.23 to 1.31)	0.176
Case		
Lithiasis[a]	(reference)	
Benign Prostatic	3.9 (0.68 to 22.32)	0.126
Hypertrophy	5.2 (1.47 to 18.44)	**0.011**
Prostate CA	0.65 (0.07 to 6.03)	0.705
Urinary Tract Infection	-	-
Ureteral/Urethral	-	-
Stricture	1.82 (0.59 to 5.66)	0.301
Lymph Node Involvement	1.3 (0.12 to 13.87)	0.828
Other causes of		
obstruction[b]		
Cancer Metastases		
Duration of obstruction (d)[c]	1.01 (1.001 to 1.02)	**0.042**
Comorbid Illnesses		
Hypertension	1.18 (0.37 to 3.75)	0.777
Diabetes Mellitus	1.86 (0.60 to 5.78)	0.283
Urinary Tract Infection	1.28 (0.11 to 14.62)	0.845
Benign Prostatic	0.83 (0.21 to 3.29)	0.778
Hypertrophy	1.03 (0.44 to 2.39)	0.954
Smoking[d]	0.88 (0.37 to 2.13)	0.789
Acute Kidney Injury[e]	1.31 (0.53 to 3.25)	0.562
Chronic Kidney Disease[e]	-	-
Gout/Hyperuricemia	-	-
Solitary kidney		
BMI[f]		
Underweight	(reference)	-
Normal	0.49 (0.05 to 5.13)	0.552
Overweight	6.18 (0.61 to 62.83)	0.124
Obese	2.18 (0.20 to 24.21)	0.525

[a] *includes nephrolithiases (such as staghorn calculi), urolithiases in any part of the urinary tract*
[b] *genitourinary tuberculosis, neurologic pathologies (such as neurogenic bladder, DM cystopathy), blood clots and pelvic inflammatory disease among females*
[c] *pertains to the number of days from the time of obstructive symptoms until any interventions to remove obstruction*
[d] *any smoking history (not specific with pack years)*
[e] *defined by the KDIGO guidelines of Acute Kidney Injury and Chronic Kidney Injury*
[f] *based on the Asia Pacific Classification of Body Mass Index (BMI).*

Types of Intravenous Fluid and POD

All of the patients whose charts were reviewed had IVF even before an intervention, and these

Table 4: Renal Factors Associated with Post-Obstructive Diuresis (POD)

Factors	Odds ratio (95% CI)	P-value
Blood Urea Nitrogen	0.99 (0.95 to 1.04)	0.705
Baseline[a]		
Serum Creatinine	1.18 (0.93 to 1.49)	0.176
Serum Sodium	1.07 (0.99 to 1.15)	0.067
Serum Potassium	0.82 (0.46 to 1.47)	0.508
eGFR	0.98 (0.97 to 0.995)	**0.009**
Ionized Calcium	0.36 (0.003 to 37)	0.667
Arterial pH	909 (0.0002 to 2890)	0.440
Arterial HCO3	0.92 (0.74 to 1.13)	0.407
Urine pH	1.37 (0.78 to 2.43)	0.274
Urine Specific Gravity	0.05 (0.005 to 3.23)	0.053
Urine Albumin	1.02 (0.67 to 1.56)	0.926
Acute Kidney Injury[b]		
Without	0.27 (0.11 to 0.65)	**0.004**
With	(reference)	-

[a] *serum levels upon admission and prior to decompression*
[b] *based on the Acute Kidney Injury criteria of the KDIGO*

The study specifically aims to identify if there is a significant difference between those who developed POD with PNSS as IVF upon admission and those who were started on PLRS. However, there was no significant difference between the two groups. Also, the study showed that the choice of IVF did not significantly predict POD (p = 0.285).

Among patients who developed POD, IVF was continued, adjusted and modified according to the levels of repeat serum electrolytes. The length of hospital stay and days with polyuria were analyzed against the choice of IVF, whether or not IVF alters the previous or not. The use of normal saline solution was inversely related to the length of hospital stay (*r -0.2502*), but the association level was weak. It also showed a longer day with polyuria, but the association was directly weak (*r 0.1416*). The choice of IVF, therefore, did not significantly alter the course of patients with POD.

There was no significant difference between the choice of IVF and length of hospital stay (p = 0.452), as shown in Table 7. On average, most of the IVF use in POD patients had a length of seven hospital days. In this light, IVF could not be used to predict hospital stays or help decrease the course in the ward.

IVFs were also studied to determine whether using a specific type would decrease the incidence of electrolyte imbalance during ongoing management of POD. Table 7 shows us the rate of electrolyte

Table 5: Choice of Intravenous Fluids Among Obstructive Uropathy Patients

	Total (n=106)	Without POD (n=76, 71.7%)	With POD (n=30, 28.3%)	P-value
	Frequency (%); Mean ± SD			
Intravenous Fluid*				0.32
PNSS	84 (79.25)	63 (82.89)	21 (70)	
D5NSS	6 (5.66)	4 (5.26)	2 (6.67)	
PLRS	9 (8.49)	4 (5.26)	5 (16.67)	
Hypertonic Solution	3 (2.83)	2 (2.63)	1 (3.330)	
D5NM	4 (3.77)	3 (3.95)	1 (3.33)	

**categories based on available data upon chart review*
PNSS plain normal saline solution; D5NSS 5% dextrose in normal saline solution; PLRS plain lactaded Ringer's solution; D5NM 5% dextrose in Normosol-M solution

Table 6: Correlation Between Intravenous Fluid[a] and the Patients' Course

Variables	Correlation coefficient	Level of association	P-value
Length of hospital stay (days)	-0.2502	Inversely weak	0.182
Polyuric state (days)	0.1416	Directly weak	0.455

[a] *IVF used for analysis was plain normal saline solution*

IVF were maintained during the episodes of polyuria.

The most common choice of IVF among patients admitted for obstructive uropathy or nephropathy was plain NSS, with the rest of the IVF comprising only 16% of the total cases. The second most commonly used IVF was the lactated Ringer's solution for both groups. But, there were no significant differences regarding the choice of IVF between the two groups (p = 0.32).

Table 7: Correlation Between Choice of IVF and Length of Hospital Stay

Variables	PNSS (n=21)	D5NSS (n=2)	PLRS (n=5)	Hypertonic (n=1)	D5NM (n=1)	P-value
	Median (IQR)					
Length of hospital stay (days)	8 (7 to 14)	7 (5 to 9)	7 (7 to 12)	7	5	0.452

Table 8: Correlation Between Choice of IVF and Potassium Levels[a]

	PNSS (n=84)	D5NSS (n=6)	PLRS (n=9)	H[b] (n=3)	D5NM (n=4)
Baseline					
With hypokalemia	13 (15.48)	2 (33.33)	0	2 (66.67)	0
Without hypokalemia	71 (84.52)	4 (66.67)	9 (100)	1 (33.33)	4 (100)
Postoperative					
With hypokalemia	11 (21.57)	0	1 (20)	0	0
Without hypokalemia	40 (78.43)	4 (100)	4 (80)	1 (100)	2 (100)

[a] *Normal level defined as 3.5-5.5 mmol/L*
[b] *Use of Hypertonic Solution such as 3% NaCl or incorporation of at least 50 mEqs NaCl in the IVF*

Table 9: Correlation Between Fluid Replacement and Hospital Stay

	With replacement (n=14)	Without replacement (n=16)	P-value
	Median (IQR)		
Polyuric state (days)	6 (3 to 17)	2 (1 to 8)	**<0.001**
Length of hospital stay (days)	7.5 (6 to 19)	8 (6 to 10)	0.801

Table 10: Correlation Between POD and Decompressive Techniques

Factors	Odds ratio (95% CI)	P-value
Duration of procedure (h)	1.64 (1.08 to 2.49)	**0.021**
Procedure		
No surgical intervention	0.20 (0.03 to 1.65)	0.136
PCN	2.70 (0.51 to 14.22)	0.240
DJ stent insertion, B	0.62 (0.23 to 1.64)	0.337
Cystostomy	-	-
TURP	4.87 (1.08 to 21.85)	**0.039**
Indwelling catheter	1.79 (0.75 to 4.23)	0.188
Lithotripsy	-	-
s/p DJ stent insertion, unilateral	0.83 (0.16 to 4.38)	0.829
Others	-	-

Acronyms: PCN—Percutaneous Nephrolithotomy, DJ—Double J, TURP—Transurethral Resection of Prostate

imbalances after decompression and with the use of specific IVFs. None of the patients had a significant change in serum sodium levels with any of the IVFs. However, some patients developed hypokalemia post-procedure or postoperatively while ongoing polyuria.

Most patients did not have baseline hypokalemia upon admission. For those who presented with baseline hypokalemia, normal saline solution was still the initial IVF of choice (15.48%, *n=13*). None of those hydrated with plain lactated Ringer's solution had an initial low potassium level. The correlation on whether the use of specific types of IVF among POD patients could not be done since most of the patients did not have repeat serum electrolytes,

Table 11: Comparison of Outcomes Between POD and Non-POD Groups

	Total (n=106)	Without POD (n=76, 71.7%)	With POD (n=30, 28.3%)	P-value
	Frequency (%); Mean ± SD			
Length of hospital stay (days)	7 (4–10)	5 (4–10)	8 (6–12)	**0.004**
Polyuric state (days)	0 (0 to 1)	0	4 (2 to 6)	**<0.001**
Baseline[a]				
Serum Creatinine	1.31 (0.95–2.45)	1.2 (0.87–2.29)	1.93 (1.28–3.1)	**0.003**
Serum Sodium	138 (133–141)	136.5 (132–140)	140 (136–142)	**0.008**
Serum Potassium	4.02 (3.6–4.56)	4.03 (3.60–4.62)	3.94 (3.7–4.4)	0.755
eGFR[b]	52.9 (22.4–78.4)	59.2 (23.9–83.3)	35.6 (15.7–58.6)	**0.008**
Ionized Calcium	1.24 (1.16–1.29)	1.24 (1.13–1.3)	1.23 (1.21–1.27)	0.879
Postoperative				
Serum Creatinine	1.70 (1.07–2.36)	1.59 (0.99–2.6)	1.81 (1.13–2.13)	0.861
Serum Sodium	139 (134–141)	139 (134–141)	138 (134–139)	0.544
Serum Potassium	4.1 (3.6–4.4)	4.11 (3.59–4.36)	4.08 (3.65–4.4)	0.800
eGFR	40.1 (25.6–66.5)	40.6 (22.4–61.5)	37.4 (32.3–70.8)	0.593
Ionized Calcium	1.14 (1.12–1.26)	1.4	1.19 (1.12–1.26)	1.000
P-value (comparison from baseline to postoperative)				
Serum Creatinine	**0.007**	0.880	**0.001**	
Serum Sodium	0.557	0.078	0.299	
Serum Potassium	0.131	0.119	0.686	
eGFR	**0.023**	**0.001**	0.966	
Ionized Calcium	0.317	-	0.317	

[a] *serum levels upon admission and prior to decompression*
[b] *based on CKD-EPI formula*

hence lacking data for comparison. Nevertheless, the levels of serum electrolytes postoperatively among POD patients will be discussed in the section below.

Fluid Replacement

In some of the patients, additional fluid was given on top of the IVF. Options included ORS-75 or pLRS/PNSS/0.45% replacement via intravenous route. A total of 15 patients were given additional fluid replacement, 86% of these were replaced with pLRS using a specific formula: Volume replacement of pLRS (mL) = [Urine output above 200 mL (mL) x 0.75]. None of the patients who were given this kind of replacement developed imbalances in sodium and potassium.

The course of patients with POD did not vary significantly with or without fluid replacement as mentioned above. There may seem to be a significant difference in the days of polyuria between those with and without additional fluid replacement. This difference may be attributed in that most patients given added fluids were already on prolonged polyuria prior to initiation. It, too, did not shorten nor prolong the day of hospital stay as compared to those who only had IVF for replacement.

Correlation Between POD and Interventions

As mentioned in prior sections, several interventions could be done to relieve the obstruction. In the majority of patients, only insertion of an indwelling catheter was needed to relieve the obstruction. This intervention, however, was not statistically significant to correlate to POD in the later course in the ward.

Significantly, patients who had obstruction and underwent transurethral resection of prostate (TURP) had a higher chance of having POD (4.87, *1.08-21.85*) as compared to other interventions ($p = 0.039$). This is compatible with the initial finding of a significant association between those who had obstruction secondary to prostate malignancy and the development of POD.

The average time (hours) of surgery of patients who had POD is 1 (0-2) and is significantly longer

Table 12: Incidence of Electrolyte Imbalance in POD after an Intervention

	Total (n=106)	Without POD (n=76, 71.7%)	With POD (n=30, 28.3%)	P-value
	Frequency (%); Mean ± SD			
With Hypokalemia (<3.5 mmoL/L) Postoperative	12 (19.05)	7 (18.42)	5 (20)	1.000
With Hypernatremia (>145 mmol/L) Postoperative	1 (1.59)	1 (2.63)	0	1.000
With Hyponatremia (<135 mmol/L) Postoperative	62 (98.41)	37 (97.37)	25 (100)	1.000

than those without POD, whose average hours of operation (OR) is 0.3 (p = 0.009). Likewise, the procedure's duration is a significant risk factor for the development of POD (p = 0.021). For every hour increase in OR, the odds of having POD increase by 64%.

Renal Outcome of Post-Obstructive Diuresis (POD)

There was a significant improvement in serum creatinine levels after the procedure (p = 0.001). There was also an expected increase in the eGFR (p = 0.966).

Table 10 shows that there is no significant difference between the baseline and postoperative values of serum sodium, potassium and ionized calcium. Looking at hospital courses, patients with POD have significantly longer hospital stays compared to the non-POD cohort (p = 0.004), with the former averaging to about 8 (6-12) days.

None of the POD patients had a further elevation of serum creatinine or decline in eGFR post-procedure.

There were only a total of five patients who had hypokalemia in the POD group, and this was not significantly different from those without diuresis. None of the POD patients had hypernatremia. Instead, most had hyponatremia after days with polyuria after the removal of the obstruction. However, P-values showed that POD did not lead to significant electrolyte imbalance compared to those without POD.

All of the patients diagnosed with POD improved and were discharged stable and with resolution of polyuria. Only one had an emergency renal replacement therapy, but it was only acute and was subsequently off hemodialysis. Except for prolonged hospital stays, no other morbidities were noted.

DISCUSSION

POD refers to the prolonged urine production of at least 200 mL per hour for two consecutive hours following the relief of urinary retention or obstruction, such as with a Foley catheter, nephrostomy, or double-J stent for ureteric obstructions.[9] The incidence of POD remains unclear, but estimates range from 0.5-52% after decompression.[1] This study found an incidence of 28.3%, with male predominance and an average age of 58 years. Many affected patients had comorbidities such as smoking, AKI, CKD and were overweight.

Common causes of obstruction leading to POD include phimosis, prostatic hyperplasia, meatal stenosis, urinary stones, posterior urethral valves, blocked Foley catheters, urological cancers (eg, prostate cancer), fecal impaction, diabetes and neurogenic disorders.[2] Among the reviewed records, 33% of patients with POD had urolithiasis (including bilateral staghorn calculi). The most significant association was with prostate malignancy, which increased the risk of POD by 5.2%. No previous studies have linked prostate cancer directly to POD.

Patients with POD had significantly longer obstruction durations, averaging 14 days, compared to 7 days in non-POD cases. The risk of POD increased with obstruction lasting two weeks or more. A 2018 case by Shankel documented a pediatric patient developing massive POD after one week of obstruction, a rare finding in literature.[16]

The most common intervention for relieving obstruction was Foley catheter insertion, although a significant association was found between TURP and POD, likely due to the higher incidence of prostate cancer in the POD group. This suggests a relationship between prostate cancer and the development of POD.

Several mechanisms have been proposed to explain POD, but none have been conclusively proven. One hypothesis involves impaired renal concentration and decreased sodium reabsorption after prolonged obstruction. This may lead to electrolyte imbalances due to leakage of potassium, magnesium and phosphorus.[9] A study by Halbgewachs and Domes (2015) proposed a combination of factors, including reduced medullary concentration gradients, decreased glomerular filtration rate and impaired response to antidiuretic hormone as causes of POD.[1] Our study did not find significant differences in specific gravity or urine pH between POD and non-POD groups, suggesting that the kidneys' ability to concentrate or acidify urine is not a primary factor.

Another theory is that POD arises from the pathophysiology of acute renal failure, which includes elevated serum creatinine, uric acid, hyperkalemia and metabolic acidosis.[9] Patients presenting with AKI before decompression had a significantly higher risk of developing POD, as evidenced by higher serum creatinine levels and lower eGFR in the POD group. A similar study by Hamdi identified high serum creatinine, sodium bicarbonate levels and urinary retention as independent risk factors for POD after decompression.[8] Our study confirmed that higher serum creatinine levels (mean 1.93 mg/dL) were associated with an increased risk of POD, whereas patients without POD had lower creatinine levels (mean 1.2 mg/dL). Lower baseline eGFR was also a predictor of POD, although bicarbonate levels did not show significant correlation with POD.

Serum sodium levels were notably higher in the POD group, with an average of 140. This suggests that sodium balance may be disrupted in these patients, though it was not correlated with the severity of POD. Identifying patients at higher risk for POD allows for better prevention of complications like severe dehydration, electrolyte imbalances and hypovolemic shock, which, if untreated, can be fatal.[9]

The average duration of polyuria in POD patients was 96 hours, significantly longer than the 48-hour diuretic phase observed in other studies such as Harrisons, et.al.[9] Despite IVF and electrolyte replacements, this phase remains critical for managing dehydration and potential renal injury. Monitoring fluid balance and electrolytes is essential during this phase.[1,2,4,5,7]

IVF management typically involves replacing urine output above 200 mL per hour, with most patients receiving lactated Ringer's solution (pLRS). One study showed that this approach significantly reduced the incidence of electrolyte imbalances, including hypokalemia.

Most fluids administered were normal saline (0.9%), although other IVF types, such as lactated Ringer's, D5NM and hypertonic solutions were also used. The choice of IVF did not significantly impact the course of POD or length of hospital stay. Notably, patients who received pLRS showed no significant electrolyte imbalances despite prolonged polyuria, unlike those receiving other fluids. This could explain the lower incidence of hypokalemia and AKI in the POD group. Excessive fluid replacement, however, might prolong diuresis, as indicated in some studies.

Hospital stay was prolonged for POD patients, with an average of eight days compared to five days for non-POD patients. This extended stay may contribute to increased healthcare costs. Despite this, POD resolution led to improvements in eGFR and reductions in serum creatinine, with no significant electrolyte imbalances. Importantly, there were no deaths related to POD in this cohort.

In summary, factors such as longer obstruction duration, prostate cancer, AKI and lower baseline eGFR were identified as significant risk factors for POD. These findings can help predict which patients are at greater risk, allowing for more targeted interventions. By monitoring fluid balance, electrolytes and renal function closely, complications from POD can be minimized, improving patient outcomes and reducing the associated healthcare burden.

CONCLUSION

The incidence of POD was 28.3%, with a mean age of 58 years and male predominance. The most frequently associated comorbid conditions include smoking, AKI and chronic kidney injury. There were also significant proportions of overweight patients in the POD group. Patients with POD had the following significant baseline renal profiles compared to the non-POD group:

higher levels of serum creatinine, higher levels of serum sodium and lower eGFR values. Risk factors associated with POD included a baseline AKI, relief of obstruction from prostate cancer and longer days of obstruction. Decompression via TURP was significantly associated with POD, and the longer duration of OR increases the risk of it as well. There was no significant difference between the use of different IVF and the length of hospital stay, days of polyuria and electrolyte imbalance. This is true with additional fluid replacement with pLRS as well. In terms of outcome, all patients improved with hydration. There were no significant electrolyte imbalances; however, the hospital stay was longer.

Limitations and Recommendations

Although the study population is comparable to recent and popular works of literature on POD, the study still needs a population for better power. Hence, we recommend a more extensive review of charts by extending the involved years. Also, since it is a relatively rare entity, a prospective study could be done in order to better follow the course and also to be able to work the patient up appropriately.

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