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Acute obstruction of the renal collecting system: the intrarenal resistive index is a useful yet time-dependent parameter for diagnosis

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Abstract. The aim of this study was to determine whether the intrarenal resistive index (RI) can be used for the diagnosis of acute obstruction in patients with renal colic and to determine whether the index is time-related. Seventy patients referred to the Emergency Department with acute renal colic and without known associated renal disease underwent duplex Doppler ultrasonography to determine the intrarenal RI at the symptomatic and asymptomatic side. The age range of the patients was 18–72 years. An RI greater than 0.68 and/or an interrenal difference in RI greater than 0.06 and/or an increase in RI of more than 11% compared with the normal side proved reliable cut-off values to diagnose acute renal obstruction. In addition, time dependency of the increase in RI was noted. No significant differences were observed within the first 6 h after the onset of symptoms. From 6 to 48 h, however, the mean RI in the affected kidney (0.70 ± 0.06; mean ± SD) was significantly different from that in the normal kidney (0.59 ± 0.04) ($P < 0.001$). In the same period the mean difference in RI was 0.08–0.13 ($P < 0.001$). After 48 h the sensitivity of RI dropped substantially. It is concluded that renal duplex Doppler ultrasonography is useful for diagnosing acute renal obstruction between 6 and 48 h after the onset of symptoms.

Key words: Kidney, US – Kidney, obstruction – US, Doppler studies – Ureter, obstruction

Introduction

Conventional ultrasonography is not very accurate for the diagnosis of obstruction of the collecting system, because dilatation of the collecting system often occurs in nonobstructive states and may fail to occur or may occur only late in obstructive states. Animal studies with direct pressure measurements demonstrated that renal obstruction causes a reversible rise in renal vascular resistance [1–3]. The vascular resistance drops after relief of the obstruction. Renal duplex Doppler sonography offers the potential to reflect the hemodynamic changes that accompany significant obstruction and, therefore, is primarily a functional test. Platt et al. [4, 5] indeed showed that renal obstruction produces alterations in the Doppler waveform of intrarenal arteries that can be quantified by the resistive index (RI). Through several major papers by Platt and coworkers, increasing numbers of sonographers became aware of the potential benefit of RI for the diagnosis of renal obstruction. In one study, however, Platt's results were criticized and these authors concluded that Doppler (a) should be considered fairly insensitive in detecting acute obstruction caused by ureteral stones or (b) should be used only at centers with great expertise in duplex Doppler ultrasonography [6].

This prospective study focuses on the value of duplex Doppler ultrasonography for the diagnosis of acute renal obstruction caused by ureteral calculi and further analyzes the evolution of RI with time.

Materials and methods

Duplex Doppler ultrasonography was performed in 140 native kidneys (70 patients) with renal obstruction caused by ureteral calculi. The diagnosis was confirmed with plain KUB films and intravenous urography (IVU) during the first or second day after the onset of symptoms. Based on the patient's clinical history, the duration of obstruction at the time of the duplex Doppler ultrasound was recorded. All patients underwent real-time gray-scale examinations with a 3.5-MHz transducer (Acuson 128, Mountain View, Calif.) and duplex Doppler evaluations of intrarenal vessels at the level of the interlobar or arcuate arteries. Doppler waveforms were obtained at the lowest pulse repetition frequency

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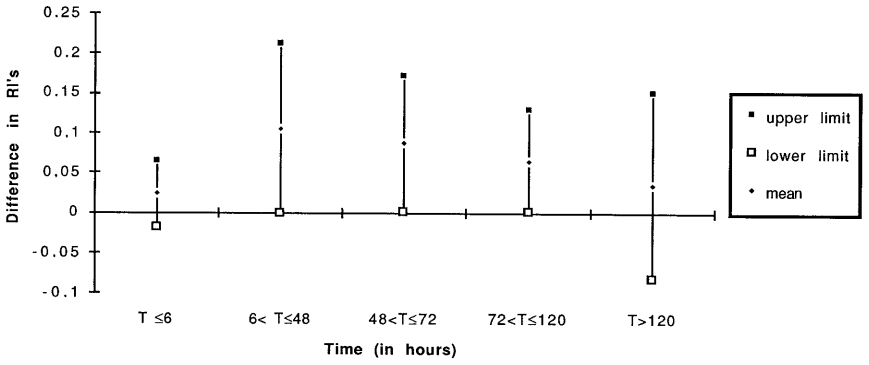

Fig. 1. The difference in resistive index (RI) between the normal kidney and the obstructed kidney and the standard deviation in relation to time ranges

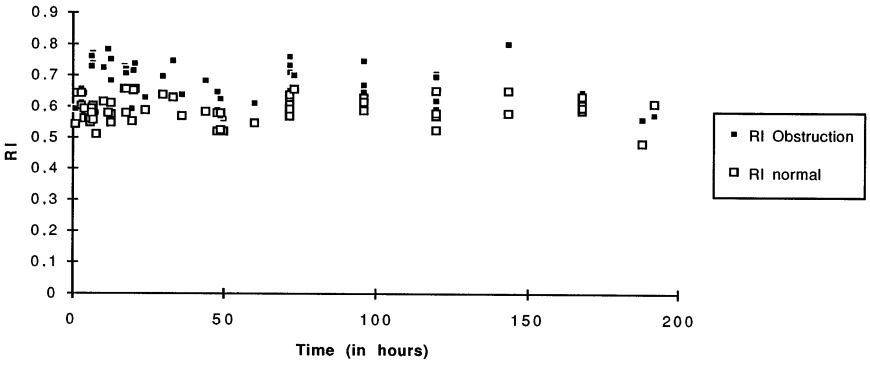

Fig. 2. The evolution of the RIs of normal and obstructed kidneys with time

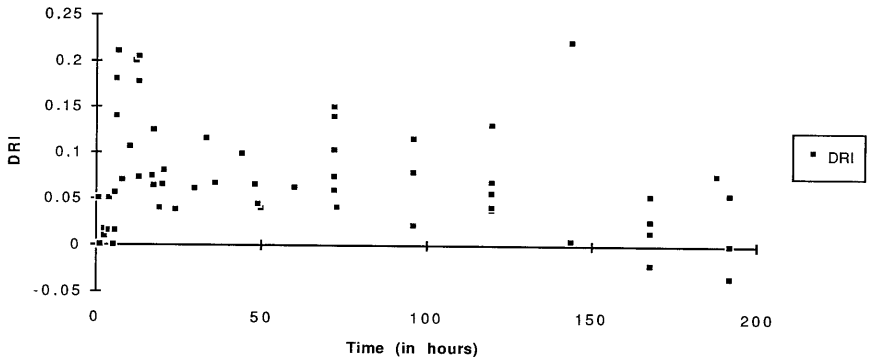

Fig. 3. The evolution of the difference in RI between the normal kidney and the obstructed kidney with time

(PRF) that did not produce aliasing. This maximizes the deflection of the Doppler spectrum and enables more accurate placement of callipers. In addition the lowest possible wall filter was selected. Doppler sample width was set at 2–5 mm. A spectrum was considered optimal if three to five consecutive similar-appearing waveforms were noted.

The intrarenal RI [defined as: RI = (peak systolic frequency shift – minimum diastolic frequency shift)/ peak systolic frequency shift] was calculated for each kidney as an average value obtained from three to five areas of the kidney (upper, middle and lower third). The difference in RI between the affected side and the asymptomatic side (interrenal ΔRI) as well as the increase in RI at the affected side compared with the asymptomatic side were calculated. Statistical analysis was performed by means of the Student two-tailed *t*-test for paired samples and the Wilcoxon matched-pairs signed-rank test.

Results

Figures 1–3 summarize the evolution of interrenal ΔRI in these 70 patients with acute renal obstruction. Less than 6 h after the onset of the symptoms ($n = 9$) there were no significant differences in intrarenal RI between the symptomatic side and asymptomatic side ($P < 0.013$) (Fig. 1). Between 6 and 48 h ($n = 23$) the mean RI of the affected kidney was 0.70 (SD, ± 0.06) (Fig. 2), which exceeded the mean RI of the asymptomatic kidney (0.59 ± 0.04) significantly ($P < 0.001$). In the same group the mean ΔRI between the symptomatic and the asymptomatic kidney was 0.11 ($P < 0.001$) (Fig. 1). In the groups of patients who had had symptoms for 48–72 h ($n = 10$) or 72–120 h ($n = 10$), the interrenal ΔRI decreased gradually (Figs. 1, 3). After 120 h ($n = 18$) there were no significant differences in RI detectable ($P < 0.047$) between the obstructed and nonobstructed kidney (Fig. 1).

Table 1. Summary of the sensitivity of different RI-related parameters with time

	Sensitivity				
	< 6 h (n = 9)	6–48 h (n = 23)	48–72 h (n = 10)	72–120 h (n = 10)	> 120 h (n = 18)
RI ≥ 0.68 (A)	0	73.9	50.0	50.0	16.6
ΔRI ≥ 0.06 (B)	0	82.6	50.0	40.0	11.1
Increase RI ≥ 11 % (C)	0	78.2	60.0	40.0	11.1
A and/or B	0	86.9	50.0	50.0	16.6
A and/or C	0	91.3	60.0	50.0	16.6
B and/or C	0	82.6	60.0	40.0	20.0
A and/or B and/or C	0	91.3	60.0	50.0	22.2

Table 1 shows the RI values of the obstructed and normal kidney correlated with time. Between 6 and 48 h after the onset of the symptoms, the RI was greater than 0.68 in 17 of the 23 obstructed kidneys (74 %). In 18 patients of this group (78 %) there was an increase in RI of more than 11 % in the obstructed kidney compared with the normal kidney. Twenty-one patients (91 %) had an RI at the affected side greater than 0.68 and/or an increase in RI of more than 11 % compared with the normal side. Thus, when adding these criteria, the sensitivity of duplex Doppler improves to 91.3 %. The sensitivity drops to 60 % in the groups with symptoms for 48–120 h. After 120 h the sensitivity decreases further to as low as 22 %.

Discussion

Obstruction of the collecting system causes hemodynamic changes in renal perfusion that can be quantified by measuring the intrarenal RI. The importance of hemodynamic events can be derived from the knowledge than the majority of renal damage from obstruction results from the impaired vascular supply [7]. The relationship between the ureteral pressure and renal blood flow is triphasic [8, 9]. Within the first 6 h of obstruction there is predominantly preglomerular vasodilatation that explains the initial fall in resistance. This vascular effect is associated with an increase in ureteral pressure [8]. Between 6 and 48 h preglomerular vasoconstriction limits further increase in the ureteral pressure [8]. Increase in downstream resistance results in a more pronounced reduction of diastolic flow than systolic flow. This explains the more pronounced increase in RIs in this time interval. Forty-eight hours after the onset of the obstruction, there is an equal fall in renal blood flow and ureteral pressure. An increase in lymphatic drainage (pyelolymphatic and pyelointerstitial backflow) and/or tubular absorption associated with partial recovery of glomerular filtration are the most likely explanation [8]. This results in only a moderate increase in RI despite a progressive degree of dilatation of the collecting system.

In this study, statistically significantly higher RI values were observed in the obstructed kidneys compared with the nonobstructed kidneys. The data suggest that RI ≥ 0.68 may be a good threshold value for the diagnosis of renal obstruction. Indeed, none of the 70 normal kidneys and an RI greater than 0.68 (specificity 100 %). There were no significant differences between the values of the RI of the asymptomatic contralateral kidney in a patient with unilateral renal obstruction and the RIs of native kidneys of a normal population [10]. This further sustains (a) the observation that the hemodynamic changes in obstruction of the collecting system are a localized intrarenal phenomenon and (b) the absence of incidental renal disease.

No significant increase in the RI was observed during the first 6 h. This is consistent with earlier reports of Platt et al. [5] who described a delay of 4–6 h before a significant increase in the RI occurred. Therefore, less than 6 h after the obstruction the increase in RI does not enable a normal and an obstructed kidney to be distinguished. A significant difference between the value of the RI of the affected and the normal kidney was (exclusively) found between 6 and 48 h after the onset of obstruction. The sensitivity of the Doppler examination to diagnose acute (and functional important) renal obstruction is 91 %. The intrarenal RI and, in particular, the interrenal difference in the RI are sensitive enough to be clinically useful for the diagnosis of acute renal obstruction. This is important in equivocal cases. In fact, the literature suggests that up to 20 % of cases of acute renal obstruction have duplex Doppler abnormalities despite a normal gray-scale ultrasonography [11].

After 48 h the ΔRI remains statistically significant but decreases gradually. Nevertheless, there was still dilatation of the collecting system due to the presence of a ureteral stone. This ‘anatomic’ obstruction seems to cause only mild ‘functionally important’ obstruction. Of course patients with acute renal colic are treated. Some of the therapeutic substances clearly have vasodilatory effects. This vasodilation explains at least partially the drop in RI observed with time in this selected group of patients.

An additional observation from this prospective study is the wide range of RI values measured in the 70 asymptomatic kidneys. The literature reports similar experience in the normal population corrected for age [8]. Focal areas with RI values greater than 0.70 may even be found [12]. Therefore, a number of RI readings should be averaged before a single representative value is reported, to avoid diagnosis of obstruction based on a single area of elevated RI.

In conclusion, a significant interrenal ΔRI enables the diagnosis of acute renal obstruction even when the RI elevation is mild. It may take time, though, to establish the increase and for the RI to exceed 0.68, particularly if the patient's baseline renal RI is at the lower end of the normal range. Duplex Doppler analysis will be especially useful in patients in whom intravenous contrast agent administration is undesirable (pregnancy, contrast agent allergy and renal dysfunction) or in centers where ultrasound is the first imaging modality used to evaluate patients with acute renal colic. Renal ultrasound performed for possible acute renal obstruction is now considered incomplete without an additional duplex Doppler study. Therefore, when ultrasonography indeed serves as a replacement for IVU, a renal Doppler study is required to improve the sensitivity for early obstruction and to provide some functional information regarding an obstructed kidney. At centers where IVU remains the primary imaging technique for acute renal colic Doppler can be used in selected cases to decide whether conservative or more aggressive therapy is indicated [11].

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