



## Revisit of Factors Influencing Renal Doppler Indices

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ABSTRACT

### PURPOSE

To determine the factors influencing the renal Doppler indices with the help of duplex Doppler ultrasonography in patients with acute unilateral renal obstruction.

### BACKGROUND

Acute renal colic due to ureteric obstruction is one of the leading causes of morbidity. Ureterolithiasis is one of the frequent reasons for admission. Sonography though useful in the diagnosis of hydronephrosis fails to reveal acute obstruction of the kidney in 35% of the cases. Changes in renal system without hydroureteronephrosis can be evaluated with the help of Doppler ultrasonography by measuring resistivity and pulsatility indices in unilateral urinary tract obstruction. This prospective study aims at determining the influence of factors responsible for changes due to acute unilateral obstruction on intrarenal arterial Doppler.

### MATERIALS AND METHODS

A total of 60 patients (60 unilaterally obstructed kidneys and 60 contralateral normal kidneys) who were referred to the Radio-Diagnosis department for a period of 10 months and Ultrasound examination were done with Philips HD11XE ultrasonography machine using curvilinear array transducer of 2.5-5.0MHz. Renal arteries were examined by Colour Doppler with a 2-5mm sample volume to calculate the renal indices. The collected data were entered in Epi info version 7.0 software and analyzed using SPSS software version 24.0.

### RESULTS

The mean RI in obstructed cases of both males and females on either side, irrespective of the size of calculus, was in the range of 0.73 and mean PI was 1.29. Similarly the mean RI and PI at different levels of obstruction and degree of hydroureteronephrosis were in the range of 0.71-0.73 and 1.27-1.29 respectively on either side. There was no statistical significance noted comparing the obstruction from right with left side and no correlation could be established between age, gender, degree of hydroureteronephrosis, side, size and site of calculus causing obstruction. Immaterial of these factors, mean RI and PI will not be affected in finding out patients with acute ureteric obstruction.

### KEYWORDS

Renal Doppler, Doppler index, Resistive index (RI), Pulsatility index (PI), calculus, hydroureteronephrosis

### INTRODUCTION

Renal colic is one of the most common conditions and accounts for 30-35% of urological emergencies. The incidence is higher in men (10-20%) than in women (3-5%) with recurrence within 5 years.<sup>1</sup> Ureterolithiasis is a frequent cause of admission to emergency departments for which conventional and colour Doppler ultrasonography (USG) promotes in diagnosing patients with flank pain.<sup>2</sup>

Ultrasonography identifies the basic anatomy of the kidneys. It is a sensitive detector of pelvicalyceal dilatation. This is important because minor dilatation is a well-recognized finding in some patients with severe obstruction, particularly those with acute ureteric obstruction caused by a calculus. With the advent of Doppler study, phenomenal areas of research have been done to diagnose defects in the functional capabilities of the kidney. Hence a combination of Ultrasound with Doppler study is the most common modality in practice for the diagnosis of renal obstruction.

In the diagnosis of renal obstruction, the sensitivity of ultrasound is much better than its specificity. Acute complete ureteric obstruction is associated with changes in renal blood flow as well as with an increase in renal pelvic pressure. In first few hours, renal blood flow increases, most likely because of

afferent arteriolar dilatation. After 3-5 hours, it decreases due to vasoconstriction produced by prostaglandins<sup>3</sup> and other vasoactive substances. The variation in renal blood flow can be demonstrated with Doppler ultrasonography.

Duplex Doppler sonography is a noninvasive, adjunctive test with good patient acceptability and also helps in study outcome, by detecting the subtle changes in intrarenal blood flow and in diagnosing various pathological conditions earlier.<sup>4</sup> In our study, the factors affecting the renal Doppler indices like Resistive index (RI), Pulsatility Index (PI) were assessed in detail.

### AIMS & OBJECTIVES

The study is to evaluate the factors affecting the renal Doppler indices in acute unilateral ureteral obstruction and its relationship with any of the index to be established.

### Factors taken into account are:

- Side predominance
- Level of calculus causing obstruction
- Grade of obstruction/hydroureteronephrosis
- Size of calculus

**RENAL DOPPLER INDICES**

$$1. \text{Resistive index (RI)} = \frac{\text{PSV} - \text{EDV}}{\text{PSV}}$$

• It is a measure of impedance to renal blood flow.

$$2. \text{Pulsatility index (PI)} = \frac{\text{PSV} - \text{EDV}}{\text{Time accelerated velocity}}$$

• It is a measure of variability of blood velocity in a vessel.

**MATERIALS & METHODS**

**INCLUSION CRITERIA:**

1. All patients with acute unilateral flank pain or ureteric colic.
2. On ultrasonography, patients who have signs of acute unilateral obstruction, ureteric calculi, blood clot, features of hydronephrosis, hydro ureter.

**EXCLUSION CRITERIA:**

1. Patients with Bilateral ureteral obstruction.
2. Patients with a diseased kidney.
3. Patients with congenital anomaly of kidneys, single kidney.
4. Patients with renal trauma.
5. Patients on hemodialysis.
6. Patients with pre-existing renal artery stenosis which can be excluded via PSV, EDV and spectral pattern.

**STATISTICAL ANALYSIS**

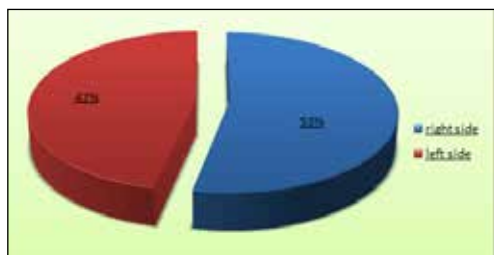
Standard protocols were applied for each patient while performing the scan after clinical history and informed consent were taken. Ultrasound and duplex Doppler study were done with Philips HD11XE ultrasonography machine using curvilinear array transducer (2.5-5 MHz). The unilateral kidney showing hydronephrosis was considered as the obstructed kidney and the contralateral normal kidney was considered to be the non-obstructed (normal) kidney. The collected data were entered in Epi info version 7.0 software and analyzed using SPSS software version 24.0 and mean was used as per the type of variable. Comparisons of renal Doppler indices such as RI, PI between obstructed and non-obstructed group were done using the paired sample t- test. p-value ≤ 0.05 were considered as statistically significant

**ETHICAL CONSIDERATIONS**

The Ethical approval was obtained from the Institute Ethics committee of SMVMC&H, Puducherry. All the ethical principles was adhered in this study.

**RESULTS**

A total of 60 patients involving equal number (30) of male and female patients were included during my study period. All the patients were in the age group of 23 – 65 years. Out of 60 patients, majority **32 (53.3%)** patients had symptoms and obstruction on the **right side** while **28 (46.7%)** patients had obstruction on the **left side**.



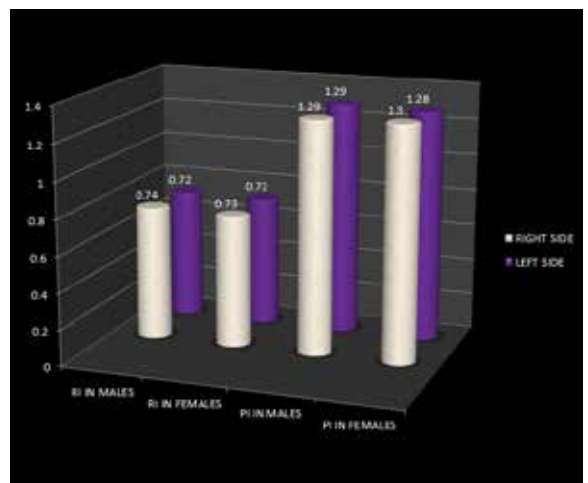
**Graph – 1 showing the 53% patients having obstruction on the right side while 47% on left side.**

**SIDE PREDOMINANCE:**

| renal index | side of obstruction | Ri In Males (Mean ± S.d) | ri in females (mean ± s.d) | t-value & degree of freedom (df) | p value |
|-------------|---------------------|--------------------------|----------------------------|----------------------------------|---------|
| RI          | RIGHT SIDE          | 0.74 ± 0.02              | 0.73 ± 0.01                | 1.436(58)                        | 0.15    |
|             | LEFT SIDE           | 0.72 ± 0.03              | 0.72 ± 0.03                | 1.404(47)                        | 0.16    |
| PI          | RIGHT SIDE          | 1.29 ± 0.20              | 1.3 ± 0.20                 | 0.042(58)                        | 0.97    |
|             | LEFT SIDE           | 1.29 ± 0.14              | 1.28 ± 0.14                | 0.043(55)                        | 0.97    |

**Table 1: Side of calculus causing obstruction along with the impact on RI, PI and their variation in males and females.**

Taking side predominance as a factor, there is not much significant change in the renal Doppler indices both RI and PI between males and females. Overall mean RI on the obstructed side was 0.72-0.74 on right and left side, whereas mean RI on the non-obstructed side was 0.60 for all patients irrespective of the gender. Both were not statistically significant (p > 0.05). Similarly the mean PI on obstructed side was 1.28-1.30 on both right and left side which was also not statistically significant (p > 0.05). Non-obstructed side showed a mild variation of mean PI from 0.94 – 1.0.



**Graph 2 – variations in the mean RI and PI values in both sexes when the obstruction occurs on either side.**

**CHANGES IN RI & PI ACCORDING TO THE LEVEL OF CALCULUS:**

| S.NO. | SITE OF CALCULUS          | RI                      |                        | PI                      |                        |
|-------|---------------------------|-------------------------|------------------------|-------------------------|------------------------|
|       |                           | RIGHT SIDE (MEAN ± S.D) | LEFT SIDE (MEAN ± S.D) | RIGHT SIDE (MEAN ± S.D) | LEFT SIDE (MEAN ± S.D) |
| 1     | PROXIMAL URETER           | 0.71 ± 0.03             | 0.73 ± 0.02            | 1.28 ± 0.19             | 1.25 ± 0.17            |
| 2     | MID URETER                | 0.70 ± 0.17             | 0.72 ± 0.15            | 1.27 ± 0.09             | 1.30 ± 0.06            |
| 3     | DISTAL URETER             | 0.73 ± 0.03             | 0.72 ± 0.04            | 1.27 ± 0.22             | 1.28 ± 0.28            |
| 4     | VESI-COURE-TERIC JUNCTION | 0.71 ± 0.17             | 0.73 ± 0.13            | 1.12 ± 0.15             | 1.13 ± 0.18            |

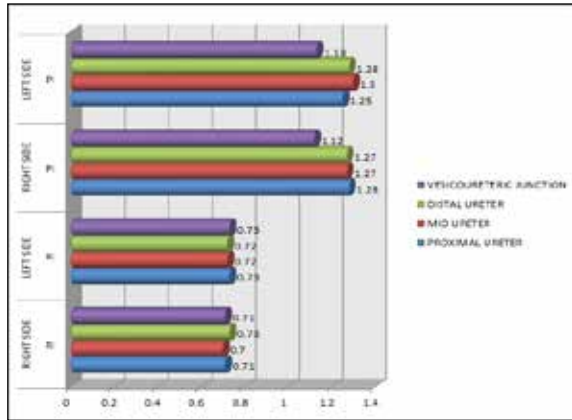
**Table 2: Calculus at different levels of ureter causing impact on the Doppler index (RI, PI)**

| RENAL DOPPLER PARAMETER | F-value & Degree of freedom (df) | p value |
|-------------------------|----------------------------------|---------|
|-------------------------|----------------------------------|---------|

|    |         |       |
|----|---------|-------|
| RI | 0.8(3)  | 0.499 |
| PI | 0.85(3) | 0.468 |

**Table 3: ANOVA test showing both RI and PI not significant at any level of obstruction.**

Study was conducted on 60 patients and of which about 32 (53%) patients had proximal ureteric calculus, 6 (10%) patients had mid ureteric calculus, 7 (12%) had distal ureteric obstruction in the form of calculus and 15 (25%) had vesicoureteric junction calculus causing mild to moderate obstruction.



**Graph 3 – comparison of mean RI and PI values at different sites of obstruction on the right side with that of opposite side.**

According to the level of calculus causing obstruction, the mean renal parameter changes in RI and PI were calculated but statistically insignificant variation ( $p > 0.05$ ) was noted. The mean RI on right side at various levels (proximal, mid, distal and vesicoureteric junction (VUJ) were between 0.70 - 0.73 but on left side, was 0.72 - 0.73. Considering mean PI on right side in proximal, mid and distal ureter, it was between 1.27 and 1.28 but on left side showed a mild variation of 1.25 - 1.30. Vesicoureteric junction alone showed a lower PI of 1.12 and 1.13 on either side without significant variation on both sides. ANOVA test showed no significance in the renal Doppler parameters on both sides with respect to the level of obstruction.

**AMOUNT OF OBSTRUCTION & ITS EFFECT ON RI:**

Of the total 60 patients, **50 (83.6%)** showed **mild degree of hydroureteronephrosis (HUN)** while **10 (16.4%)** showed **moderate degree of hydroureteronephrosis**. There was **no** statistical significance noted in resistive index (RI) between mild and moderate degree of obstruction on either side.

| s.no. | amount of obstruction hydroureteronephrosis (hun) | ri changes on right side (mean ± s.d) | ri changes on left side (mean ± s.d) | t-value & Degree of freedom (df) | p value |
|-------|---|---------------------------------------|--------------------------------------|----------------------------------|---------|
| 1     | MILD HUN  | 0.72 ± 0.02                           | 0.72 ± 0.04                          | 1.602(58)                        | 0.115   |
| 2     | MODERATE HUN                                      | 0.73 ± 0.05                           | 0.74 ± 0.03                          | 0.954(9.6)                       | 0.364   |

**Table 4: Amount of obstruction in the form of Hydroureteronephrosis (HUN) with their corresponding effect on RI.**

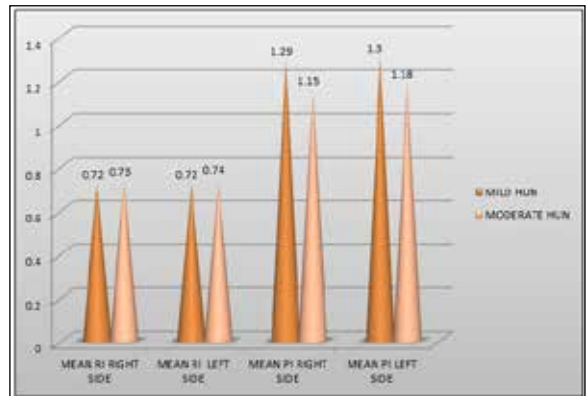
**AMOUNT OF OBSTRUCTION & ITS EFFECT ON PI:**

**No** statistical significance ( $p > 0.05$ ) noted in pulsatility index (PI) between mild and moderate degree of obstruction on either side.

| s.no. | amount of obstruction hydroureteronephrosis (hun) | pi changes on right side (mean ± s.d) | pi changes on left side (mean ± s.d) | t-value & Degree of freedom (df) | p value |
|-------|---|---------------------------------------|--------------------------------------|----------------------------------|---------|
| 1     | MILD HUN  | 1.29 ± 0.14                           | 1.30 ± 0.17                          | 1.162(58)                        | 0.250   |

|   |              |             |             |             |       |
|---|--------------|-------------|-------------|-------------|-------|
| 2 | MODERATE HUN | 1.15 ± 0.19 | 1.18 ± 0.18 | 1.102(12.2) | 0.292 |
|---|--------------|-------------|-------------|-------------|-------|

**Table 5: Amount of obstruction in the form of Hydroureteronephrosis (HUN) with their corresponding effect on PI.**



**Graph 4 – representing no significant change in the mean RI and PI values between mild and moderate HUN on both sides**

**CALCULUS SIZE:**

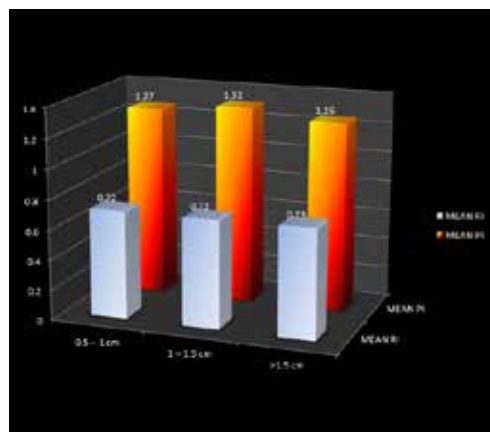
| CALCULUS SIZE | NUMBER (N) | RI (MEAN ± S.D) | PI (MEAN ± S.D) |
|---------------|------------|-----------------|-----------------|
| 0.5 – 1 cm    | 32         | 0.72 ± 0.02     | 1.27 ± 0.16     |
| 1 – 1.5 cm    | 24         | 0.72 ± 0.02     | 1.32 ± 0.17     |
| >1.5 cm       | 4          | 0.73 ± 0.07     | 1.26 ± 0.25     |

**Table 6: Comparison of mean RI and mean PI with respect to calculus size**

| RENAL DOPPLER PARAMETER | F-value & Degree of freedom (df) | p value |
|-------------------------|----------------------------------|---------|
| RI                      | 2.885(2)                         | 0.06    |
| PI                      | 1.209(2)                         | 0.306   |

**Table 7: ANOVA test showing both RI and PI not significant with respect to calculus.**

Majority **32/60** (54%) had **subcentimetric (<1 cm)** calculus with a mean RI of 0.72 and mean PI of 1.27. **24 (40%)** patients who had calculus of size between 1 – 1.5 cm and **4** patients who had calculi more than 1.5cm, also showed similar mean RI of 0.72 and 0.73 and mean PI of 1.32 and 1.26 respectively. Statistically no significant correlation was achieved between renal Doppler indices and size of calculus. ANOVA test showed no significance in the renal Doppler parameters on both sides with respect to the calculus size.

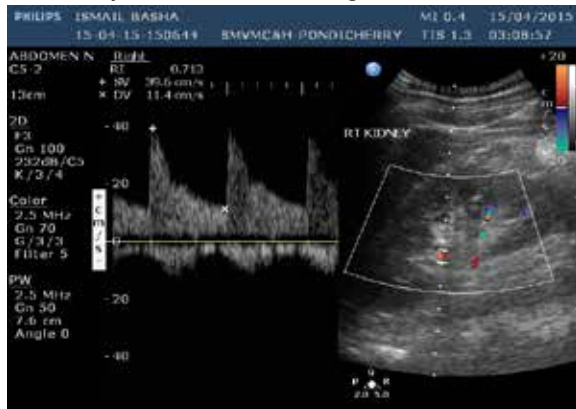


**Graph 5 - Calculus size distribution frequency among the patients.**

## CASE OBSERVATIONS



**Figure 1: Grayscale image showing 0.89cm right vesicoureteric junction calculus causing mild HUN**



**Figure 2: Doppler image showing RI of 0.71 in obstructed (right) kidney**



**Figure 3: Doppler image showing PI of 1.34 in obstructed (right) kidney**

## DISCUSSION

Patients with renal colic are usually examined with one or more of the following modalities like X-ray KUBU (Kidney, Ureter, Bladder and Urethra), Ultrasonography (USG), Intravenous Urography (IVU) and CT KUB. Of these USG is the only radiation-free modality of choice used when contraindications for other modalities like contrast allergy, pregnancy, renal impairment and repeated episodes of renal colic are present. Conventional USG shows 90% sensitivity and specificity varies from 65 – 84% in urinary tract obstruction. Though renal obstruction in conventional USG is dependent on anatomical criteria of dilated pelvicalyceal system (PCS) and ureter proximal to the site of obstruction, it is an indirect sign of diagnosis which has lesser positive predictive value of only 35%.<sup>1</sup> Renal Doppler USG is a highly sensitive and specific test that can be useful in the diagnosis of acute unilateral renal obstruction.<sup>2</sup> By allowing direct assessment of haemodynamic response in intrarenal arteries, Doppler ultrasonography has

increased the possibility of early detection of obstruction. Acute unilateral ureteric obstruction results in a complex sequence of changes in renal blood flow and ureteric pressure. **Resistive Index (RI)** is a physiological parameter that ensures indirect measurement of the degree of resistance within intrarenal vessels.<sup>5</sup>

Lin ZY *et al*<sup>6</sup> studied in 135 subjects between the age range of 17-68 years, showed a very weak correlation between intrarenal RI and age but there was no clinical importance. Kavakli HS *et al*<sup>7</sup> made a study on 70 participants whom he divided into 3 groups and found that there was no significant difference noted in the RI levels with respect to age and gender ( $p > 0.5$ ,  $p > 0.05$  respectively). Similarly **no** statistical significance noted between age or gender and intrarenal RI and PI in cases presenting with unilateral obstruction due to calculus.

Platt JF *et al*<sup>7</sup>, studied 27 acute ureteric obstruction cases and found that the mean RI was elevated in proximal, mid and distal ureteral obstruction but there was no statistical difference in the mean RI at different levels and size of calculus. Studies done by Sayani R *et al*<sup>8</sup>, Shokeir *et al*<sup>9</sup> and Gurel S *et al*<sup>10</sup> revealed that the level of ureteric obstruction had no significant impact on RI in their study which was in agreement with our study having no change in the mean RI and PI values recorded at different levels of obstruction and size of calculus.

Saboo S *et al*<sup>4</sup> and deToledo *et al*<sup>11</sup> studied the factors affecting the renal Doppler indices and found that the patients with proximal ureteric obstruction have higher RI than those with distal obstruction. In our study, there was no difference in the mean RI in proximal, mid and distal ureteric obstruction but there was mild drop in the mean PI alone when the obstruction was at the level of vesicoureteric junction. However, the difference was not statistically significant on either side.

Several authors have assessed the relationship between degree of pelvocalyceal dilatation and RI. Results got from Platt JF *et al*<sup>7</sup>, Brkljacic *et al*<sup>12</sup>, Rodgers PM *et al*<sup>13</sup>, Gurel *et al*<sup>10</sup>, Saboo SS *et al*<sup>4</sup> showed no statistically significant correlation between severity of hydronephrosis and Doppler indices although Chen *et al*<sup>14</sup> detect a correlation among mild and significant obstructive cases with that of Doppler indices. In our study, there was no significant renal Doppler indices variation with respect to mild hydronephrosis. However there was mild decline in mean PI in patients presented with moderate hydronephrosis compared with mild hydronephrosis though there was insignificant difference in mean PI on either side.

Miletić D *et al*<sup>15</sup> conducted study on 78 patients and used ANOVA test to determine the influence of degree of hydronephrosis on RI and  $\Delta$ RI between obstructed and non-obstructed kidneys. There was no significant correlation achieved between pelvocaliectasis and renal Doppler values which was in line with the results of our study.

Piazzese EMS *et al*<sup>1</sup> also found no correlation between mean RI values and the level of obstruction, degree of dilatation, size of the obstructing calculus or duration of the pain which was also similar to the results of our study data.

## CONCLUSION

Doppler USG is an useful diagnostic tool in unilateral acute renal obstruction. The sensitivity of gray scale USG for detecting obstruction was found to be 77.5%. Doppler was useful even when USG were normal. Increase in RI and PI value in the obstructed side in comparison with that of contralateral non-obstructed side clearly defines obstructive pathology is on the chart to consider. However, from our study, its proved that mean RI and PI values are independent of all these factors - gender, level and degree of obstruction and size of calculus.

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