ORIGINAL ARTICLE

Renal doppler assessment in differentiating obstructive from non-obstructive hydronephrosis in children

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ABSTRACT

Background: To determine the usefulness of Doppler ultrasound measurement of resistive index (RI) in differentiating obstructive from non-obstructive hydronephrosis in children.

Methods: From August 2011 to November 2012, renal Doppler assessments of the intra-renal renal arteries were performed on 16 children (19 kidneys) with congenital hydronephrosis. The independent T-test was used to assess for significant difference in RI values between those with obstructive hydronephrosis (6 kidneys) and those with non-obstructive hydronephrosis (13 kidneys) as determined by dynamic renal scintigraphy. The assessor was blinded to the clinical findings and scintigraphy results.

Results: RI was significantly different between obstructive and non-obstructive hydronephrosis. Obstructive hydronephrosis returned higher RI values, with mean RI of 0.78. Mean RI in non-obstructive hydronephrosis was 0.70, and the difference was significant (p <0.05). The sensitivity and specificity of Doppler ultrasound were 100% and 53% respectively.

Conclusion: Doppler ultrasound measurement of resistive index is useful in differentiating obstructive from non-obstructive hydronephrosis and provides an alternative non-ionizing investigation other than dynamic renal scintigraphy.

KEY WORDS:
Doppler; ultrasound; sonography; resistive index; hydronephrosis; children; paediatric

INTRODUCTION

Most congenital anomalies of the urinary tract present with hydronephrosis. In neonates the commonest cause of hydronephrosis is transient or physiological and it accounts for about 50% of cases.[1,2] This type of hydronephrosis is usually benign and resolves spontaneously within 1 year of life. However, some may persist beyond a year and most of these are pathological.

Ultrasound examination is commonly used in the assessment of the urinary tract to screen for hydronephrosis and other congenital anomalies, as well as for follow-up assessment of congenital hydronephrosis.[1,3]

Current definitive investigation of hydronephrosis is either micturating cystourethrography (MCUG) and/or dynamic renal scintigraphy (DTPA). These investigations are required to determine the type of hydronephrosis (obstructive or non-obstructive) as well as the cause of congenital anomaly. They are important because further management, whether surgical or medical, will rely on the results.

Risk of radiation exposure is a concern to many parents. Doppler ultrasound has been used in the assessment of renal arteries in babies with congenital hydronephrosis.[4] Apart from being non-ionizing and non-invasive, it has been reported to help in differentiating obstructive from non-obstructive hydronephrosis by renal arterial resistive index (RI) measurements.[3,5,6]

The main purpose of this study is to validate the usefulness of Doppler ultrasound measurement of RI in differentiating obstructive from non-obstructive hydronephrosis in children.

It is hoped that the results of this study would support the use of Doppler ultrasound as an alternative non-ionising investigation in the assessment of hydronephrosis in children at our centre, other than MCUG and DTPA which use ionising radiation, and in areas where DTPA is not available.

MATERIALS AND METHODS

This is a cross sectional study conducted from August 2011 to November 2012 in our centre. All children, aged 1 day to 12 years referred for USG of the renal system and found to have hydronephrosis, were included. Children with lethal abnormalities or who were critically ill, those without consent from the mother, those who did not undergo DTPA, or those with equivocal DTPA findings (the definition is elaborated below) were excluded (Fig. 1).

Renal Doppler assessment was performed to obtain the RI in patients with hydronephrosis. DTPA scan was used as the

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gold standard in differentiating obstructive from non-obstructive hydronephrosis. The RI of obstructive and non-obstructive hydronephrosis was compared. The final diagnosis of the cause of obstructive or non-obstructive hydronephrosis was based on DTPA scan, MCUG or surgical findings where relevant.

Ultrasound machine Philips EnVisor HD was used in this study. Examination was performed using linear probe 12 MHz. Patient was examined in supine position. The anteroposterior diameter (APD) of the renal pelvis was measured in millimeter (mm). Hydronephrosis was graded into mild (≤ 9 mm), moderate (10-15 mm) and severe (> 15 mm).[2,7]

The RI measurements were taken at renal hilar level. Ultrasound was performed without sedation or breath-holding. The ultrasound transducer and Doppler cursor were placed at sites where colour signal was optimum and scanning was performed continuously for a number of respiratory cycles. Since patients did not breath-hold, the Doppler tracings appeared and disappeared as the kidney moved with respiratory movements. After 'image freeze', the scrolling application was applied to review all images and acquire the best Doppler spectrum for RI measurements. A good Doppler spectrum acquisition was when at least three consecutive systolic-diastolic tracings were obtained. An adequate Doppler spectrum acquisition was when one complete systolic-diastolic tracing was obtained. The RI was calculated by the existing ultrasound machine computer software. The measurement of RI was based on the formula:[4]

RI = (PSV – EDV) / PSV
PSV: Peak Systolic Velocity; EDV: End Diastolic Velocity

Obstructive or non-obstructive hydronephrosis was determined by DTPA findings. In obstruction, clearance half-time of the radionuclide (technetium-99m DTPA) after furosemide administration was more than 20 minutes. In non-obstructive hydronephrosis, the clearance of radionuclide was less than 10 minutes. If clearance was between 10 to 20 minutes, the result was considered as equivocal.[3]

Measurements of renal pelvis diameter and RI were collected. Demographic data such as age, gender and race were collected as well. The determination of the causes of obstructive and non-obstructive hydronephrosis were based on MCUG, DTPA with or without operative findings.

The measured renal pelvis APD and RI were tabulated according to their pathology, i.e. obstructive or non-obstructive hydronephrosis. The RI values were compared between the obstructive or non-obstructive hydronephrosis groups. RI values greater than 0.7 were graded 'high', while those equal or less than 0.7 were graded 'low'. The choice of this cut-off value was based on several studies that had recorded RI ≤0.7 as normal.[4-6,8] Statistical analysis was done using SPSS software version 20. P-value of <0.05 was taken to be statistically significant.

RESULTS

The study included a total of 16 children with 19 kidneys (3 children had bilateral hydronephrosis). There were 9 males and 7 females, age ranging from 1 month to 7 years old with mean age being 1.75 years (Table I). There was predominance of Malay patients (50%), followed by Chinese (44%) and Indian (4%).

Majority (63%) of the kidneys were grossly hydronephrotic irrespective of being obstructed or not. Six (31.5%) of 19 hydronephrotic kidneys were obstructive while the rest were non-obstructive (Table II). There was a relatively higher percentage of obstructed kidneys presenting with gross hydronephrosis (83.3% or 5/6) compared to non-obstructed kidneys (53.8% or 7/13). None of the obstructed kidneys presented with mild hydronephrosis (Table II).

The RI ranged from 0.73 to 0.85 in obstructive hydronephrosis with a mean of 0.78 and standard deviation (SD) of 0.04. The RI in non-obstructive hydronephrosis ranged from 0.62 to 0.81 with a mean of 0.70 and SD of 0.07 (Figure 2). There was significant difference in the mean RI of obstructive and non-obstructive hydronephrosis, with a p-value of 0.04 ($p<0.05$).

Taking 0.7 as the cut-off value, all obstructive hydronephrosis had high RI value (RI>0.7), whereas in non-obstructive hydronephrosis only 4 of the 13 kidneys had high RI reading.

In relation to the patients' age, the younger age group showed higher RI regardless of the type of hydronephrosis, whether obstructive or non-obstructive (Table I).

DISCUSSION

Hydronephrosis can be obstructive or non-obstructive. The common causes of obstructive hydronephrosis include pelviureteric junction (PUJ) obstruction, ureterovesical junction (UVJ) obstruction and posterior urethral valve. Vesicoureteric reflux (VUR) is a cause of non-obstructive hydronephrosis. Surgical intervention may be required for obstructive hydronephrosis to prevent further damage to the renal parenchyma. It has been reported that obstructive hydronephrosis accounts for about 16% of antenatally diagnosed hydronephrosis in neonates.[7]

It has been reported that hydronephrosis due to obstruction caused a change in the renal arterial Doppler spectra, and several pathophysiological pathways have been postulated. In a tense obstructed system, there is an elevation of renal vascular resistance causing intra-renal vasoconstriction. This will result in a decrease of blood flow velocity which is greater during diastole than during systole.[4-6,9-12] The decrease in diastolic velocity causes elevation of the RI, based on the equation: RI = (PSV – EDV) / PSV. Thromboxane A2 (TXA2), a vasoconstricting agent secreted in the obstructed system, may be responsible for the elevation of the vascular resistance, along with other vasoactive agents.[6,8,11]

The theory was supported by a Doppler ultrasound study of hilar renal arteries in 19 children with hydronephrosis caused by PUJ stricture.[6] The authors reported that RI was 0.84 in patients with obstructive PUJ stricture and 0.65 in those with

Table I: Patient age distribution in relation to type of hydronephrosis and RI grading

Age (year)	Frequency	Type of Hydronephrosis		RI Grading	
		Obstructive	Non-obstructive	High (>0.7)	Low (≤0.7)
< 1	6	3	3	5	1
1 to < 2	4	2	2	2	2
2 to < 3	3	0	3	1	2
3 to < 4	1	0	1	0	1
≥ 4	2	1	1	1	1
Total	16	6	10	9	7

Table II: Degree and type of hydronephrosis

Degree of hydro-nephrosis	Number of kidneys (%)	Type of hydronephrosis		
		Obstructive	Non- obstructive	Total
Mild	3 (16)	0	3	3
Moderate	4 (21)	1	3	4
Gross	12 (63)	5	7	12
Total	19 (100)	6	13	19

Table III: Disposition of subjects in referenced studies

Study	Number of kidneys (N)	Obstructed Kidneys		Non-obstructed Kidneys	
		RI ± SD	(N)	RI ± SD	(N)
Okada *et al*	22	0.84	7	0.65	15
Svitac *et al*	19	0.77	11	0.69	8
Kessler *et al*	36	0.77±0.05	20	0.63±0.06	16
Mallek *et al*	20	0.77±0.03	8	0.63±0.08	12
Platt *et al*	21	0.77±0.04	14	0.64±0.04	7

Table IV: Disposition of sensitivity, specificity, PPV and NPV

Study	Samples	Sensitivity	Specificity	PPV	NPV
Kessler *et al*	36 (20 obst.)	100%	94%	95%	100%
Platt *et al*	21 (14 obst.)	92%	88%	-	-
Brkljacic *et al*	29 (17 obst.)	70 %	92%	-	-

*Obst. - obstructive hydronephrosis; PPV - positive predictive value; NPV - negative predictive value.

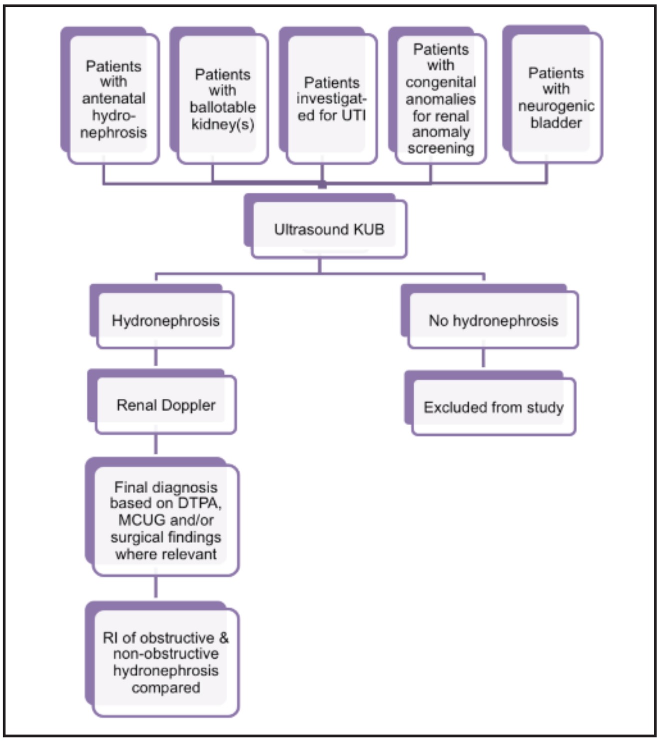

Fig. 1: Study work flow.

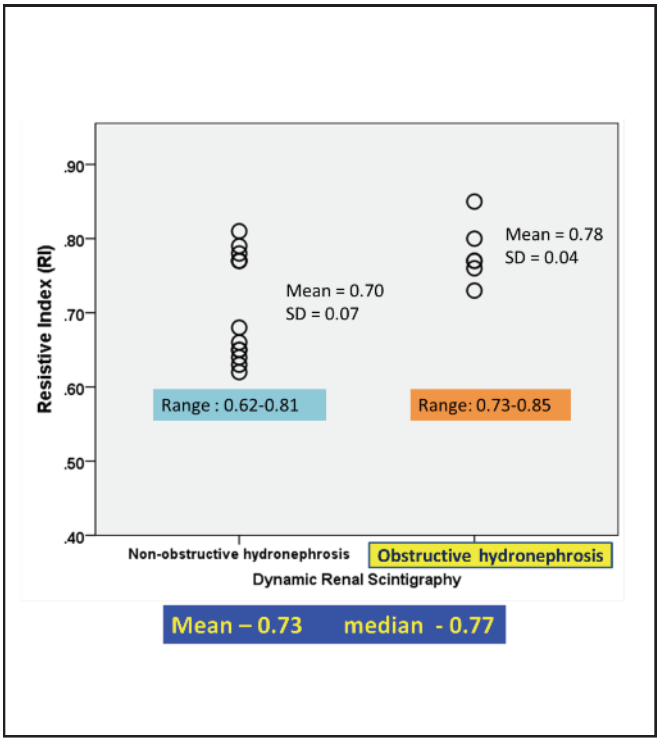

Fig. 2: RI (mean ± SD) in obstructive and non-obstructive hydronephrotic kidneys. Overall mean RI was 0.73 with median of 0.77.

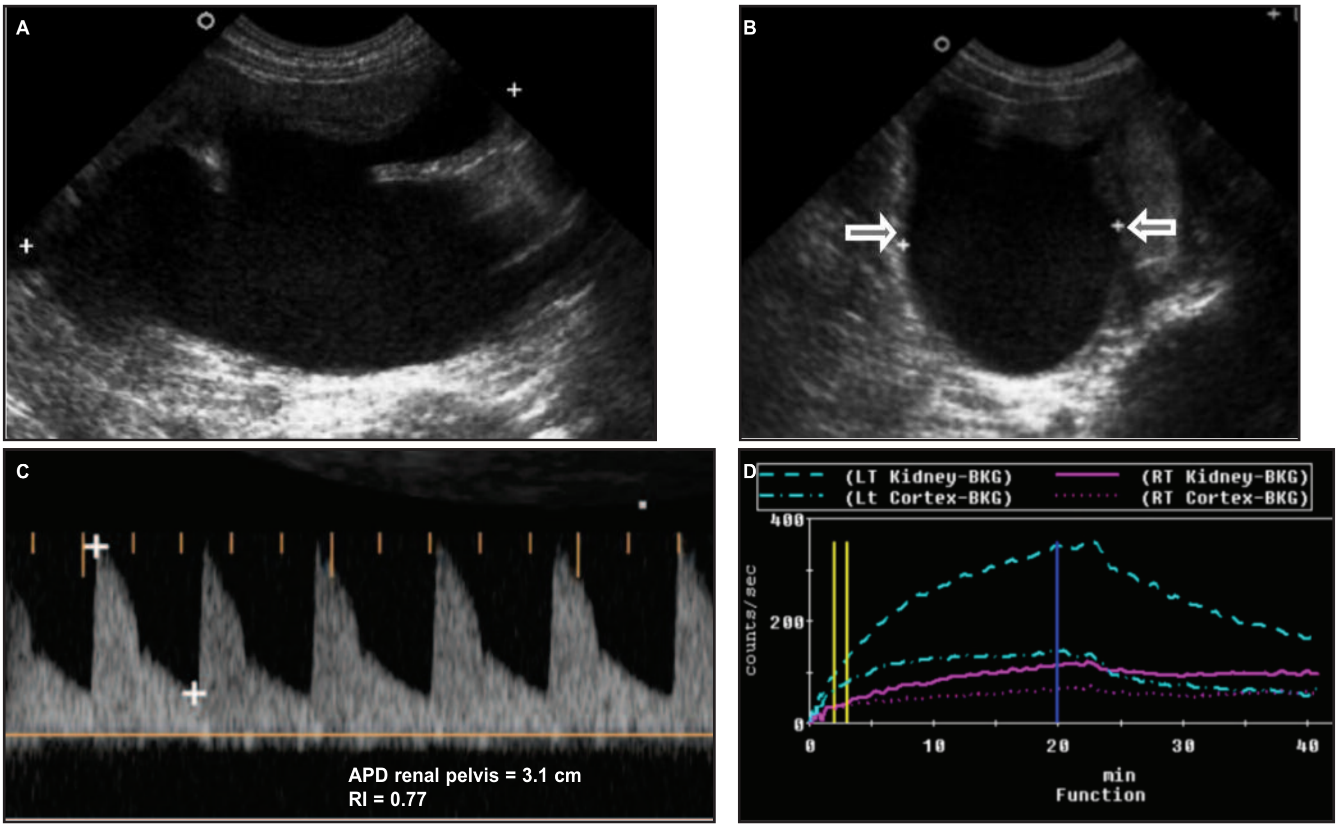

Fig. 3: A false positive case: 11-month-old boy with bilateral Grade V vesicoureteric reflux. Ultrasound images show gross hydronephrosis of the left kidney A. in longitudinal plane B. in transverse plane, with renal pelvic APD of 3.1 cm. C. Spectral Doppler yielded resistive index of 0.77. D. Dynamic renal scintigraphy confirmed non-obstructive hydronephrosis. (APD = anteroposterior diameter).

non-obstructive PUJ stricture.[6] In a study of 229 kidneys with pyelocaliectasis, the RI in the arcuate cortical renal arteries was 0.77 ± 0.05 in patients with obstruction and 0.63 ± 0.06 in patients without obstruction.[5] Other studies have also reported similar findings (Table III).[5,6,8-10,13]

Operative correction for children with obstructive hydronephrosis has been shown to reduce RI of renal arteries. In a Doppler study of children with PUJ stricture, post-surgical treatment showed a drop in RI levels. Mean RI before surgery and after surgery were 0.75 ± 0.03 and 0.65 ± 0.05 respectively.[5]

The RI measurement has demonstrated good sensitivity and specificity in differentiating obstructive from non-obstructive hydronephrosis. Sensitivity ranged from 70 to 100% and specificity ranged from 87 to 94% (Table IV). [5,8,10,14]

The children in this study ranged from 1 month to 7 years old. Thirty-seven percent were aged less than 1 year, the largest among all age groups. This most likely resulted from early detection of congenital hydronephrosis during antenatal ultrasound. Earlier studies had a larger age range of up to 21 years.[5,6,8]

Majority (63%) had gross hydronephrosis, with 21% moderate and 16% mild hydronephrosis. This was due to selection of pathological cases who had renal scintigraphy. In comparison, previous studies had larger numbers of mild and moderate hydronephrosis because of the higher prevalence of physiological hydronephrosis.[3,7]

In this study, the mean RI of obstructive hydronephrosis was higher (0.7800 ± 0.04) compared to non-obstructive hydronephrosis (0.7092 ± 0.07) (Figure 2). This difference in RI is significant, with a p-value of 0.04 (<0.05). This finding was consistent with other studies.[5,6,9,10,13]

There were 4 false positive results in this study, contributed by patients from less than 1-year-old age group or those with high grade VUR. These findings are further elaborated below.

Several studies have found higher RI values in young children who have normal kidneys, compared to adults. This is predominantly seen in the age group of 4 years and below.[4,12,15] A study of 115 healthy children ranging from neonates to 16 years showed the RI values were highest in the first year of life with a mean value of 0.71 ± 0.06. In this age group about 40% of the sample had high RI (>0.70) and these were seen up to the age of 4 years. The postulated reasons for higher RI values in the neonate included: the immature kidney, higher vascular resistance, high level of renin and lower glomerular filtration compared to adult age group.[15] Another study of 84 children with normal kidneys concluded that although normal neonates had higher RI, none of the normal kidneys had RI value greater than 0.70.[5] The mean RI in the age group of less than 1 year old was 0.62 ± 0.04 while the RI in the age group more than 1 year old was 0.57 ± 0.05.5 Several other studies had also concluded RI ≤0.7 as normal.[4,6,8] Our study has recorded high RI (>0.7) in 5 out of 6 patients who were less than 1 year old, 2 of which were non-obstructive. RI is thus relatively less reliable in differentiating obstructive from non-obstructive hydronephrosis in younger patients.

Two children with false positive RI were diagnosed with severe VUR (Grade V) (Figure 3). A study of 64 children with VUR showed that children with high grade VUR (Grade IV & V) had higher RI values compared to those with low grade VUR (Grade I-III).[16] The mean RI in high grade VUR was 0.77 ± 0.07 compared to 0.60 ± 0.07 in low grade VUR.[16] It was postulated that the underlying cause could be recurrent infection of the urinary tract with subsequent renal parenchymal scarring.[16] The resulting renovascular damage in later stage of the disease led to an increase in vascular resistance, and was reflected as higher RI value.[16]

The sensitivity and specificity of this study were 100% and 53%. The positive and negative predictive values were 50% and 100% respectively. Sensitivity was 100% as all obstructive hydronephrosis had high RI values. The good sensitivity and negative predictive values were comparable with previous studies (92-100%).[5,10,14] The specificity in this study however was much lower compared to previous studies which recorded better specificities of 83% and 94%.[5,8,10,14] This is most likely due to a larger percentage of very young children (< 4 years old) in this study whose RI fall within the higher range, leading to false positives. A number of high-grade non-obstructive hydronephrotic kidneys also had high RI.

A limitation of this study was the small number of patients. On top of that, 63% of them were less than 2 years old. This led to a higher false positive rate because of the higher range of RI observed in non-obstructed kidneys in younger patients.[4,12,15] The intervals between ultrasound Doppler and renal scintigraphy ranged from a few days to 10 months. This variability might cause increased discrepancies or inaccuracies in Doppler assessments. The examinations were performed without sedation, and an uncooperative child could affect the accuracy of Doppler readings. As examinations were done on walk-in basis, inadequate hydration could result in an inadvertent elevation of RI. Dehydration as a cause of increased RI has been postulated to be related to preferential reduction in diastolic pressure in the case of a general reduction in systemic blood pressure.[12]

The sensitivity and specificity of the Doppler study could be improved by several methods. RI of hydronephrotic kidneys could be compared to that of normal contralateral kidneys. This measurement, known as resistive index ratio (RIR) has been found to enhance the accuracy of the Doppler assessment.[17] A ratio of more than 1.1 was considered elevated and suggestive of an obstruction.[8,9] RI measurement of contralateral normal kidney was particularly important in some cases of acute obstruction in which the RI had not yet increased above 0.70.[10]

The other alternative measurement would be the difference in RI (delta RI) between hydronephrotic kidney and normal contralateral kidney.[8,17] A difference of more than 0.08 – 0.10 was considered significant.[5,10] The RIR and delta RI were not affected by patients' age, while RI value alone is variable in the younger age group.[17] Both measurements were not used in this study. It would not be feasible in the 3 children who had bilateral hydronephrosis.

Ensuring adequate hydration would enhance the diagnostic accuracy of RI in differentiating obstructive and non-obstructive hydronephrosis.[12]

And lastly, in dealing with an uncooperative child, adequate sedation may be required for better evaluation of the kidney and the rest of the urinary tract.

CONCLUSION

Doppler ultrasound measurement of resistive index is useful in differentiating obstructive from non-obstructive hydronephrosis. It can be used as a screening tool and provides a non-ionising alternative to dynamic renal scintigraphy, especially beneficial in hospitals with no radionuclear scan facilities. With high level of sensitivity, Doppler studies would be able to detect the higher RI in an obstructed system and avoid unnecessary delay in intervention.

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