Original Research Article

Role of doppler sonographic evaluation of intra-renal hemodynamic changes in diagnosis of obstructive uropathy and in differentiation of acute and chronic obstructive uropathy

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Abstract

Background: Sonography is the most commonly used modality for initial evaluation and diagnosis of renal obstruction. Gray scale sonography can detect hydronephrosis and hydroureter proximal to the level of obstruction and Doppler helps in differentiating acute obstruction from chronic obstruction. The Aim of our study is to determine usefulness of the renal Doppler especially venous impedance index in evaluating obstructive uropathy and to differentiate acute obstruction from chronic cases. **Methods:** Twenty patients were enrolled which include eight patients with acute renal colic from unilateral stone disease, four patients with unilateral chronic obstruction due to various causes and eight normal persons. The diagnosis was confirmed by computed tomography in all cases. All patients were examined prospectively by conventional and Doppler sonography. The impedance indices and peak flow signals of the interlobar arteries and veins of both kidneys were calculated from spectral Doppler waveforms in all three groups. **Results:** The mean venous impedance index on the acutely obstructed side was lower than the index on the unobstructed side: 0.26 ± 0.06 and 0.53 ± 0.3 (mean ± SD). The mean venous impedance index on the acutely obstructed side was less than the indices both on the chronically obstructed side and in the control subjects. In acute cases, the mean arterial resistive index on the obstructed side was higher than the index on the unobstructed side: 0.62 ± 0.06 and 0.57 ±0.06, respectively. No statistically significant difference was detected between other parameters evaluated for the test and control groups. **Conclusion:** Renal venous impedance index values may be helpful in differentiating acute obstruction from chronic cases when used along with the arterial resistive index

Key Words: Doppler sonography, Renal hemodynamics, Obstructive uropathy, Interlobar veins, Interlobar arteries.

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Received Date: 22/01/2018 Revised Date: 19/02/2018 Accepted Date: 16/03/2018

DOI: https://doi.org/10.26611/1013531

Access this article online	
Quick Response Code:	Website: www.medpulse.in
	Accessed Date: 20 March 2018

INTRODUCTION

Sonography is widely used modality in the initial evaluation and diagnosis of renal obstruction. Gray scale sonography can be used to detect hydronephrosis and hydroureter proximal to the level of obstruction, which indirectly proves the obstruction. However, it is not possible to differentiate acute and chronic urinary tract obstructions with gray scale sonography alone. It also fails to reveal collecting system dilatation in up to 21% to 35% of cases with acute obstruction. [1,2] Doppler sonography has been used for obtaining more functional information in cases of urinary system obstruction. In the acute phase of renal obstruction, pressure within the collecting system increases substantially, and a reduction in compliance of the renal vessels would be expected to develop rapidly. As a result of this, an increase in vascular resistance is observed. [3,4] Renal perfusion alterations induced by collecting system obstruction can be evaluated by color duplex Doppler sonography of the intrarenal arteries. The arterial resistive index (RI)

How to cite this article: Ketan Rathod, Nandish Kumar, Nandini Bahri. Role of doppler sonographic evaluation of intra-renal hemodynamic changes in diagnosis of obstructive uropathy and in differentiation of acute and chronic obstructive uropathy. *MedPulse – International Journal of Radiology*. March 2018; 5(3): 24-29. http://www.medpulse.in/Radio%20Diagnosis/

measurements have poor sensitivity and specificity for the simultaneous increase in resistance and reduction in compliance.[2,5,6] Recently, it has been suggested that the venous impedance index is a more sensitive measure of physiologic changes and that it can be useful in the evaluation of renal parenchymal compliance in cases of obstruction.[4] The aim of our study is to determine usefulness of the renal Doppler especially venous impedance index in evaluating obstructive uropathy and to differentiate acute obstruction from chronic cases.

MATERIALS AND METHODS

This prospective study was conducted at the Department of Radiodiagnosis, shree M.P. Shah govt. medical college and Shri Gurugobind Singh Government Hospital, Jamnagar, Gujarat from September 2017 to December 2017. After taking informed consent, eight patients with acute renal colic having unilateral stone disease and another four patients having unilateral chronic obstruction due to various causes were evaluated sonographically for the duration of four months. Children were excluded from the study. The diagnosis was confirmed by computed tomography (CT urography) in all cases. All patients were 18 to 60-year age group with youngest subject of 18 years of age and oldest of 60 years of age. There were seven male subjects and five female subjects. Eight subjects with normal kidneys were investigated as a control group which included five males and three females within the age group of 24 to 40 years. All patients were examined prospectively by conventional gray scale and Doppler sonography. The impedance indices and peak flow signals of the interlobar arteries and veins of both kidneys were calculated from spectral Doppler waveforms in all 3 groups.

RESULTS

Control Group: No significant difference was found between the right and left kidneys in either the arterial resistive or venous impedance indexes or peak flows. The peak venous flow rate was always significantly lower than the arterial flow rate, and on average, the arterial rate was twice the venous rate. (Table 1, Fig.1)

Unobstructed Kidneys: The unobstructed kidneys showed the same findings as that of the control group.

Obstructed Kidneys: The mean venous impedance index on the acutely obstructed side was lower than the index on the unobstructed side: 0.26 ± 0.06 and 0.53 ± 0.3 (mean ± SD). The mean venous impedance index on the acutely obstructed side was less than the indices both on the chronically obstructed side and in the control subjects. In acute cases, the mean arterial resistive index on the obstructed side was higher than the index on the unobstructed side: 0.62 ± 0.06 and 0.57 ±0.06, respectively. No statistically significant difference was detected between other parameters evaluated for the test and control groups. (Table 2-3, Fig. 2-3)

Table 1: Control

No.	Age (Years)	Sex	Arterial resistive Index		Peak Arterial velocity (cm/sec)		Venous Impedance Index		Peak Venous velocity (cm/sec)	
			Right	Left	Right	Left	Right	Left	Right	Left
1	28	F	0.61	0.67	47	40	0.53	0.5	11.3	8.5
2	31	F	0.61	0.5	37	29	0.5	0.41	10.9	16.4
3	35	M	0.63	0.65	39	30	0.4	0.56	25	10
4	28	M	0.64	0.6	33	36	0.52	0.54	13.9	14.6
5	24	F	0.60	0.65	35	36	0.5	0.52	15	13
6	30	M	0.61	0.63	32	35	0.53	0.5	14.6	15.2
7	40	M	0.62	0.62	41	40	0.49	0.51	12.2	14
8	27	M	0.64	0.65	40	38	0.46	0.49	16	15.1

Table 2: Acute Obstruction

No.	Age (Years)	Sex	Obstructed side	Arterial resistive Index		Peak Arterial velocity (cm/sec)		Venous Impedance Index		Peak Venous velocity (cm/sec)	
				Obstructed	Unobstructed	Obstructed	Unobstructed	Obstructed	Unobstructed	Obstructed	Unobstructed
1	23	M	Right	0.63	0.6	21	48	0.31	0.53	15	20
2	18	F	Right	0.61	0.63	44	34	0.39	0.53	17	10
3	55	M	Right	0.59	0.58	34	38	0.30	0.52	13.9	14
4	46	M	Left	0.61	0.67	23	47	0.36	0.63	15	18
5	50	M	Left	0.68	0.6	21	46	0.29	0.65	18	13
6	60	M	Right	0.67	0.73	15	44	0.31	0.58	9	23
7	25	F	Left	0.65	0.61	38	46	0.26	0.57	19	25
8	34	F	Left	0.64	0.62	37	42	0.31	0.59	17	22

Table 3: Chronic Obstruction

No.	Age (Years)	Sex	Obstructed side	Arterial resistive Index		Peak Arterial velocity (cm/sec)		Venous Impedance Index		Peak Venous velocity (cm/sec)	
				Obstructed	Unobstructed	Obstructed	Unobstructed	Obstructed	Unobstructed	Obstructed	Unobstructed
1	41	F	Left	0.63	0.6	33	35	0.52	0.52	14	14.2
2	40	M	Right	0.60	0.65	34	36	0.51	0.52	15	13
3	60	F	Right	0.61	0.62	32	35	0.53	0.52	14	15.4
4	35	M	Right	0.63	0.62	39	40	0.49	0.51	14.3	14
5	42	M	Left	0.62	0.61	38	38	0.50	0.52	15	15.1
6	38	F	Right	0.64	0.60	36	37	0.48	0.53	14.4	14.2

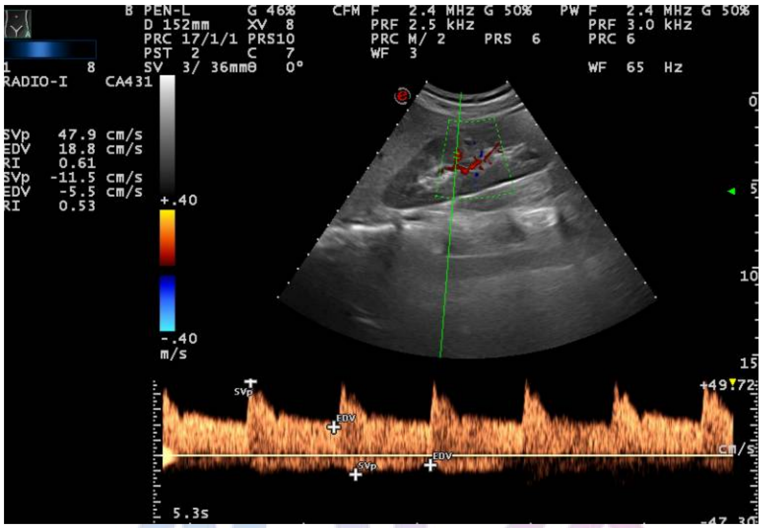

Figure 1: Doppler sonogram of subject with no evidence of renal disease shows arterial signal (depicted as positive values) and venous signal (depicted as negative values).

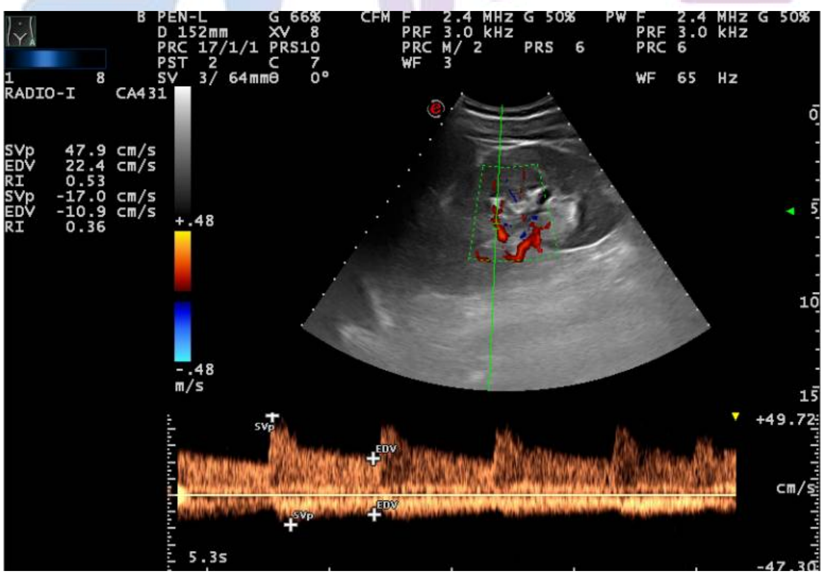

Figure 2: Doppler sonogram of subject with acute Obstructive uropathy shows reduction in venous impedance on the obstructed side.

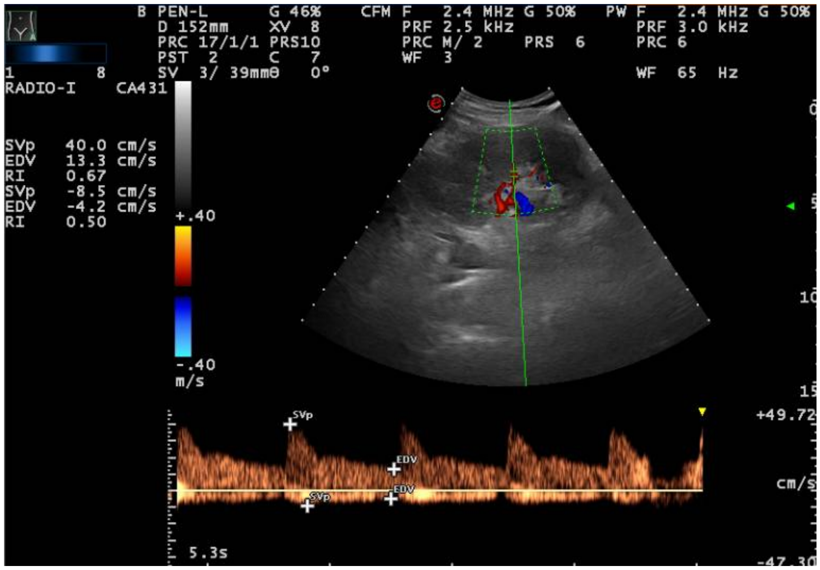

Figure 3: Doppler sonogram of subject with chronic Obstructive uropathy shows no difference in venous impedance on the obstructed side.

DISCUSSION

Sonography is the initial diagnostic tool for detecting renal disease; however, sensitivity and specificity of gray scale sonography in detecting acute ureteric obstruction is low[1]. Urinary system dilatation seen on conventional gray scale sonography has been shown to be sensitive (≥90%) but not specific (65%–84%) in the diagnosis of renal obstruction[7]. It has been reported that the diagnosis of obstructive uropathy may be missed by conventional sonography because pyelocaliectasis may occur late in obstructive conditions, and often the findings of sonography may be normal despite severe renal dysfunction.[8] Arterial RI measurements by duplex Doppler sonography have been advocated for the diagnosis of obstruction. Doppler sonography enables detection of subtle intrarenal blood flow changes associated with various pathophysiologic conditions. It is useful to assess renal blood flow by Doppler sonography together with real-time sonographic information of the collecting system.[5,9,10] Urinary tract obstruction caused by the blockage of urine flow may be acute or chronic or unilateral or bilateral. Both acute and chronic unilateral urinary system obstructions have been investigated extensively to understand the clinical importance and outcome.[11-14] The pathophysiologic changes affecting the pressure in the collecting system and kidney perfusion outline the basis for the correct interpretation of real time and color Doppler sonography. The hemodynamic response of renal arterial blood flow to complete urinary obstruction is phasic.[12,15-17] After the onset of obstruction, an immediate increase in renal pelvic pressure causes diffuse vasodilatation of the renal vascular bed caused by release of circulating vasodilator factors.[13,18] As the obstruction continues, some complex hormonal regulatory systems produce diffuse vasoconstriction of the renal vascular bed. This phase occurs 6 to 8 hours after the onset of obstruction. As renal blood flow decreases in response to chronic partial obstruction of the ureter, urine filtration also decreases. Subsequently, intrapelvic pressure returns to normal. Other factors causing normalization of intrapelvic pressure include increased venous and lymphatic resorption of urine and dilatation of the urinary tract proximal to the obstruction.[14,17,20] Renal arterial circulation has low-impedance blood flow under normal homeostatic conditions, with antegrade flow also maintained during diastole. However, increased renal vascular resistance causes a decrease in renal diastolic blood flow, which is more pronounced than the decrease in the systolic component.[21,22,23] The increase in intrarenal vascular resistance can be measured sonographically by the RI, which is a physiologic parameter indirectly reflecting the degree of resistance in renal vasculature.[7] It is calculated as a value of the peak flow signal minus that of the diastolic flow divided by the peak flow value. The RI is actually a misnomer because the Doppler waveform is altered not by vascular resistance alone but by the interaction of vascular resistance and compliance. Therefore, it should be called the “impedance index.” The urinary system obstruction causes an increase in interstitial pressure, which results in increased vascular resistance and reduced compliance.[2,24] The RI values can be affected by a number of physiologic and pathologic factors. It has been used for evaluating several renal disorders, including obstructive uropathy. However, some authors have reported that the RI is an unreliable parameter that is prone to systemic and local influences.

Also, it is not specific and can change in a number of other conditions, such as old age, circulating endogenic factors or drugs, and other nephropathies. [6,25] There is considerable controversy in the literature about the use of the RI in cases of urinary system obstruction. The impedance index measurements show varying sensitivity (37%–90%) and specificity (82%–90%) in the diagnosis of acute obstruction.[6,7,16] Because of these discrepant findings, there is skepticism over the utility of the intrarenal arterial RI as a measure of acute obstruction. This wide range of results may be attributed to complex mechanisms of change in renal blood flow after obstruction. Despite those shortcomings, Doppler sonography remains an important complementary technique to conventional sonography for the diagnostic evaluation of acute and chronic urinary tract obstruction. In acute renal obstruction, reduced renal parenchymal compliance caused by increased pressure in the collecting system results in dampening of renal venous pulsatility. Considering this factor and difficulties associated with the use of arterial waveform analysis, Bateman and Cuganesan[4] focused on the venous side of the renal vascular tree for the diagnosis of acute obstruction. Normally, there is a triphasic waveform in intrarenal veins produced by right atrial pressure changes.[4,12] Bateman and Cuganesan hypothesized that the reduced compliance in acute renal obstruction results in dampening of these renal venous signals, and intraparenchymal venous flow is affected to a greater degree than the arterial flow. As a result, they concluded that the venous impedance index is a more sensitive measure of physiologic changes that takes place in acute renal obstruction. In our series, also, we observed that the venous impedance index values on the obstructed side were lower than on the unobstructed side and in the control subjects. The difference between venous impedance index values of the acutely obstructed kidneys and the corresponding kidneys of the control group was also meaningful statistically in our series but lacked statistical significance in the above-mentioned study.[4] That may be due to the difference of mean times from the onset of symptoms to the sonographic examination, which was longer in our study. In our study, we mainly concentrated on impedance index values obtained from the venous side of the renal vascular tree and tried to determine whether this test could be helpful in differentiating acute versus chronic cases. The peak systolic velocities in both the arterial and venous sides were also compared for the same purpose. The subjects forming the control group of our study were selected cautiously to exclude subjects with renal or any systemic disease, which may have had potential effects on the RI. The age ranges of our study and control groups were very close to each other because age is an important factor in assessing the RI. Arterial RI change is also a time-dependent parameter, occurring between 6 and 48 hours after the onset of symptoms that precede pyelocaliectasis.[8] Therefore, RI values obtained within 6 hours of acute obstruction may result in false-negative readings. In our study, the mean time from the onset of symptoms to the sonographic examination was 12 ± 5 hours. We excluded very early acute obstruction cases from our study to avoid misleading results. Additional studies may be needed to find out whether the venous impedance indices are helpful in those cases in which arterial RI is usually within normal limits. In this study, the patients with acute renal obstruction had a lower venous impedance index than the patients with chronic obstruction. There was no statistically significant difference between the venous impedance index values of chronically obstructed kidneys and those in control subjects. This finding indicates that the venous impedance index value may be helpful in differentiating acute obstruction cases from chronic cases. Venous impedance index values in the acutely obstructed side were also less than in the control cases. However, we think that it is important to assess the contralateral kidneys in unilateral acute obstruction, and it may be more useful to compare 2 kidneys. The mean venous impedance index on the acutely obstructed side was less than the mean venous impedance index in the unobstructed kidney of the same patient. Neurohumoral changes are probably responsible for such impairments in renal hemodynamics. For chronic cases, the mean venous impedance index on the obstructed side was higher than that on the unobstructed side, but this was not statistically significant. The pathophysiologic changes underlying chronic obstruction and renal parenchymal changes are complex, but they do not seem to produce venous impedance index changes. Many researchers have used mainly arterial RIs as indicators of renal vascular resistance. Our findings were compatible with reports in the literature stating that the arterial RI is a useful finding in acute obstruction cases. However, the venous impedance index may be more accurate in differentiating abnormal waveforms because the compliance of venous vascular structures was affected earlier than on the arterial side. Still, these preliminary results need to be verified by a larger study because the study groups were small in this investigation. We conclude that, in acute obstruction cases, renal venous impedance index values evaluated by Doppler sonography are decreased. This may be a helpful finding in evaluating renal obstruction and differentiating acute urinary system obstruction from long-standing cases. We do not claim that the venous impedance index values can be used exclusively in the evaluation of renal obstruction, but this measurement can be useful in assessing renal hemodynamics in cases of obstruction when used in conjunction with arterial RI values. Additional studies are required before this technique may be used routinely in the diagnostic workup of obstructive uropathy.

CONCLUSION

Renal venous impedance index values may be helpful in evaluating renal hemodynamics in obstruction and in differentiating acute obstruction from chronic cases when used in conjunction with the arterial resistive index.

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Source of Support: None Declared
Conflict of Interest: None Declared