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Impact of Hydronephrosis on CT Scan on Blood Pressure and Serum Creatinine in Patients by Age and Sex

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ABSTRACT

Background: Hydronephrosis is an imaging finding of collecting-system dilatation that may accompany urinary tract obstruction and has been linked to impaired renal function and higher blood pressure, particularly when it is severe or bilateral. This study examined the cross-sectional associations of CT-defined hydronephrosis severity and laterality with serum creatinine and blood pressure in a hospital-based cohort of adults.

Methods: This retrospective cross-sectional study used the medical records of 87 adults with hydronephrosis on abdominal computed tomography (CT) at Royal Prima Medan Hospital, North Sumatra, Indonesia, selected by purposive sampling. Hydronephrosis was graded 1–4 from CT radiology reports (grade of the more severely affected kidney) and classified as unilateral or bilateral. Serum creatinine and blood pressure were abstracted from the same clinical episode. Multiple linear regression models including age and sex estimated adjusted associations with serum creatinine, systolic blood pressure, and diastolic blood pressure.

Results: Mean age was 53.2 ± 14.8 years; 29.9% of participants had bilateral and 21.8% had Grade 4 hydronephrosis. After adjustment, bilateral hydronephrosis was associated with higher serum creatinine (B = 1.280 mg/dL; 95% CI 0.58–1.98), systolic blood pressure (B = 6.850 mmHg; 95% CI 1.06–12.64), and diastolic blood pressure (B = 4.120 mmHg; 95% CI 0.23–8.01). Compared with Grade 1, Grade 4 hydronephrosis was associated with higher serum creatinine (B = 1.911 mg/dL; 95% CI 1.21–2.61), systolic blood pressure (B = 16.820 mmHg; $p < 0.001$), and diastolic blood pressure (B = 8.940 mmHg; 95% CI 2.94–14.94). Age was associated with systolic blood pressure only (B = 0.521 mmHg/year; $p < 0.001$).

Conclusion: In this single-center hospital cohort, bilateral and Grade 4 hydronephrosis on CT were associated with higher serum creatinine and blood pressure. These adjusted cross-sectional associations require confirmation in prospective studies with comprehensive clinical covariates and functional renal assessment.

Keywords: hydronephrosis, computed tomography, serum creatinine, blood pressure, laterality, obstructive uropathy

Introduction

Hydronephrosis refers to dilatation of the renal pelvis and calyces; it most often results from urinary outflow obstruction but may also occur without functionally significant obstruction (Patel & Batura, 2020). It is encountered from primary care to specialized nephrology and urology practice, and its detection has increased with the widespread use of ultrasound and CT (Leo et al., 2017). Clinical presentation ranges from acute symptomatic obstruction with renal colic to chronic, asymptomatic dilatation that may remain undetected until renal damage occurs (Thotakura & Anjum, 2023). In adults, common causes include nephrolithiasis, benign prostatic hyperplasia, and pelvic or urological malignancies, and the cause, duration, and laterality of obstruction may each influence renal and blood-pressure outcomes (Chen et al., 2024; Iqbal et al., 2017; Nørregaard et al., 2023).

Hydronephrosis and obstructive uropathy have been associated with elevated blood pressure, although this association may be underrecognized, particularly in unilateral or partial obstruction (Al-Mashhadi et al., 2018; Carlström, 2019). Proposed mechanisms include reduced renal perfusion with activation of the intrarenal renin–angiotensin–aldosterone system (RAAS), renal sympathetic activation, impaired nitric-oxide signaling, and altered tubuloglomerular feedback (Nørregaard et al., 2023; Yaxley & Yaxley, 2023). Angiotensin II promotes

vasoconstriction and aldosterone-mediated sodium reabsorption, which may contribute to volume expansion and hypertension (Crowley et al., 2024; Nørregaard et al., 2023). In some patients, blood pressure improves after relief of obstruction (Al-Mashhadi et al., 2018; Yaxley & Yaxley, 2023); however, treatment response was outside the scope of the present study.

In adults, the relationship between hydronephrosis and blood pressure is heterogeneous because obstruction differs in cause, duration, and severity. Benign prostatic hyperplasia may cause obstruction and renal impairment in older men, although secondary hypertension is not inevitable (Yaxley & Yaxley, 2023). Kidney stones, a frequent cause of unilateral obstruction, are more common in men, although this sex difference is narrowing (Gillams et al., 2021; Özsoy et al., 2019), and pregnancy-related hydronephrosis is usually transient (Demiroğlu & Solakhan, 2026). Evidence from pediatric ureteropelvic junction obstruction, in which hypertension may improve after surgical correction (Tian et al., 2025), provides biological context but cannot be extrapolated directly to adults. Because etiology and duration may influence both the severity and laterality of hydronephrosis and the renal and blood-pressure outcomes, they are potential confounders of these associations.

The severity, duration, and laterality of hydronephrosis influence renal impairment and the risk of secondary hypertension (Nørregaard et al., 2023; Yaxley & Yaxley, 2023). CT can depict collecting-system dilatation and parenchymal thinning, but it does not measure renal function, and CT findings should be interpreted together with functional tests (Chávez-Iñiguez et al., 2020). Bilateral involvement is particularly important because it limits compensation by the contralateral kidney and increases the risk of acute kidney injury (Nørregaard et al., 2023; Rashid et al., 2021). Acute complete obstruction may rapidly reduce glomerular filtration, whereas partial or slowly progressive obstruction may cause gradual injury (Turgut et al., 2023), and persistent obstruction promotes tubular injury, interstitial fibrosis, and nephron loss (Jay & Nicol, 2017; Wang et al., 2023). Duration of obstruction is therefore an important determinant, but it is often not documented in routine records.

Evidence on how CT-defined hydronephrosis severity and laterality are jointly associated with serum creatinine and blood pressure in adults remains limited (Al-Mashhadi et al., 2018; Nørregaard et al., 2023). Previous studies have generally examined renal or blood-pressure outcomes separately, and evidence from Southeast Asia is scarce. In a Taiwanese cohort with ketamine-associated uropathy, hydronephrosis was independently associated with renal-function decline after adjustment for age, sex, and baseline creatinine (Ou et al., 2020), but this etiology-specific finding may not apply to adult hydronephrosis in general. In routine hospital records, important determinants of creatinine and blood pressure, such as obstruction etiology and duration, comorbidities, and medication use, are often incompletely documented, so analyses of severity and laterality must be interpreted in light of these potential confounders.

Therefore, this study aimed to examine the cross-sectional associations of CT-defined hydronephrosis severity (Grades 1–4) and laterality (unilateral vs bilateral) with serum creatinine and with systolic and diastolic blood pressure, adjusted for age and sex, among adults at Royal Prima Medan Hospital. We hypothesized that bilateral and higher-grade hydronephrosis would be associated with higher serum creatinine and blood pressure. The analysis was explanatory (association-based) rather than a prediction-model study.

Methods

Study Design and Setting

This was a retrospective cross-sectional study of medical records at Royal Prima Medan Hospital, North Sumatra, Indonesia. The exposures (CT findings) and outcomes (serum creatinine and blood pressure) were abstracted from the same clinical episode, without follow-up. Medical records were reviewed from February 2026. The study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement (von Elm et al., 2007).

Participants and Sampling

The study population comprised adults (≥18 years) with hydronephrosis reported on abdominal CT at Royal Prima Medan Hospital. Records were excluded if CT grade, laterality, serum creatinine, or blood pressure data were missing, or if they documented pre-existing conditions judged to independently affect renal function or blood pressure, such as established chronic kidney disease. Hypertension was not an eligibility criterion. Eligible records were selected by purposive sampling from the hospital records of adult patients with hydronephrosis on abdominal CT; this non-random selection may introduce selection bias. Because inclusion required CT, the cohort may over-represent more symptomatic, complicated, or diagnostically uncertain cases, and exclusion of patients with major renal or cardiovascular comorbidity may yield a lower-comorbidity sample than routine practice.

The minimum sample size was initially estimated with Slovin's formula from an estimated source population of 100 adult patients with hydronephrosis on abdominal CT in the hospital records (5% margin of error), giving a minimum of 80 participants; 87 records were included. Because this formula is not designed for regression analyses, we also assessed adequacy for the multivariable models: with 87 participants and seven model parameters (six predictors and the intercept), there were approximately 12 observations per parameter, and the study had 80% power ($\alpha = 0.05$) to detect an individual predictor explaining about 9% of the residual variance ($f^2 \approx 0.10$). Smaller associations, and estimates for the small Grade 3 (n = 14) and Grade 4 (n = 19) groups, are therefore imprecise.

Data Collection

Serum creatinine (mg/dL) was the renal outcome and was used as a marker of renal excretory function, recognizing that it is influenced by age, sex, muscle mass, hydration, and acute illness; estimated glomerular filtration rate (eGFR), baseline creatinine, and functional renal imaging were not available. Systolic and diastolic blood pressure (mmHg) were the hemodynamic outcomes. For each patient, the serum creatinine value and the blood pressure reading recorded closest in time to the CT examination during the same clinical episode were abstracted; blood pressure was a single routine clinical measurement as documented in the medical record. Whether CT was contrast-enhanced and whether creatinine was measured before or after contrast exposure, as well as the timing of blood pressure relative to pain, analgesia, and antihypertensive treatment, were not consistently documented. The independent variables were radiological grade, laterality, age (years), and sex. Laterality was defined as unilateral or bilateral hydronephrosis on CT, not as functionally confirmed obstruction. Radiological grade was abstracted from the original CT radiology reports using a four-grade descriptive scale: Grade 1, mild dilatation of the renal pelvis without significant calyceal blunting; Grade 2, moderate dilatation with mild calyceal blunting and preserved papillary impressions; Grade 3, marked dilatation with significant calyceal blunting and loss of papillary impressions; and Grade 4, severe pelvicalyceal distension with cortical thinning and loss of corticomedullary differentiation. This scale is adapted from descriptive grading systems used in hydronephrosis reporting (Onen, 2020), which were developed largely for ultrasound and pediatric populations and have not been formally validated for adult CT. Grades were taken from routine reports rather than re-read for this study, so reader blinding and inter-rater reliability could not be assessed. In bilateral cases, the grade of the more severely affected kidney was used. Data on obstruction etiology and duration, comorbidities such as diabetes, antihypertensive and analgesic/NSAID use, infection, and body size were not consistently available and were not analyzed. Data were abstracted using a standardized form and entered into a secure electronic database.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 26. Continuous variables are summarized as mean ± SD and categorical variables as frequencies and percentages. Only records with complete data for all study variables were included (complete-case analysis); no imputation was performed.

Separate multiple linear regression models were fitted for serum creatinine, systolic blood pressure, and diastolic blood pressure, each including age (continuous), sex (male vs female),

laterality (bilateral vs unilateral), and radiological grade entered as indicator variables with Grade 1 as the reference category. Regression assumptions (linearity, normality and independence of residuals, and homoscedasticity) and multicollinearity (variance inflation factor, VIF) were assessed. Results are presented as unstandardized coefficients (B) with standard errors, 95% confidence intervals (CIs), and p-values; standardized coefficients are reported for the creatinine model only and are not used to rank predictors. Model fit is summarized using R^2, adjusted R^2, and the F statistic with its degrees of freedom. Where standard errors and 95% CIs were not reported in the original tables, they were derived from the reported coefficients and exact p-values using the t distribution with 80 degrees of freedom. Because three outcomes and several grade contrasts were examined, the analyses were considered exploratory; no adjustment for multiple testing was made, and interpretation emphasizes effect sizes and confidence intervals. A two-sided $p < 0.05$ was considered statistically significant.

Ethical Considerations

The study protocol, including a waiver of informed consent for the use of anonymized retrospective medical records, was approved by the Health Research Ethics Committee, Faculty of Medicine, Dentistry, and Health Sciences, Universitas Prima Indonesia, and permission was obtained from Royal Prima Medan Hospital. Data were coded without personal identifiers, stored securely, and reported only in aggregate.

Result

Baseline Characteristics of the Study Population

A total of 87 eligible patients with hydronephrosis on CT were included in the analysis. Their demographic and clinical characteristics are summarized in Table 1.

Table 1. Demographic and Clinical Characteristics of Study Subjects (N = 87)

Characteristic	Overall Cohort (N = 87)
Age (Years), Mean ± SD	53.2 ± 14.8
Sex, n (%)	
Male	43 (49.4%)
Female	44 (50.6%)
Laterality of Hydronephrosis, n (%)	
Unilateral	61 (70.1%)
Bilateral	26 (29.9%)
Radiological grade (more severely affected kidney), n (%)	
Grade 1	30 (34.5%)
Grade 2	24 (27.6%)
Grade 3	14 (16.1%)
Grade 4	19 (21.8%)
Clinical Measurements, Mean ± SD	
Serum Creatinine (mg/dL)	2.3 ± 2.1
Systolic Blood Pressure (mmHg)	135.4 ± 19.3
Diastolic Blood Pressure (mmHg)	87.2 ± 10.7

The cohort had a balanced sex distribution (44 women, 50.6%; 43 men, 49.4%), and the mean age was 53.2 ± 14.8 years.

Unilateral hydronephrosis was more common than bilateral hydronephrosis (61 patients, 70.1%, vs 26 patients, 29.9%).

Radiological grade was distributed as follows: Grade 1 in 30 patients (34.5%), Grade 2 in 24 (27.6%), Grade 3 in 14 (16.1%), and Grade 4 in 19 (21.8%); 33 patients (37.9%) had Grade 3 or 4 hydronephrosis. Mean serum creatinine was 2.3 ± 2.1 mg/dL; the large SD relative to the mean indicates a right-skewed distribution with some markedly elevated values. Mean systolic and diastolic blood pressures were 135.4 ± 19.3 mmHg and 87.2 ± 10.7 mmHg, respectively.

Multiple Linear Regression Analysis for Serum Creatinine

Table 2 shows the adjusted associations of hydronephrosis characteristics with serum creatinine.

Table 2. Multiple Linear Regression of Serum Creatinine on Hydronephrosis Laterality, Radiological Grade, Age, and Sex (N = 87)

Independent Variable	Unstandardized B	Std. Error	Standardized Beta	95% CI	p-value
Intercept	0.099	0.487	—	[-0.87, 1.07]	0.834
Age (per year)	0.010	0.009	0.070	[-0.008, 0.028]	0.264
Sex (Male vs. Female)	0.415	0.241	0.099	[-0.06, 0.89]	0.089
Bilateral vs. unilateral hydronephrosis	1.280	0.351	0.281	[0.58, 1.98]	< 0.001*
Radiological grade (ref: Grade 1)					
Grade 2	0.093	0.312	0.020	[-0.53, 0.72]	0.766
Grade 3	0.403	0.353	0.071	[-0.30, 1.11]	0.257
Grade 4	1.911	0.353	0.378	[1.21, 2.61]	< 0.001*

*Model summary: $R = 0.757$, $R^2 = 0.574$, adjusted $R^2 = 0.542$, $F(6, 80) = 17.97$, $p < 0.001$. Standardized β calculated as B × SDx/SDy using the sample SDs in Table 1. *p < 0.05. CI, confidence interval.*

The model explained 57.4% of the variance in serum creatinine (adjusted $R^2 = 0.542$; $F(6, 80) = 17.97$; $p < 0.001$).

After adjustment, bilateral hydronephrosis was associated with 1.280 mg/dL higher serum creatinine than unilateral hydronephrosis (95% CI 0.58–1.98; $p < 0.001$; standardized $\beta = 0.281$). Because creatinine was right-skewed and baseline renal function was unknown, the clinical meaning of this difference may vary between patients with near-normal and markedly elevated creatinine.

Compared with Grade 1, Grade 4 hydronephrosis was associated with 1.911 mg/dL higher serum creatinine (95% CI 1.21–2.61; $p < 0.001$; standardized $\beta = 0.378$). The estimates for Grade 2 (B = 0.093; 95% CI −0.53 to 0.72; $p = 0.766$) and Grade 3 (B = 0.403; 95% CI −0.30 to 1.11; $p = 0.257$) were small and imprecise, and no formal trend test was performed.

Age (B = 0.010 per year; 95% CI −0.008 to 0.028; $p = 0.264$) and sex (B = 0.415; 95% CI −0.06 to 0.89; $p = 0.089$) were not statistically associated with serum creatinine after adjustment in this sample.

Multiple Linear Regression Analysis for Blood Pressure Parameters

Separate models for systolic and diastolic blood pressure are presented in Table 3.

Table 3. Multiple Linear Regression of Systolic and Diastolic Blood Pressure on Hydronephrosis Laterality, Radiological Grade, Age, and Sex (N = 87)

Independent Variable	B	SE	95% CI	p-value
Systolic blood pressure				
Intercept	112.45	—	—	< 0.001*
Age (per year)	0.521	[from SPSS]	[from SPSS]	< 0.001*
Sex (male vs. female)	2.140	2.832	[−3.49, 7.77]	0.452
Bilateral vs. unilateral hydronephrosis	6.850	2.909	[1.06, 12.64]	0.021*
Radiological grade (ref: Grade 1)				

Grade 2	3.120	4.737	[−6.31, 12.55]	0.512
Grade 3	9.450	4.381	[0.73, 18.17]	0.034*
Grade 4	16.820	[from SPSS]	[from SPSS]	< 0.001*
Diastolic blood pressure				
Intercept	68.32	—	—	< 0.001*
Age (per year)	0.142	0.080	[−0.02, 0.30]	0.081
Sex (male vs. female)	0.980	1.974	[−2.95, 4.91]	0.621
Bilateral vs. unilateral hydronephrosis	4.120	1.953	[0.23, 8.01]	0.038*
Radiological grade (ref: Grade 1)				
Grade 2	1.850	3.429	[−4.97, 8.67]	0.591
Grade 3	5.210	2.858	[−0.48, 10.90]	0.072
Grade 4	8.940	3.016	[2.94, 14.94]	0.004*

Systolic model: R^2 = 0.316, adjusted R^2 = 0.265, F(6, 80) = 6.16, p < 0.001. Diastolic model: R^2 = 0.172, adjusted R^2 = 0.110, F(6, 80) = 2.77, p = 0.017. SE and 95% CI were derived from B and the exact p-value (t distribution, 80 df); for estimates with p < 0.001 they are taken from the SPSS output. *p < 0.05.

The systolic blood pressure model explained 31.6% of the variance (adjusted R^2 = 0.265). Age was associated with systolic blood pressure (B = 0.521 mmHg per year; p < 0.001), assuming a linear relationship across the age range.

Bilateral hydronephrosis was associated with 6.850 mmHg higher systolic blood pressure than unilateral hydronephrosis (95% CI 1.06–12.64; p = 0.021).

Compared with Grade 1, systolic blood pressure was 3.120 mmHg higher for Grade 2 (95% CI −6.31 to 12.55; p = 0.512), 9.450 mmHg higher for Grade 3 (95% CI 0.73–18.17; p = 0.034), and 16.820 mmHg higher for Grade 4 (p < 0.001). Coefficients were larger at higher grades; however, no formal trend test was performed, and the Grade 3 estimate (n = 14) was imprecise. Sex was not associated with systolic blood pressure (B = 2.140; 95% CI −3.49 to 7.77; p = 0.452).

The diastolic blood pressure model explained 17.2% of the variance (adjusted R^2 = 0.110). Bilateral hydronephrosis (B = 4.120 mmHg; 95% CI 0.23–8.01; p = 0.038) and Grade 4 hydronephrosis (B = 8.940 mmHg; 95% CI 2.94–14.94; p = 0.004) were associated with higher diastolic blood pressure. Age (B = 0.142; 95% CI −0.02 to 0.30; p = 0.081) and sex (B = 0.980; 95% CI −2.95 to 4.91; p = 0.621) were not statistically associated with diastolic blood pressure.

Discussion

In this hospital-based cohort of adults with CT-detected hydronephrosis, bilateral and Grade 4 hydronephrosis were associated with higher serum creatinine, systolic blood pressure, and diastolic blood pressure after adjustment for age and sex. Grade 3 hydronephrosis was associated with higher systolic, but not diastolic, blood pressure, and older age was associated with higher systolic blood pressure only. These findings are compatible with the proposed relationship between obstructive uropathy, reduced renal excretory function, and secondary hypertension (Nørregaard et al., 2023; Pérez-Aizpurua et al., 2024).

The association between bilateral hydronephrosis and higher serum creatinine is biologically plausible because unilateral obstruction may be partly compensated for by the contralateral kidney (Nørregaard et al., 2023; Pérez-Aizpurua et al., 2024). In our data, bilateral hydronephrosis was associated with 1.280 mg/dL higher serum creatinine, which should be interpreted as an adjusted cross-sectional difference rather than a causal effect. Grade 4 hydronephrosis may be accompanied by cortical thinning, tubular injury, and interstitial fibrosis (Nørregaard et al., 2023), although radiological grade cannot establish irreversible nephron loss. The imprecise estimates for Grades 2 and 3 may reflect a threshold relationship or limited statistical power. Comparison with previous adult studies is limited by differences in populations, imaging definitions, and covariate adjustment: in adults, arterial pressure has been reported to change after relief of obstruction (Al-Mashhadi et al., 2018; Yaxley & Yaxley, 2023), and in a Taiwanese cohort with ketamine-associated uropathy, hydronephrosis was associated with subsequent renal-function decline (Ou et al., 2020). Our cross-sectional findings are directionally consistent with these reports but cannot address change over time.

Age was associated with systolic but not diastolic blood pressure, compatible with age-related arterial stiffening; the estimate of 0.521 mmHg per year assumes a linear relationship and applies to this population. Bilateral and Grade 4 hydronephrosis were also associated with higher blood pressure, which is compatible with mechanisms involving reduced renal perfusion, RAAS activation, and sodium retention (Carlström, 2019; Nørregaard et al., 2023). However, renin, aldosterone, sodium balance, and sympathetic activity were not measured, so the results are compatible with, but do not confirm, these mechanisms; acute pain, anxiety, analgesia, volume status, and antihypertensive treatment at the time of measurement may also have influenced blood pressure. No statistically significant association with sex was observed; given the sample size, this should be interpreted as insufficient evidence for an association rather than evidence of no difference, and sex-specific etiologies and menopausal status could modify these relationships. Persistent obstruction may lead to tubular injury, inflammation, and interstitial fibrosis (Khater et al., 2025; Pérez-Aizpurua et al., 2024), and the associations with bilateral involvement are consistent with reduced compensatory capacity (Patel & Batura, 2020). Nevertheless, radiological severity alone cannot establish irreversible damage; functional assessment and longitudinal follow-up are required (Onen, 2020).

Patients with bilateral or Grade 4 hydronephrosis may warrant careful assessment of renal function and blood pressure. In clinical practice, this assessment would include eGFR, urine output, and functional imaging where appropriate, although these measures were not analyzed in the present study. The decision and urgency of decompression depend on infection, acute kidney injury, anuria, symptoms, obstruction cause, and functional status, which were not evaluated here (Pérez-Aizpurua et al., 2024). Blood-pressure management should follow general guideline recommendations based on overall cardiovascular risk (Giacona & Vongpatanasin, 2026; Gulati et al., 2025); the present data do not inform drug choice or hydronephrosis-specific blood-pressure targets. CT characterizes collecting-system dilatation and cortical thinning but should not be used as the sole measure of renal function (Onen, 2020).

This study has several limitations. First, the retrospective cross-sectional design precludes causal or temporal inference. Second, residual confounding is likely, because obstruction etiology and duration, baseline renal function, diabetes and other comorbidities, antihypertensive and analgesic/NSAID use, infection, hydration status, and body size were not available. Third, there are measurement limitations: serum creatinine was used without eGFR or baseline values and may have been influenced by contrast exposure; blood pressure was a single routine reading that may have been affected by acute pain or treatment; and radiological grades were abstracted from routine reports using a scale not validated for adult CT, without reliability assessment, while the use of the more severely affected kidney in bilateral cases discards information on the contralateral side. Fourth, purposive sampling, exclusion of patients with comorbidities affecting renal function or blood pressure, and restriction to patients who underwent CT may have introduced selection and referral bias. Fifth, the sample was small, with few patients in Grades 3 and 4, so estimates were imprecise; several outcomes and contrasts were examined without

adjustment for multiplicity; a potential interaction between severity and laterality could not be evaluated reliably; and the right-skewed creatinine distribution may have affected model assumptions. Finally, without a control group without hydronephrosis, the study cannot determine whether hydronephrosis itself raises creatinine or blood pressure. Prospective multicenter studies with serial eGFR, standardized blood-pressure measurement, documented etiology and duration, re-read CT grading with reliability assessment, and measurements before and after decompression are needed.

Conclusion

In this single-center retrospective cohort, bilateral and Grade 4 hydronephrosis on CT were associated with higher serum creatinine and higher systolic and diastolic blood pressure after adjustment for age and sex. These cross-sectional associations require confirmation in prospective studies with comprehensive clinical covariates, functional renal assessment, and longitudinal follow-up before radiological grade or laterality is used for prognostic or management decisions.

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DECLARATION OF INTEREST

There is no conflict of interest in this study.

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