Predicting Parameters of Renal Function Recoverability After Obstructive Uropathy Treatment in Adults

William Saputra Wijaya,[1] Gampo Alam Irdam,[2] Fakhri Rahman[2]*

[1] Department of Urology, Adam Malik Hospital, Faculty of Medicine Universitas Indonesia, Jakarta, Indonesia.
[2] Department of Urology, Faculty of Medicine Universitas Indonesia - Cipto Mangunkusumo Hospital, Jakarta, Indonesia.

** Corresponding Author:*
Gampo Alam Irdam, MD. Department of Urology, Dr. Cipto Mangunkusumo Hospital. Jl. Diponegoro no. 71, Jakarta 10430, Indonesia. E-mail: gampo.alam@yahoo.com.

ABSTRACT

Obstructive uropathy can have many causes and can manifest as supravesical, vesical, or infravesical levels of obstruction. Treatment of obstructive uropathy, whether definitive or temporary, has a risk of complications or could worsen the patient's quality of life. Thus, knowledge of the parameters that predict recoverability of renal function after obstructive uropathy treatment is essential for patients and their families. Several studies have evaluated many factors that might potentially predict recoverability of renal function after obstruction release and these essentially are divided into factors predicting unilateral or bilateral obstruction. Almost all unilateral obstruction studies used ureteropelvic junction obstruction cases as their subjects and utilized nuclear scan renography to evaluate kidney recoverability. Factors confirmed as predicting factors for recoverability of renal function were age, hemoglobin level, BUN-to-creatinine ratio, postoperative urine volume and sodium excretion, cortical thickness, type of renal pelvis, hydronephrosis grade, corticomedullary differentiation, parenchymal echogenicity, renal resistive index, and initial kidney function. Thus, these studies all had different criteria for defining the recovery of renal function, and this might explain the differences observed from study to study.

Keywords: *Hydronephrosis, obstructive uropathy, predicting factor, recoverability, renal function.*

INTRODUCTION

Hydronephrosis is a term used to describe a dilated renal pelvis, with or without involvement of its calyces, and might arise due to a physiological or pathological condition.[1] In the physiological situation, a dilatation of a urinary tract structure can occur following events such as diuresis, increased intra-abdominal pressure (e.g., straining), or the influence of gravity.[2] This dilatation is essential to allow efficient urine expulsion from the renal pelvis.[2,3] However, in a pathological condition, also known as obstructive uropathy, a dilatation of the urinary tract structure happens in response to obstruction at the supravesical, vesical, or infravesical level.[4–7]

In women, obstructive uropathy can occur due to pelvic organ prolapse.[8–10] In men, hydronephrosis may follow a benign prostatic obstruction.[11] Regardless of gender, other common causes of obstructive uropathy include urinary tract stone disease, urothelial carcinoma, other malignancies, and neurogenic bladder.[4,5,12] To a lesser degree, obstructive uropathy can also be induced by infection, drug administration, and radiotherapy.[13–15] Therefore, complaints related to obstructive uropathy may vary depending on the underlying cause.[16] The presence of obstructive uropathy is also crucial in determining the prognosis and disease progression.[17–19]

If obstructive uropathy is not suitably treated, it may cause irreversible structural changes and deteriorate renal function.[20,21] Irrespective of the cause of the obstruction, optimal urine diversion is a mainstay in addition to definitive treatment and is performed using an indwelling catheter, double-J stent (DJ stent), or nephrostomy tube according to the obstruction location. However, the use of a urine diversion method, and specifically the DJ stent insertion and the nephrostomy tube, often harms the patient's quality of life (QoL).[22] Moreover, urine diversion does not provide a complete guarantee of return of full renal function after definitive treatment. This could be due to the occurrence of other pathological processes that affect kidney function in addition to obstructive uropathy. The duration of urinary tract obstruction is mostly unknown, especially in silent ureteral stone disease or malignancy.[20,23]

The risk of complications associated with definitive treatment or urinary diversion, as well as the possibility of worsening the patient's QOL by urinary diversion, necessitate thorough discussion with the patient and family, especially regarding disease prognosis. Therefore, knowledge of the parameters that could predict renal function recoverability after obstructive uropathy treatment is essential. The aim of this review is to explore those parameters based on the currently available literature.

EFFECTS OF OBSTRUCTIVE UROPATHY ON THE KIDNEY

Acute kidney injury (AKI), or even chronic kidney disease, can occur due to obstructive uropathy, especially with bilateral obstruction.[24] The obstruction effects on the kidney can be influenced by factors such as the duration, extent (partial or complete obstruction), or position (unilateral or bilateral obstruction) of the obstruction, as well as infection and the initial renal function.[25,26] The difference between unilateral ureteral obstruction (UUO) and bilateral ureteral obstruction (BUO) lies in the ureteral pressure and renal blood flow within the acute phase. The total glomerular filtration rate (GFR) is still maintained in UUO and prevents acute kidney injury due to the presence of a functional contralateral kidney; nevertheless, the affected kidney will suffer GFR decrease and tubular damage within five minutes after the onset of the obstruction.[24,27,28] Tubular damage causes kidney tubular dysfunction. Dysfunction of ion transport and urinary acidification is seen in both UUO and BUO. However, the urine concentrating ability due to Aquaporin-2 impairment is more marked in BUO, whereas hypertrophy of the contralateral kidney is seen for compensation in UUO.[27]

Damage from interstitial fibrosis becomes significant following renal obstruction.[24,27,28] Inflammatory cells, such as leukocytes and macrophages, infiltrate in the early stage of obstruction, and they produce several cytokines. Cytokines and vasoactive agents, like Tumor Necrosis Factor α (TNF-α), Transforming Growth Factor β (TGF-β), Angiotensin II, and Interleukin-18, are believed responsible for the occurrence of interstitial fibrosis.[27,29,30] Apoptosis also occurs due to obstructive uropathy and leads to tubular and interstitial atrophy.[29] An animal study has also indicated that fibrosis progression continues even after release of the obstruction.[26]

Microscopically, the apoptosis of tubular and interstitial cells begins as soon as four days after onset of the obstruction and peaks at day 15. Thinning of the kidney parenchymal tissue can be seen within a month. Most experts agree that a kidney obstruction lasting longer than six weeks causes irreversible damage.[27,28] Therefore, any delay in obstruction release can affect long-term renal function.[31]

PERIOPERATIVE PARAMETERS PREDICTING KIDNEY FUNCTION RECOVERABILITY AFTER OBSTRUCTION RELEASE

A summary of the current literature discussing the predicting parameters of recoverability kidney function after obstructive uropathy release in unilateral obstruction is shown in **Table 1**. A similar summary for bilateral obstruction or unilateral obstruction in single kidney patient is shown in **Table 2**. A summary of parameters that are positively correlated with kidney function recoverability after obstruction release is shown in **Figure 1.**

Table 1. Predicting parameters of renal function recoverability after obstructive treatment in unilateral obstruction

Author and year of study	Type of Study and Analysis	Population and Obstructive Treatment	Parameters Studied	Recovery Renal Function Criteria	Results/Conclusion
Harraz et al. (2014)[32]	Retrospective; multivariate analysis	Unilateral UPJO with normal contralateral kidney; Anderson-Hynes dismembered pyeloplasty	- Age - Sex - PO DRF - PO ipsilateral GFR - Cortical thickness - Renal pelvis antero-posterior diameter	Not specified	Lower baseline DRF (<40%) and thicker cortical thickness were predicting parameters for renal function improvement
Liu et al. (2015)[33]	Retrospective; bivariate analysis	Unilateral UPJO with normal contralateral kidney; Anderson-Hynes dismembered pyeloplasty	- PO TTT - PO DRF - Side of affected kidney - Surgery method	> 5% DRF increase compared to basal value using 99mTC-DTPA	PO delayed TTT positively associated with renal function improvement
Li et al. (2018)[34]	Retrospective; multivariate analysis	Unilateral UPJO and normal contralateral kidney; Anderson-Hynes dismembered pyeloplasty	- Age - Gender - BMI - Comorbidity (diabetes, hypertension) - Health-related behavior (alcohol, tobacco) - PO symptom - Affected side - Renal pelvic type (intraparenchymal or extraparenchymal) - Length of narrow segment - Hydronephrosis grade - PHAR - PO renal RI - POR renal RI declined - PO DRF - POR DRF	>10% DRF improvement in affected kidney using 99mTC-MAG3 diuretic renography	Parameters affecting recoverability of renal function, based on bivariate analysis: - Age - History of hypertension - Renal pelvic type - Hydronephrosis grade - PHAR - PO renal RI - 3-, 6-, and 12-month POR renal RI decline - PO DRF Parameters affecting recoverability of renal function in patients < 35 years old, based on multivariate analysis: - Renal pelvic type - Hydronephrosis grade

BMI, body mass index; BCR, BUN-to-creatinine ratio; BUN, blood urea nitrogen; CMD, corticomedullary differentiation; CrCl, creatinine clearance; DRF, differential renal function; GFR: glomerular filtration rate; IPP, intrapelvic pressure; PCN, percutaneous nephrostomy; PHAR, renal parenchyma to hydronephrosis area ratio; PO, preoperative; POR, postoperative; RI, resistive index; TTT, tissue tracer transit; UPJO, ureteropelvic junction obstruction; USG; ultrasonography

Table 1. Predicting parameters of renal function recoverability after obstructive treatment in unilateral obstruction (cont.)

Author and year of study	Type of Study and Analysis	Population and Obstructive Treatment	Parameter Studied	Recovery Renal Function Criteria	Results / Conclusion
					- PHAR - PO renal RI - 12-month POR renal RI decline Parameters affecting recoverability of renal function in patients > 35 years old, based on multivariate analysis: - Renal pelvic type - Hydronephrosis grade - PHAR
Khalaf et al. (2004)[35]	Prospective; multivariate analysis	Unilateral obstructive uropathy with normal contralateral kidney; various treatment	- Parenchymal thickness - Reduction in length of the ipsilateral kidney after treatment - Reduction in width of the ipsilateral kidney after treatment - Parenchymal echogenicity - CMD - Compensatory hypertrophy of the contralateral kidney - PO ipsilateral kidney GFR - Renal perfusion of the ipsilateral kidney (using 99mTC-DTPA) - PO renal RI of the ipsilateral kidney - Changes in the RI of the ipsilateral kidney after treatment	> 5% GFR increase compared to basal value using 99mTC-DTPA	Parameters affecting recoverability of renal function, based on bivariate analysis: - PO ipsilateral kidney GFR - Renal perfusion of ipsilateral kidney - Parenchymal thickness - Parenchymal echogenicity - Corticomedullary differentiation - Changes of RI of ipsilateral kidney after treatment - Compensatory hypertrophy of contralateral kidney Parameters affecting recoverability of renal function, based on multivariate analysis: - Renal perfusion of ipsilateral kidney - PO ipsilateral kidney GFR

BMI, body mass index; BCR, BUN-to-creatinine ratio; BUN, blood urea nitrogen; CMD, corticomedullary differentiation; CrCl, creatinine clearance; DRF, differential renal function; GFR: glomerular filtration rate; IPP, intrapelvic pressure; PCN, percutaneous nephrostomy; PHAR, renal parenchyma to hydronephrosis area ratio; PO, preoperative; POR, postoperative; RI, resistive index; TTT, tissue tracer transit; UPJO, ureteropelvic junction obstruction; USG; ultrasonography

Table 1. Predicting parameters of renal function recoverability after obstructive treatment in unilateral obstruction (cont.)

Author and year of study	Type of Study and Analysis	Population and Obstructive Treatment	Parameter Studied	Recovery Renal Function Criteria	Results / Conclusion
					PO GFR value > 10 ml/min/1.73 m^2 could predict stabilization or improvement of renal function after obstruction release
Ortapamuk et al. (2003)[36]	Prospective; bivariate analysis	Unilateral UPJO with normal contralateral kidney; Anderson-Hynes dismembered pyeloplasty	- Age - Symptom (infection, pain) - PO DRF Parenchymal thickness	>5% DRF improvement in affected kidney using 99mTC-MAG3 diuretic renography, 6 months after surgery	No factor could predict recovery of renal function after obstruction release
Wu et al. (2012)[37]	Retrospective; multivariate analysis	Unilateral > 6 months obstructive uropathy with various causes; various treatment	- Age - Comorbidity (diabetes, hypertension) - Health-related behavior (alcohol, tobacco, drug use) - PO DRF	>7% DRF improvement in affected kidney using 99mTC-MAG3 diuretic renography	Younger age and lower PO DRF could predict > 7% DRF improvement

BMI, body mass index; BCR, BUN-to-creatinine ratio; BUN, blood urea nitrogen; CMD, corticomedullary differentiation; CrCl, creatinine clearance; DRF, differential renal function; GFR: glomerular filtration rate; IPP, intrapelvic pressure; PCN, percutaneous nephrostomy; PHAR, renal parenchyma to hydronephrosis area ratio; PO, preoperative; POR, postoperative; RI, resistive index; TTT, tissue tracer transit; UPJO, ureteropelvic junction obstruction; USG; ultrasonography

Table 2. Predicting parameters of renal function recoverability after obstructive treatment in bilateral obstruction or unilateral obstruction in a single kidney

Author and year of study	Type of Study and Analysis	Population and Obstructive Treatment	Parameter Studied	Recovery Renal Function Criteria	Results/Conclusion
Bundu et al. (2018)[38]	Retrospective; bivariate analysis	Obstructive uropathy patients; treatment not specified	- Obstructive etiology - PO hemoglobin level - PO blood glucose level - PO serum potassium level - PO BCR - Parenchymal thickness	Serum creatinine < 2 mg/dL, 2 months after obstruction release	Parenchymal thickness ≥ 10 mm, hemoglobin ≥ 10 mg/dL, and BCR ≥ 10 positively associated with renal function recoverability
Hussain et al. (1997)[39]	Prospective; bivariate analysis	Obstructive uropathy due to stone disease; PCN	- Kidney size - Degree of hydronephrosis - Cortical thickness - POR urine volume - POR urine pH - POR urinary sodium	Serum creatinine < 3 mg/dL or CrCl > 10 ml/ minute, 3 months after obstruction release	POR urine pH < 6, 2-8 L/24 hours POR diuresis, and POR urinary sodium > 30 mEq/L positively associated with renal function recoverability
Lutaif et al. (2003)[40]	Prospective; bivariate analysis	Obstructive uropathy due to stage III-IV cervical cancer; PCN	- Age - Need for dialysis before PCN - History of radiotherapy treatment - Degree of hydronephrosis - Cortical thickness	Serum creatinine < 1.4 mg/dL, 1 month after obstruction release	Younger age and cortical thickness positively associated with renal function recoverability
Shokeir et al. (2002)[41]	Prospective; bivariate analysis	Obstructive uropathy with anuria; various treatments	- 3-day POR renal RI difference	>20% reduction of serum creatinine value, 3 days after obstruction release	Reduction POR renal RI could predict recovery of renal function after obstruction release Mean difference of renal RI change for good recovery of renal function was 0.14

BMI, body mass index; BCR, BUN-to-creatinine ratio; BUN, blood urea nitrogen; CMD, corticomedullary differentiation; CrCl, creatinine clearance; DRF, differential renal function; GFR: glomerular filtration rate; IPP, intrapelvic pressure; PCN, percutaneous nephrostomy; PHAR, renal parenchyma to hydronephrosis area ratio; PO, preoperative; POR, postoperative; RI, resistive index; TTT, tissue tracer transit; UPJO, ureteropelvic junction obstruction; USG; ultrasonography

Table 2. Predicting parameters of renal function recoverability after obstructive treatment in bilateral obstruction or unilateral obstruction in a single kidney (cont.)

Author and year of study	Type of Study and Analysis	Population and Obstructive Treatment	Parameter Studied	Recovery Renal Function Criteria	Results / Conclusion
Sharma et al (2015)[42]	Prospective; multivariate analysis	Moderate-severe hydronephrosis due to chronic complete ureteral obstruction and had chronic renal failure; PCN	- Infection presentation - PO serum creatinine level - POR Urine pH - Renal length and width - Cortical thickness - Hydronephrosis grade - IPP - PCN output - CMD - Parenchymal echogenicity - Contralateral kidney status	>10% CrCl improvement compared to basal value at 1 month after obstruction release	Parameters affecting recoverability of renal function, based on bivariate analysis: - IPP - PCN output - PO serum creatinine level - Urine pH - Parenchymal echogenicity - Hydronephrosis grade - CMD - Contralateral kidney status Parameters affecting recoverability of renal function, based on multivariate analysis: - CMD - Parenchymal echogenicity - PO serum creatinine level - Contralateral kidney status

BMI, body mass index; BCR, BUN-to-creatinine ratio; BUN, blood urea nitrogen; CMD, corticomedullary differentiation; CrCl, creatinine clearance; DRF, differential renal function; GFR: glomerular filtration rate; IPP, intrapelvic pressure; PCN, percutaneous nephrostomy; PHAR, renal parenchyma to hydronephrosis area ratio; PO, preoperative; POR, postoperative; RI, resistive index; TTT, tissue tracer transit; UPJO, ureteropelvic junction obstruction; USG; ultrasonography

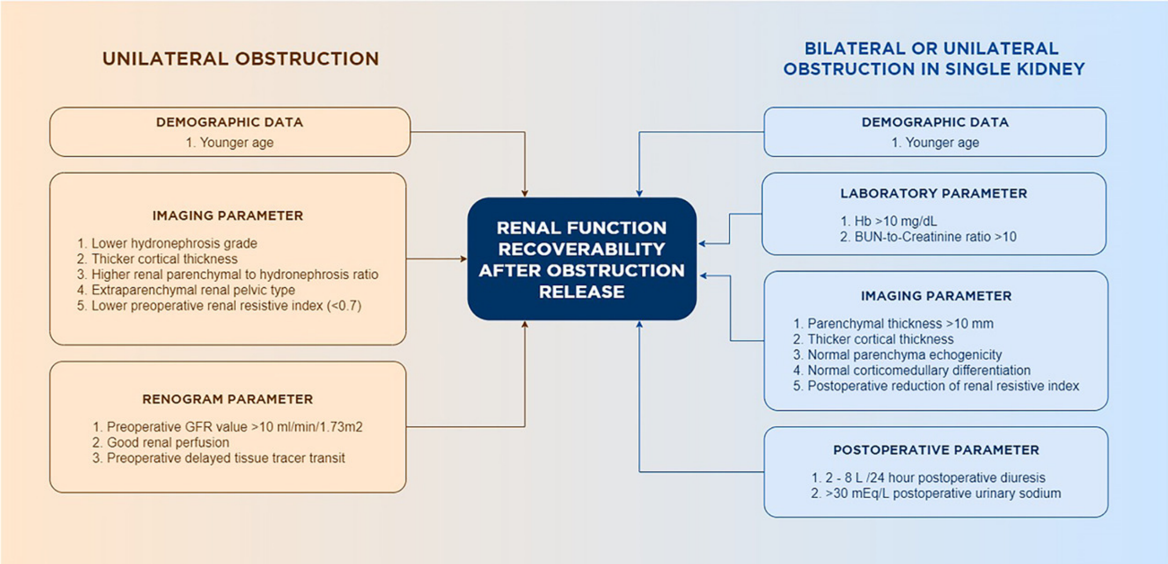

Figure 1.

Patient History and Demographic Characteristics

Patient history and demographic characteristics, such as age, sex, history of diabetes and hypertension, health-related behavior (smoking, alcohol drinking, or drug use), obstruction-related symptoms, and obstruction etiology, have been discussed in the current literature studying the recoverability of kidney function after obstruction release. Age is known to have negative effects on structural and functional kidney changes. The development of nephrosclerosis and a decrease in nephron number leads to a reduction in the glomerular filtration rate (GFR).[43] Hypertension and diabetes mellitus are other known independent risk factors for kidney disease and are more commonly seen in older patients.[44,45] Conflicting results have been reported regarding the association between smoking and alcohol drinking and kidney disease. Theoretically, smoking could lead to kidney damage and early studies showed that smoking or drinking more than four serving of alcohol per day was associated with chronic kidney disease (CKD). However, the current literature does not identify these as independent risk factors for CKD. Drug use, such as heroin or cocaine use, has a confirmed association with CKD.[46,47] Gender can also influence the occurrence of kidney disease, with a more rapid decline in kidney function seen in men than in women due to a protective effect of estrogen.[48] No evidence currently suggests that obstruction-related symptoms, such as pain, are signs of persisting renal function, and no difference in renal recovery is observed between benign and malignant causes after obstruction treatment.[49]

Of the factors studied, age was the only parameter that could predict recoverability of renal function after obstruction release according to three studies, and younger age was positively correlated with recoverability.[34,37,40] One study used a cut-off value of 35 years of age in predicting recoverability of renal function.[34]

Lab Parameters

The levels of blood glucose, serum potassium, and hemoglobin, the BUN-to-creatinine ratio (BCR), the urine pH, and the postoperative urinary sodium levels have been evaluated for their possible roles in predicting kidney function recoverability. Only the hemoglobin level, BCR, urine pH, and postoperative urinary sodium levels were predictive parameters. [38,39]

Hemoglobin can be affected by several factors, such as bleeding or nutritional status. However, in a kidney that develops CKD, anemia becomes one of the signs due to depletion of the erythropoietin level.[50] A hemoglobin level > 10 mg/dL has a positive association with the return of kidney function after obstruction release.[38]

A direct relationship between urine pH and acute or chronic kidney failure is not clear. Low urine pH is associated with metabolic syndrome, which is a risk factor of CKD, and metabolic acidosis is also a common feature in CKD.[51,52] Low urinary pH has also been viewed as a predictor of CKD, and alkaline urine could be a protective factor for decreased renal function.[53,54] On the contrary, Hussain et al. showed that a urine pH < 6 had a positive association with the recoverability of renal function. This urine pH sample was taken from a nephrostomy tube following administration of an antibiotic to prevent the influence of urea-splitting organisms on urine pH.[39] This contradictory result is still unresolved.

Historically, the BCR has been used to differentiate between pre-renal and intra-renal causes of AKI, with a ratio of 10:1 considered normal and a ratio greater than 20:1 considered a pre-renal cause of AKI.[55,56] Increased BCR in prerenal AKI occurs due to elevation of the antidiuretic hormone (ADH) levels, leading to increased urea reabsorption. However, this cut-off value for the BCR is currently in question.[56,57] In a uropathy obstructive state, an elevation of BCR is expected due to the slower blood flow through the vasa recta. The slower urinary flow due to the obstruction also causes an increase in the urea reabsorption time, thereby leading to a higher total urea reabsorption.[55] A BCR of more than 10:1 is a predicting factor of renal recovery after obstruction release, even though the theoretical explanation underlying this cut-off value is unclear.[38] Therefore, the exact cut-off value for BCR in predicting renal recoverability after obstruction release should be studied further. The elevation in BCR could also be caused by many other factors that increase urea production, such as a high protein diet and gastrointestinal bleeding.[57] Thus, caution is needed when using this parameter.

Natriuresis of more than 30 mEq/L is associated with the recovery potential of kidney function.[39] It is correlated with post obstructive diuresis (POD), which will be further discussed in the subsection on postoperative clinical parameters.

Imaging

Kidney Anatomy Evaluation

The following kidney anatomy parameters have been studied for their roles in predicting kidney function return after obstruction release: kidney size, cortical and parenchymal thickness, parenchymal echogenicity, corticomedullary differentiation (CMD), degree of hydronephrosis, renal parenchyma to hydronephrosis ratio (PHAR), and type of renal pelvis (either intra-parenchymal or extra-parenchymal).

Kidney size, cortical and parenchymal thickness, and CMD can be evaluated using ultrasonography (USG). The normal values for renal length, cortical thickness, and parenchymal thickness are 10–12 cm, 7–10 mm, and 15–20 mm, respectively. Cortical thinning is a sign that can be radiographically observed in patients with hydronephrosis.[58] A reduction in cortical thickness may reflect atrophy as part of the pathogenesis of hydronephrosis.[12] When the cortex and medulla are difficult to differentiate, which is defined as poor CMD, the parenchymal thickness can be used instead of the cortical thickness.[58] Thicker parenchymal and cortical thicknesses are associated with better potential of recoverability of kidney function, with no return of kidney function observed when the cortical thickness is less than 12 mm.[38,40] CMD can also predict the return of kidney function, according to multivariate analysis.[42] Recent studies have failed to show kidney size as a predicting factor for return of kidney function.[39,42]

Parenchymal echogenicity can also be evaluated using USG. Renal parenchyma echogenicity is determined by comparing it with that of the liver or spleen parenchyma, which is usually isoechoic or hyperechoic.[59] Increased renal echogenicity could indicate fibrosis or severe interstitial infiltration and tubular atrophy.[60] A multivariate analysis by Sharma et al. showed that parenchymal echogenicity had a significant relationship with renal function recoverability after obstruction release.[42] It was also correlated with decreased eGFR, while decreased eGFR indicated a poor prognosis for renal function recoverability.[60]

A study conducted by Li et al. demonstrated that the degree of hydronephrosis and PHAR could predict the return of kidney function after obstruction release, irrespective of the patient's age.[34] The degree of hydronephrosis and PHAR can be evaluated using several methods other than USG, such as computed tomography (CT) scans, magnetic resonance imaging (MRI), or intravenous pyelography (IVP). Li et al. used USG to determine the SFU classification for the degree of hydronephrosis and PHAR was calculated using a contrast CT scan.[34] In infants, PHAR is a promising parameter for predicting surgery success in patients with high-grade prenatal hydronephrosis.[61]

The renal pelvic type is considered extraparenchymal if more than 50% of the renal pelvis is contained outside the kidney parenchymal volume, and intraparenchymal if more than 50% of the renal pelvis is contained inside the kidney parenchymal volume. The extraparenchymal type of pelvis is positively correlated with kidney function improvement after obstruction treatment.[34] This might reflect the small volume that is constrained in the intraparenchymal pelvis, so a volume excess could lead to high intrapelvic pressure.[62] Thus, hypothetically, less compliance is found in the intraparenchymal renal pelvis, making it more susceptible to obstruction. However, this theory requires further proof.

Kidney function evaluation

The kidney function evaluation parameters of renal perfusion, differential renal function (DRF), and tissue tracer transit (TTT) were used to predict recoverability of kidney function were studied in adult ureteropelvic junction obstruction (UPJO) patients. These three parameters were obtained using nuclear scan renography, either 99mTC-MAG3 or 99mTC-DTPA, and were confirmed in current studies as potential parameters for predicting recovery of renal function.[33-35,37]

Khalaf et al. found that good renal perfusion was positively correlated with the recoverability of renal function. Renal perfusion is determined using 99mTC-DTPA and is considered good perfusion if the first 30 seconds of the vascular phase after tracer injection represents one third or more of the total curve counts.[35]

Better recoverability of renal function was found for a low DRF than for a higher one.[32,37] However, this finding was challenged by Li et al., who found a higher baseline DRF in a group showing kidney function improvement after treatment.[34] Moreover, a kidney with a DRF less than 10% has long been known to have a small chance of recovery.[25]

The TTT is defined as the transit of a physiological tracer from the parenchyma to the renal pelvis and is considered delayed if the tracer transit is slower than that in the contralateral kidney. A tracer that is relatively stable within the kidney in images at three and nine minutes or a tracer that shows increased activity in the renal parenchymal is a sign of delayed TTT. Liu et al. showed that delayed TTT was positively associated with the return of kidney function after therapy.[33]

Resistive index (RI) measurement

RI is measured using Doppler USG. Renal RI can be calculated as the peak systolic velocity – end diastolic velocity divided by peak systolic velocity when the Doppler USG image is obtained on the interlobar renal artery.[63] A high renal RI (> 0.65) was associated with severe renal fibrosis and a decrease in renal function.[64] This result agrees with that of Li et al., who showed a correlation between a lower preoperative RI and better recoverability of kidney function.[34] A study by Shokeir et al. also reported that a mean difference between postoperative and preoperative RI of 0.14 indicated a good chance of renal function return.[35]

Intraoperative Parameter

Intrapelvic pressure can be measured intraoperatively during percutaneous nephrostomy (PCN). This parameter was measured using a manometer after putting a needle inside the kidney with the mid-axillary line as its reference point.[42] Even though this pressure showed significant correlation with recoverability of renal function after obstruction release, it failed to show a significant influence in multivariate analysis.[42]

Postoperative Clinical Parameters

Postoperative diuresis of 2–8 liters per 24 h after obstruction release is associated with better outcomes in terms of renal recovery.[39] Decompression of a renal obstruction leads to post-obstructive diuresis (POD), which is a physiological response when body tries to eliminate excess water and solutes due to an obstruction. POD usually happens in patients with bilateral obstruction or a single-kidney unilateral obstruction.[65] This physiological polyuria response lasts for less than 48 h, and if it persists more than 48 h, pathological POD occurs. Therefore, as it is a natural response, POD might be a good sign for kidney function return. However, careful monitoring should be done due to the risk of dehydration and electrolyte imbalance.[27]

FUTURE DIRECTIONS

The literature available to date indicate that different criteria are used to determine the recoverability of renal function after obstruction release. Nuclear scan renography has been used in unilateral obstruction, mostly due to UPJO, whereas laboratory parameters, such as GFR or serum creatinine, have been used in cases of bilateral obstruction or non-UPJO causes to assess kidney function. These differences cannot be circumvented due to the different natural courses of the disease between UUO and BUO. However, similar criteria should be used to evaluate the recoverability of renal function. This study proposes that an improvement of > 7% DRF and GFR > 30 ml/min/1.73 m^2 (Kidney Disease Outcomes Quality Initiative – KDOQI criteria) should be used as criteria for recoverability of renal function for unilateral and bilateral obstructions, respectively. A GFR > 30 ml/min/1.73 m^2 is proposed because the symptoms of CKD are commonly found in stage 4 and 5 disease.

CONCLUSION

Various perioperative parameters can predict the recoverability of renal function, but these vary from study to study. These differences might reflect the differences in the study populations and the criteria used to determine renal recoverability.

REFERENCES

1. Mevorach RA, Hulbert WC, Rabinowitz R. Hydronephrosis. Pediatric clinical advisor. Elsevier; 2007. p. 283–4.
2. Murnaghan GF. The physiology of hydronephrosis. Postgrad Med J. 1958;34:143–8.
3. Roshani H. Dynamics and modulation of ureteric peristalsis. https://pure.uva.nl/ws/files/3452426/32410_UBA002000992_04.pdf. Accessed 28 June 2020
4. Vaidyanathan S, Selmi F, Abraham KA, Hughes P, Singh G, Soni B. Hydronephrosis and renal failure following inadequate management of neuropathic bladder in a patient with spinal cord injury: Case report of a preventable complication. Patient Saf Surg. 2012;6:1–6.
5. Choi JI, Yoo JG, Kim SJ, Lee HN, Kim MJ. Acute renal failure due to obstructive uropathy secondary to ureteral endometriosis. Case Rep Obstet Gynecol. 2015;2015:1–4.
6. Zambon JP, Koslov DS, Mihai B, Badlani GH. Bladder and ureteral dysfunction leading to hydronephrosis and hydroureteronephrosis in adults. Urolog. 2018;117:1–8.
7. Tran VH, Nelson M, Nogar J, Bramante RM. Bilateral hydronephrosis and cystitis resulting from chronic ketamine abuse. West J Emerg Med. 2014;15:382–4.
8. Annie Hui SY, Symphorosa Chan SC, Judy Lam SY, Lau TK, Tony Chung KH. A prospective study on the prevalence of hydronephrosis in women with pelvic organ prolapse and their outcomes after treatment. Int Urogynecol J. 2011;22:1529–34.
9. Dancz CE, Walker D, Thomas D, Özel B. Prevalence of hydronephrosis in women with advanced pelvic organ prolapse. Urology. 2015;86:250–4.
10. Nuraj P, Hyseni N. The diagnosis of obstructive hydronephrosis with color Doppler ultrasound. Acta Inform Medica. 2017;25:178.
11. Riyach O, Ahsaini M, Kharbach Y, et al. Bilateral ureteral obstruction revealing a benign prostatic hypertrophy: A case report and review of the literature. J Med Case Rep. 2014;8:2–5.
12. Byers LA, Rochon PJ. Obstructive uropathy. Springer International Publishing; 2018. p. 477–87.
13. Lojanapiwat B, Sripralakrit S, Soonthornphan S, Wudhikarn S. Intravesicle formalin instillation with a modified technique for controlling haemorrhage secondary to radiation cystitis. Asian J Surg. 2002;25:232–5.
14. Kurata S, Tobu S, Udo K, Noguchi M. Outcomes of ureteral stent placement for hydronephrosis in patients with gynecological malignancies. Curr Urol. 2017;10:126–31.
15. Orchard J, Tward JD, Lenherr S, Hotaling JM, Brant WO, Myers JB. Surgical management of ureteral strictures arising from radiotherapy for prostate cancer. Urol Case Reports. 2016;6:47–9.

16. Halle MP, Toukep LN, Nzuobontane SE, Ebana HF, Ekane GH, Priso EB. The profile of patients with obstructive uropathy in Cameroon: case of the Douala general hospital. Pan Afr Med J. 2016;23:3–8.
17. Patel K, Foster NR, Kumar A, et al. Hydronephrosis in patients with cervical cancer: an assessment of morbidity and survival. Support Care Cancer. 2014;23:1303–9.
18. Pradhan TS, Duan H, Katsoulakis E, Salame G, Lee Y-C, Abulafia O. Hydronephrosis as a prognostic indicator of survival in advanced cervix cancer. Int J Gynecol Cancer. 2011;21:1091–6.
19. Luo HL, Kang CH, Chen YT, et al. Severity of hydronephrosis correlates with tumour invasiveness and urinary bladder recurrence of ureteric cancer. BJU Int. 2013;112:489–94.
20. Marchini GS, Vicentini FC, Monga M, et al. Irreversible renal function impairment due to silent ureteral stones. Urology. 2016;93:33–9.
21. Balikci Ö, Turunç T, Bal N, Çelik H, Özkarde\cs H. Comparison of Cajal-like cells in pelvis and proximal ureter of kidney with and without hydronephrosis. Int Braz J Urol. 2015;41:1178–84.
22. Shoshany O, Erlich T, Golan S, et al. Ureteric stent versus percutaneous nephrostomy for acute ureteral obstruction - clinical outcome and quality of life: a bi-center prospective study. BMC Urol. 2019;19:1–7.
23. Makris K, Spanou L. Acute kidney injury: definition, pathophysiology and clinical phenotypes. Clin Biochem Rev. 2016;37:85–98.
24. Klahr S. Obstructive nephropathy. Intern Med. 2000;39:355–61.
25. Shokeir AA, Provoost AP, Nijman RJM. Recoverability of renal function after relief of chronic partial upper urinary tract obstruction. BJU Int. 1999;83:11–7.
26. Ito K, Chen J, El Chaar M, et al. Renal damage progresses despite improvement of renal function after relief of unilateral ureteral obstruction in adult rats. Am J Physiol - Ren Physiol. 2004;287:1283–93.
27. Meldrum K. Patophysiology of urinary tract obstruction. In: Wein AJ, Kavoussi LR, Partin AW, Peters CA, editors. Campbell-Walsh Urology. 11th ed. Philadelphia: Elsevier; 2016.
28. Mourmouris P, Chiras T, Papatsoris A. Obstructive uropathy: from etiopathology to therapy. World J Nephrol Urol. 2014;3:1–6.
29. Lucarelli G, Mancini V, Galleggiante V, et al. Emerging urinary markers of renal injury in obstructive nephropathy. Biomed Res Int. 2014;2014.
30. Chevalier RL. Pathogenesis of renal injury in obstructive uropathy. Curr Opin Pediatr. 2006;18:153–60.
31. Lucarelli G, Ditonno P, Bettocchi C, et al. Delayed relief of ureteral obstruction is implicated in the long-term development of renal damage and arterial hypertension in patients with unilateral ureteral injury. J Urol. 2013;189:960–5.
32. Harraz AM, Taha DE, Shalaby I, Hafez AT. Evaluation of factors predicting recoverability of renal function after pyeloplasty in adults. Urol Int. 2014;93:403–5.
33. Liu M, Fu Z, Li Q, et al. Delayed renal tissue tracer transit in Tc-99m-DTPA renography correlates with postoperative renal function improvement in UPJO patients. Nucl Med Commun. 2015;36:833–8.
34. Li XD, Wu YP, Wei Y, et al. Predictors of recoverability of renal function after pyeloplasty in adults with ureteropelvic junction obstruction. Urol Int. 2018;100:209–15.
35. Khalaf IM, Shokeir AA, El-Gyoushi FI, Amr HS, Amin MM. Recoverability of renal function after treatment of adult patients with unilateral obstructive uropathy and normal contralateral kidney: A prospective study. Urology. 2004;64:664–8.
36. Ortapamuk H, Naldoken S, Tekdogan UY, Aslan Y, Atan A. Differential renal function in the prediction of recovery in adult obstructed kidneys after pyeloplasty. Ann Nucl Med. 2003;17:663–8.
37. Wu AK, Tran TC, Sorensen MD, Durack JC, Stoller ML. Relative renal function does not improve after relieving chronic renal obstruction. BJU Int. 2012;109:1540–4.
38. Bundu A, Danarto H. Prognostic parameters for the recovery of renal function in patients with obstructive uropathy. Indones J Urol. 2018;25:59–63.
39. Hussain M, Ali B, Ahmed S, Zafar N, Naqvi SA, Rizvi SAH. Prediction of renal function recovery in obstructive renal failure due to stones. J Park Med Assoc. 1997;47:159–61.
40. Lutaif NA, Sc M, Yu L, Ph D. Factors influencing the non-recovery of renal function after the relief of urinary tract obstruction in women with cancer of cervix. Ren Fail. 2003;25:215–23.
41. Shokeir AA, Shoma AM, Abubieh EA, Nasser MA, Eassa W, El-Asmy A. Recoverability of renal function after relief of acute complete ureteral obstruction: Clinical prospective study of the role of renal resistive index. Urology. 2002;59:506–10.
42. Sharma U, Yadav S, Tomar V. Factors influencing recoverability of renal function after urinary diversion through percutaneous nephrostomy. Urol Ann. 2015;7:499–503.
43. Denic A, Glassock RJ, Rule AD. Structural and functional changes with the aging kidney. Adv Chronic Kidney Dis. 2016;23:19–28.
44. Verma A, Vyas S, Agarwal A, Abbas S, Agarwal DP, Kumar R. Diabetic kidney disease and hypertension: a true love story. J Clin Diagnostic Res. 2016;10:OC11–3.
45. Price AJ, Crampin AC, Amberbir A, et al. Prevalence of obesity, hypertension, and diabetes, and cascade of care in sub-Saharan Africa: a cross-sectional, population-based study in rural and urban Malawi. Lancet Diabetes Endocrinol. 2018;6:208–22.
46. Bundy J, Bazzano L, Xie D, et al. Self-reported

tobacco, alcohol, and illicit drug use and progression of chronic kidney disease. Clin J Am Soc Nephrol. 2018;13:993–1001.
47. Shankar A, Klein R, Klein BEK. The association among smoking, heavy drinking, and chronic kidney disease. Am J Epidemiol. 2006;164:263–71.
48. Carrero JJ, Hecking M, Chesnaye NC, Jager KJ. Sex and gender disparities in the epidemiology and outcomes of chronic kidney disease. Nat Rev Nephrol. 2018;14:151–64.
49. Organ M, Norman RW. Acute reversible kidney injury secondary to bilateral ureteric obstruction. 2011;5:392–6.
50. Mehdi U, Toto RD. Anemia, diabetes, and chronic kidney disease. Diabetes Care. 2009;32:1320–6.
51. Maalouf NM, Cameron MA, Moe OW, Adams-Huet B, Sakhaee K. Low urine pH: A novel feature of the metabolic syndrome. Clin J Am Soc Nephrol. 2007;2:883–8.
52. Prasad GR. Metabolic syndrome and chronic kidney disease: Current status and future directions. World J Nephrol. 2014;3:210.
53. Nakanishi N, Fukui M, Tanaka M, et al. Low urine pH is a predictor of chronic kidney disease. Kidney Blood Press Res. 2012;35:77–81.
54. Bazzi C, Tagliabue E, Raimondi S, Rizza V, Casellato D, Nangaku M. High (≥6.5) spontaneous and persistent urinary pH is protective of renal function at baseline and during disease course in idiopathic membranous nephropathy. Int J Nephrol. 2015;2015.
55. Marshall S. Urea-creatinine ratio in obstructive uropathy and renal hypertension. JAMA. 1964;190:719–20.
56. Uchino S, Bellomo R, Goldsmith D. The meaning of the blood urea nitrogen/creatinine ratio in acute kidney injury. Clin Kidney J. 2012;5:187–91.
57. Manoeuvrier G, Bach-Ngohou K, Batard E, Masson D, Trewick D. Diagnostic performance of serum blood urea nitrogen to creatinine ratio for distinguishing prerenal from intrinsic acute kidney injury in the emergency department. BMC Nephrol. 2017;18:1–7.
58. Hansen K, Nielsen M, Ewertsen C. Ultrasonography of the kidney: A pictorial review. Diagnostics. 2015;6:2.
59. Faubel S, Patel NU, Lockhart ME, Cadnapaphornchai MA. Renal relevant radiology: use of ultrasonography in patients with AKI. Clin J Am Soc Nephrol. 2014;9:382–94.
60. Lee JH, Cho MH, Chung SI, Lim SD, Kim KS. Relationship of renal echogenicity with renal pathology and function. Child Kidney Dis. 2017;21:47–52.
61. Rickard M, Lorenzo AJ, Braga LH. Renal parenchyma to hydronephrosis area ratio (phar) as a predictor of future surgical intervention for infants with high-grade prenatal hydronephrosis. Urology. 2017;101:85–9.
62. Tomaszewski JJ, Cung B, Smaldone MC, et al. Renal pelvic anatomy is associated with incidence, grade, and need for intervention for urine leak following partial nephrectomy. Eur Urol. 2014;66:949–55.
63. Ikee R, Kobayashi S, Hemmi N, et al. Correlation between the resistive index by Doppler ultrasound and kidney function and histology. Am J Kidney Dis. 2005;46:603–9.
64. Bigé N, Lévy PP, Callard P, et al. Renal arterial resistive index is associated with severe histological changes and poor renal outcome during chronic kidney disease. BMC Nephrol. 2012;13:1–9.
65. Halbgewachs C, Domes T. Postobstructive diuresis: Pay close attention to urinary retention. Can Fam Physician. 2015;61:137–42.