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# Correlation between Doppler sonography and diuretic renogram in the diagnosis and follow-up of infants with unilateral pelvi-ureteric junction obstruction



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# Abstract

**Background** Conventionally, diuretic isotope renogram is used to establish and quantify severity of the obstruction in pelvi-ureteric junction obstruction. Doppler ultrasonography too assesses obstruction by evaluating the resistive index (RI) and resistive index ratio (RIR) in the intrarenal vasculature of the kidneys. This study aimed to note correlation between RI, RIR on Doppler ultrasonography and perfusion index (PI) on diuretic isotope renogram in suspect unilateral pelvi-ureteric junction obstruction in infants. A prospective study (2016–2019) in infants with suspect unilateral hydronephrosis, i.e. anteroposterior pelvic diameter (APPD) > 15 mm, divided into Group A (0–6 months) and Group B (6–12 months) based on the age at diagnosis. The RI, RIR and PI were noted at diagnosis, at 3 and 6 months, post-interventions and the correlation assessed.

**Results** 37/94 with hydronephrosis were included in the study. 30 among these underwent surgical intervention. A decrease in RI and RIR and increase in PI following surgery were documented at follow-up. Also, the improvement was statistically more significant in the first 3 months following intervention.

**Conclusions** An increased RI and RIR and a decreased PI are good indicators of obstruction in unilateral hydronephrosis in infants. The decline in RI with increase in PI following relief of obstruction shows a positive correlation between the two. Doppler sonography may be effective in monitoring unilateral hydronephrosis with unobstructed or equivocal renogram curves and consequently negate the need for repeated nuclear scans.

**Keywords** Pelvi-ureteric junction obstruction, Doppler sonography, Resistive index, Resistive index ratio, Diuretic renogram, Perfusion index

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# Background

Among the antenatally detected fetal anomalies, 20-50% involve the genitourinary system and 50% of these manifest as hydronephrosis [1]. The incidence of antenatally detected hydronephrosis is 2-9 per 1,000 live births, the prevalence being 0.6-5.4% [2, 3]. Postnatal imaging shows resolution of hydronephrosis in 41-88% of these infants. Intervention is warranted only in a small percentage of children; of which pelvi-ureteric junction obstruction is the most common [4]. Hydronephrosis with antero-posterior pelvic diameter (APPD) > 10 mm



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persisting postnatally necessitates evaluation using an isotope diuretic renogram to confirm obstruction [5].

Advancements in Doppler ultrasound have helped in better understanding of renal physiology and enable the detection of subtle renal blood flow changes associated with various pathophysiological conditions. These changes may be quantified by calculating the intrarenal vascular resistive index (RI) which is a reliable indicator of obstruction and is helpful to differentiate obstructive from non-obstructive hydronephrosis [6–8]. The perfusion index (PI) first interpreted by Hilson in 1976 in renal transplant units serves as a good indicator of vascular perfusion of the affected renal unit which improves after appropriate surgical intervention [9]. The resistive index (RI) of > 0.7 and the resistive index ratio (RIR) of > 1.1 signify obstruction and comply well with the results of isotope diuretic renogram [10, 11].

Thus far, there has been no correlative analysis between Doppler ultrasonography (RI, RIR) and diuretic renogram (PI), in obstructed and non-obstructed kidneys. This study aimed to analyse these values in unilateral hydronephrosis and look for any correlation.

## Methods

This is a single-centre, prospective study conducted in the Department of Paediatric Surgery, over 36 months (2016–2019) based on a departmental protocol as depicted in Fig. 1. All infants with unilateral hydronephrosis and APPD > 15 mm were included in the study and those with APPD < 15 mm, bilateral hydronephrosis, unilateral/bilateral hydroureteronephrosis, solitary kidneys with hydronephrosis were excluded. Our departmental protocol is formulated based on the "Revised guidelines on management of antenatal hydronephrosis" by Indian society of Paediatric Nephrology (ISPN) with minor modifications.

All infants with hydronephrosis underwent renal function test, urine culture and a renal ultrasound to assess the APPD. Infants with unilateral hydronephrosis and APPD>15 mm were further subdivided into two groups based on their age at diagnosis, i.e. Group A (0-6 months) and Group B (6-12 months). These underwent a Doppler ultrasonography initially to document the resistive index, i.e. (peak systolic velocity-lowest diastolic velocity)/peak systolic velocity) in the intersegmental arteries of the affected kidney, and resistive index ratio, i.e. (RI of hydronephrotic kidney/ RI of normal kidney), performed by a single experienced radiologist. An isotope diuretic EC renogram was then performed to confirm the obstruction, and the perfusion index, i.e. (Hilson's Index = area under arterial curve to peak/area under renal curve×100), was recorded apart from other parameters like intra renal transit, tracer hold up, t 1/2 for tracer clearance.



Fig. 1 Departmental protocol for the management of infants with unilateral hydronephrosis (as per ISPN revised guidelines)

Infants were catheterized with a suitable sized infant feeding tube under aseptic precautions, well hydrated orally, had a secure peripheral line placed prior to the procedure and the F 0 protocol for the scan was followed [12]. On Doppler sonography, RI > 0.7 and

RIR > 1.1 (Fig. 2A), and an impaired PI on isotope diuretic renogram (in addition to the standard renogram parameters—tracer uptake and drainage curve), respectively, confirmed obstruction of the affected renal unit pre-operatively (Fig. 3a-c).



**Fig. 2 A** A 8-month-old boy with right hydronephrosis, Doppler image depicting resistive index of 0.82 in the affected right kidney, where in the waveform shows a delayed upstroke with reduced frequency, indicating resistance to the vascular flow and signifying obstruction. **B** Doppler sonography image of the child post-intervention at 6 months depicting, resistive index of 0.60 in the affected right kidney, where in the waveform shows a rapid upstroke with a good amplitude and increase in frequency, indicating least resistance to the vascular flow following relief of obstruction



Fig. 3 a A 5-month-old girl with left hydronephrosis—renogram image of perfusion phase showing minimal perfusion in the affected left kidney. a1 Renogram image of perfusion phase showing normal perfusion in the left kidney in follow-up. b Minimal tracer uptake in the left kidney (obstructed). b1 Good tracer uptake following surgery. c Obstructed renogram curve of left kidney at diagnosis. c1 Unobstructed renogram curve of left kidney 6 months post-surgery

## Interventions

Once obstruction was confirmed, majority underwent a standard Anderson Hynes dismembered pyeloplasty (26). Laparoscopic pyeloplasty, vascular adhesiolysis (in those with vascular adhesions) and pyelo ureterostomy (for lower pole aberrant vessels) were other surgeries performed in some (4). The ones with non-obstructive hydronephrosis were managed conservatively with uroprophylaxis and were on a close follow-up.

### Follow-up

All the infants were followed up initially at 3 and 6 months, and then annually. Renal ultrasound to monitor the APPD, colour Doppler sonography for RI and RIR (Fig. 2B) isotope renogram to assess the PI and postoperative relief of obstruction (Fig. 3a1, b1, c1) were the key points documented at follow-up. The decrease in the RI and RIR and increase in the PI at follow-up in infants operated and those on uro-prophylaxis were statistically analysed, and a P value of < 0.05 was considered to be significant. Statistical analysis used was as follows (1) for RI, PI and APPD: paired t test, (2) gender and laterality of affected kidney: chi-square test of independence, (3) differential function (DF) (%): Z-test for equality of two proportions, (4) first minute perfusion: chi-square test of independence/equality of proportions. Statistical analysis was done using SPSS software, and the results were tabulated.

This study was approved by the Institutional Ethics Committee, and an informed verbal as well as written consent had been obtained from the parents of the infants included in this study.

# Results

Among 94 infants with hydronephrosis, 37 were diagnosed to have unilateral hydronephrosis with APPD>15 mm. Of these 37, Group A had 24 infants and Group B had 13. The average age distribution

among Group A was 3 months, and Group B infants was 9 months, respectively. Antenatal detection of hydronephrosis was noted in 73% (27) most in the III trimester (63%). Boys were commonly affected with a right-sided predominance. All but 4 infants were symptomatic, a palpable mass was the commonest presentation in 19 infants, most of whom were in Group B, and the other presenting symptoms included pain, dysuria and fever. In Group A (24), 19 underwent surgery, 5 were managed conservatively and in Group B (13), 11 underwent surgery, and 2 were managed conservatively. 7 managed conservatively were placed on uro-prophylaxis and followed up at 3 and 6 months from the diagnosis and hydronephrosis gradually resolved. Of the 30, 26 underwent Anderson Hynes dismembered pyeloplasty; laparoscopic pyeloplasty (1), pyelo ureterostomy (1) and vascular adhesiolysis (2) were the other surgeries done. Post-operative complications were seen in 8, 6 had urinary tract infection, managed with antibiotics, one had stent migration into the pelvis, which was retrieved endoscopically, and 1 infant with vascular adhesions had persistent obstruction after the procedure and needed a standard pyeloplasty. Demographic details, gender, laterality of affected kidney, antenatal diagnosis, presenting symptoms, modes of management and complications in both Group A and Group B were collated (Table 1).

The findings on Doppler sonography and isotope diuretic renogram at diagnosis, 3 months and 6 months post-interventions were analysed individually among the groups. It was noted that the absolute decrease in the mean RI at 6 months following an intervention was 0.09 in Group A and 0.008 in Group B, respectively. This was significant in both the age groups with a *P* value of < 0.001, and the noted decrease was more in the first 3 months. Similarly, the absolute increase in mean PI at 6-month follow-up following an intervention was 4.8 in Group A and 5.23 in Group B, showing significant improvement in both the age groups, and the improvement in

 Table 1
 Demographic details, gender, laterality of affected kidney, antenatal diagnosis, presenting symptoms, modes of management

 and complications, in both Group A and Group B infants
 Infants

	N = 37 infants (Group A and Group B)				
Age (average)	Group A-3 months		Group B-9 months		
Sex (M: F)	31:6				
Laterality (Right kidney: left kidney)	23: 14				
Antenatal detection	27				
Symptoms	Palpable mass-19	Dysuria-7	Pain-4	Fever-3	
Interventions	Surgical-30		Conservative-7		
Complications	Urinary tract infection-6	Stent migration-1	Redo surgery-1		

the first 3 months was statistically significant with a P value < 0.001 (Table 2). The RIR reflects the RI of the affected kidney with respect to the unaffected kidney, and both the age groups showed significant decrease in the mean RIR at 3 months and 6 months (Table 3). The median follow-up in our study was 18 months.

At follow-up, we noted a decrease in RI and increase in PI, which was statistically significant, in younger infants, i.e. Group A than Group B, and obvious in the first 3 months post-intervention than after 6 months. Changes in RI and RIR were concurrent (Fig. 4). 1/37 expired several weeks after pyeloplasty due to other comorbidities. Among those managed only on uro-prophylaxis, follow-up Doppler sonography showed static or decreasing RI but, with improvement in PI and good drainage from the affected renal units (having equivocal renogram curves at diagnosis) on isotope renogram.

## Discussion

Hydronephrosis is the most commonly detected antenatal renal anomaly [1]. Conventionally isotope renogram as a dynamic study is used to confirm obstruction, while Doppler ultrasonography assesses resistive index in the intrarenal vasculature to document obstruction [5, 6]. **Table 3** Changes in the resistive index ratio in both the age groups (Group A and Group B), at diagnosis, 3 months and 6 months post-intervention

	At diagnosis	3-month follow-up	6-month follow-up
Resistive index	ratio		
Group A	1.13	1.06	1
Group B	1.11	1.05	1

Our study aimed to note the correlation between these two investigation modalities in the assessment of unilateral hydronephrosis in infants.

Routine antenatal ultrasonographic screening has led to an early diagnosis of pelvi-ureteric junction obstruction in infants. Depending on the diagnostic criteria and gestation, the prevalence of antenatally detected hydronephrosis ranges from 0.6 to 5.4%, and we noted that 73% of the infants in our study were antenatally detected, 37% in the second trimester and 63% in the third trimester, in contradiction to the observation by Kim et al. [13] who have noted that antenatal detection was commoner in the second trimester and required surgery more often

Table 2 Changes in resistive index and perfusion index in both the age groups, at diagnosis, 3 months and 6 months postintervention

	At diagnosis	3-month follow-up	6-month follow-up
Resistive index			
Group A			
Mean RI	0.80	0.73	0.71
Decrease after intervention	_	0.07	0.02
Significance	-	Significant	Significant
<i>P</i> value		< 0.001	< 0.001
Group B			
Mean RI	0.78	0.73	0.70
Decrease after intervention	-	0.05	0.03
Significance	_	Significant	Significant
<i>P</i> value		< 0.001	< 0.001
Perfusion index			
Group A			
Mean Pl	43.2	46.6	48.0
Increase after intervention	_	3.4	1.4
Significance	_	Significant	Not significant
<i>P</i> value		< 0.001	>0.05
Group B			
Mean Pl	44.15	49.44	49.38
Increase after intervention	_	5.29	- 0.06
Significance	_	Significant	Not significant
<i>P</i> value		< 0.001	>0.05

Bold values indicate statistically significant improvement in the resistive index and perfusion index of the affected kidney at 3 months and 6 months follow up



Fig. 4 Graphical representation of decrease in the resistive index, increase in perfusion index and decrease in resistive index ratio, at diagnosis to 6-month follow-up of infants

than those diagnosed during the third trimester. However, male predominance (82%) and right side affection (65%) is comparable to the series by Zhang et al. [14]. A palpable mass was common in the Group B infants, in contrast to the observation by Gonzalez [15] where infants < 6 months of age presented more often with an abdominal mass.

Renal ultrasonography detects dilatation of the urinary system proximal to the level of obstruction, thus providing an indirect clue to the diagnosis, and yet it fails to reveal collecting system dilatation in 21-35% of cases with acute obstruction [16, 17]. In chronic renal obstruction, pressure within the collecting system increases substantially, and a reduction in compliance of the renal vessels develops with an increase in vascular resistance, recorded as the resistive index of the affected kidney, which can be evaluated by colour Doppler sonography of the intersegmental arteries [18, 19]. Isotope renogram provides an accurate measurement of individual renal function; however, when obstruction is equivocal on diuretic renography, findings on Doppler ultrasonography may assist in distinguishing between obstructed and non-obstructed kidneys [12]. 37 infants with hydronephrotic kidneys with APPD>15 mm were systematically followed up from diagnosis (30 obstructive, 7 non-obstructive) in infancy over 6 months with Doppler sonography (RI, RIR), and an isotope diuretic renogram (PI) and their response to surgical relief of obstruction (30/37) or to conservative management (7/37) were scrutinized. We noted a significant decrease in the APPD in both the age groups of infants at 3 months and 6 months after surgery, which is similar to the studies by Sarhan et al. [20].

All the 37 infants had a RI > 0.7, and a RIR of > 1.1 at diagnosis indicating obstruction as noted by Shokier and Tublin [6, 8]. A statistically significant decrease in the RI was seen in both the age groups at 3- and 6-month follow-up after a surgical intervention along with decrease in RIR. In a study of 23 renal units, RI was > 0.7 in 22 pre-operatively and after pyeloplasty, 21 renal units showed reduction in RI to < 0.7 at 1-year follow-up [21]. Boubaker [22], using RI as an indicator of absolute function, reported that in 53 children who underwent surgery improvement was seen in 88% after 5-15 years of follow-up. The absolute decline in the RI over 6 months in our infants was similar in both the groups; however, the proportion of decline was more significant in the first 3 months of follow-up. This decline is most evident in Group A, pointing to a greater recovery of the obstructed system in younger infants. It is now generally accepted that the RI is an age dependent parameter, with infants younger than 6 months of age, having higher mean resistive index values than adults and the values tend to decrease with increasing age [23]. Developmental renal physiology and plasma renin levels, which are elevated at infancy which gradually decreases by the age of 4 years, might explain this observation [24]. This physiological

occurrence is overcome in our infants as we have also checked RIR and documented higher indices establishing obstruction.

All infants underwent a diuretic isotope renogram and showed a decrease in the PI, and 7 of these did not have an obstructive renogram curve (equivocal) and were continued on uro-prophylaxis. At follow-up, the absolute increase in mean PI was significant in both the groups of infants; however, there was a statistically significant increase in the 3 months post-intervention than a nonsignificant increase at 6 months. Similar discrepancies exist in literature too, where in PI increased by>10% over a 2-year follow-up period in 28/32 patients after pyeloplasty than at a later follow-up of 5 years [25]. The improvement in the perfusion of the affected kidney after intervention could be explained due to vascular remodelling caused by relief of obstruction which continues all along infancy.

Though it is generally believed that surgical intervention is aimed at relief of urinary flow obstruction yielding the best results when performed in the first half of infancy, some authors reported differently. In 44 patients, operated after 13.3 months, 42 improved or attained the initial function within 6–24 months despite the delay at the age of surgery [26, 27], though in our study there was no delay in interventions after the diagnosis. Small sample size, however, has been a limitation of our study.

# Conclusions

This study takes a refreshed look at trends in RI, RIR and PI in obstructed and non-obstructed kidneys, which are sparsely studied in unilateral pelvi-ureteric junction obstruction in infancy. Despite a few aberrations, there is a predictable trend in the RI and PI when employed in combination for the management of unilateral pelviureteric junction obstruction. This positive correlation serves as a safe and effective tool in monitoring infants with unilateral hydronephrosis with un-obstructed or equivocal renogram curves. This avoids performance of repeated isotope renograms that can be reliably substituted by a non-invasive colour Doppler sonography.

#### Abbreviations

- APPD Antero-posterior pelvic diameter
- RI Resistive index
- PI Perfusion index
- RIR Resistive index ratio
- ISPN Indian Society of Pediatric Nephrology
- EC Ethylene dicysteine

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Not applicable.

#### Author contributions

Dr. AMS/Dr. KD contributed to the conception and design of the work. Dr. NP was involved in the acquisition and analysis of data. Dr. AMS/Dr. KD/DR PKV/

Dr. PGR were involved in the interpretation of data. Dr. NP prepared the initial draft. Dr. AMS reviewed the draft and critically revised it. Dr. PKV was involved in performing the Doppler and its interpretation. Dr. PGR did the nuclear scans and interpreted them. DR AMS/KD/NP were involved in the management of the children. All authors have reviewed the final draft and approved the submitted version.

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#### Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

#### Declarations

#### Ethics approval and consent to participate

Study is approved by Institutional Ethics committee St Johns Medical College – 395/2015. Parents of children have consented for participation in the study.

#### **Consent for publication**

Parents have consented for publication.

#### Competing interests

The authors declare that they have no competing interests.

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