The renal resistive index as a predictor of acute hydronephrosis in patients with renal colic

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KEYWORDS

Renal colic;
Hydronephrosis;
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ultrasound;
Renal resistive index.

Abstract *Introduction:* The objective of this study was to determine whether the renal resistive index (RI) can predict hydronephrosis in patients with renal colic (RC) and whether or not its performance is time-dependent.

Materials and methods: The study population was composed of 54 patients admitted for unilateral RC. At the time of the first observation (time point I, tpI), each patient underwent routine examinations, abdominal ultrasonography, and renal color Doppler ultrasound (CDUS) with measurement of the RI. The two imaging studies were repeated 6, 12, 18, 24, 36, and 48 h later (tpII, tpIII, tpIV, tpV, tpVI, tpVII). In addition, each patient underwent non-contrast urinary tract CT 48–60 h after admission. A mean renal RI of >0.70 (mRI+) for the symptomatic kidney was considered indicative of obstruction. Patients were retrospectively divided into two groups: those who developed dilatation (group A) and those who did not (group B).

Results: A mRI+ on CDUS predicted the onset of hydronephrosis with 100% sensitivity, 84% specificity, 92.6% accuracy, PPV and NPV of 87.9% and 100%, and diagnostic efficiency of 84%. In group A, mRI+ were always observed before onset of hydronephrosis in a time-dependent manner. In group B, mRI+ were observed occasionally in 4/25 patients (16%) and all were recorded at tpII. In these cases, the RI had returned to normal by tpIII.

Conclusions: In our RC patients, renal RI obtained with CDUS predicted the onset of acute dilatation with higher sensitivity, specificity, accuracy, and diagnostic efficiency than ultrasonography, and it can be used routinely in the emergency department to supplement ultrasound findings.

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Sommario *Introduzione:* Obiettivo di questo studio è stato verificare se l'Indice di Resistenza Renale (IR) possa essere considerato un parametro predittivo dell'insorgenza dell'idronefrosi (IN) in caso di colica renale (CR) monolaterale e se esso è tempo correlato.

Materiali e metodi: Lo studio ha incluso 54 pazienti ricoverati per CR monolaterale. Al momento della prima osservazione (time point I) tutti i pazienti sono stati sottoposti a esami routinari, a Ecografia addome e a Eco color Doppler renale (ECD) bilaterale con misurazione dell'IR. Dopo 6 (tpII), 12 (tpIII), 18 (tpIV), 24 (tpV), 36 (tpVI) e 48 (tpVII) ore è stata ripetuta l'ecografia dell'apparato urinario e l'ECD con la misurazione bilaterale dell'IR. A 48–60 ore dal ricovero inoltre tutti i pazienti sono stati sottoposti a TC dell'apparato urinario senza mezzo di contrasto. Un valore medio di IR maggiore di 0,70 (mRI+) a livello del rene sintomatico è stato considerato come suggestivo di ostruzione. I pazienti, in relazione allo sviluppo di IN, sono stati suddivisi a posteriori in gruppo A (dilatazione presente) e B (dilatazione assente). *Risultati:* L'ECD con il rilevamento dei valori mRI+ ha mostrato un significativo valore diagnostico relativamente all'insorgenza dell'IN con una sensibilità del 100%, specificità 84%, accuratezza 92,6%, VPP 87,9%, VPN 100% ed efficienza diagnostica 84%. Inoltre, nel gruppo A, i valori mRI+ sono stati registrati sempre precocemente rispetto all'insorgenza dell'idronefrosi e in modo tempo correlato. Anche nel gruppo B sono stati registrati alcuni mRI+, ma solo in 4/25 pazienti (16%) e tutti al time point II; in questi casi comunque i valori di mRI sono rientrati nei range della normalità già nel time point successivo.

Conclusioni: Nel nostro studio l'ECD con la misurazione dell'IR si è dimostrato capace di diagnosticare anticipatamente l'insorgenza della dilatazione acuta con livelli di sensibilità, specificità, accuratezza ed efficienza diagnostica superiori all'ecografia; si può prospettare quindi il suo impiego routinario nei reparti di emergenza ad integrazione dell'ecografia.

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Introduction

Renal colic (RC) is one of the most common conditions seen in the emergency department (ED). The frequency of RC in the general population ranges from 2% to 12%, and it accounts for 30–35% of all urological emergencies. The incidence is higher in men (10–20% vs 3–5% in women), and 30–40% of all patients experience symptomatic recurrence within 5 years [1–3]. In most cases, the colic is caused by ureteral spasm in response to the passage of a calculus, but in rare cases the pain stems from the transit of a blood clot (secondary to trauma or neoplastic disease), fibrin (caused by infection), tissue fragments (urinary tract tumors or acute renal necrosis), or other factors [4,5].

Regardless of the cause, patients with RC are at risk for acute urinary obstruction (partial or complete) leading to hydronephrosis. The frequency of this complication ranges from 33% to 68.3% [6–9]. Hydronephrosis is a serious clinical problem because it can produce progressive deterioration of renal function over time [10]. If the obstruction is caused by urolithiasis, spontaneous resolution can occur, more or less rapidly. The frequency of this outcome depends on the size of the stone. If the latter is less than 2 mm in diameter, all cases generally resolve spontaneously within 4 weeks; the frequency drops to 80% for calculi 2–4 mm, to 50% for those 4–6 mm, and to 10% for those larger than 6 mm. If the calculus has not been expelled after 4–5 weeks, renal function impairment can become severe and sometime irreversible [11]. For this reason, the obstruction needs to be diagnosed and treated as soon as possible. Some studies have shown that dilatation may be

absent in the early phases of renal colic, especially in dehydrated patients (30% of all cases), and this can lead to misdiagnosis [12].

The imaging studies most frequently ordered in the ED for patients with renal colic are plain abdominal radiography and ultrasonography; urography, CT, and MRI are considered second-line studies. The advantages, limitations, and sensitivity/specificity of each of these methods in identifying the cause, site, and degree of obstruction have been well documented in the literature. Plain films alone of the urinary tract are of limited value in identifying ureteral calculi (sensitivity 53–62%, specificity 67–69%) [13,14]. Urography has a sensitivity of 87% and specificity of 94% [15,16], but most authors do not feel that it is useful in the acute phase of RC, particularly in view of the risks it entails and its contraindications (renal failure, dehydration, allergy to contrast material, pregnancy). For this reason, they prefer to use urography more selectively as a second-level study for cases that cannot be diagnosed with other means [17]. CT without contrast enhancement has excellent sensitivity (91–100%) and specificity (91–97%) [18,19], and it is undoubtedly the examination of choice when RC is suspected because it reduces assessment times and allows the physician to identify other causes of the patient's pain [20,21]. In fact, in 57% of the patients whose CTs are negative for urinary calculi, other lesions are discovered (aneurysms of the abdominal aorta, appendicitis, diverticulitis, bladder tumors). A major drawback to the use of CT is the radiation exposure it causes, which makes it unsuitable for monitoring purposes [22,23]. In addition, calculi that are not radiopaque and those smaller than 3 mm are difficult to

detect and to differentiate from other hyperdense images, such as phleboliths or vascular calcifications [24]. MRI displays good diagnostic accuracy in identifying urinary tract dilatation (sensitivity 100%, specificity 96%) and the cause of the obstruction (in 88–92% of all patients). It can also be used to distinguish between acute and chronic ureteral obstruction (on the basis of the perirenal signal) [25,26]. However, because of its cost and its limited availability, MRI is still not routinely used in EDs.

As for ultrasonography, this method has displayed high sensitivity and specificity for detection of urinary tract obstruction. Sensitivity ranges from 91% to 92% (94–97% when it is combined with plain films of the urinary apparatus), and sensitivity is around 90%. However, its advantages (repeatability and absence of exposure to radiation or iodinated contrast agents, which makes it safe—even in pregnant women) must be weighed against its limitations: operator-dependency, results that are influenced by patient hydration, and variable rates of success in identifying ureteral calculi (4–38%), especially in patients who are obese or uncooperative and those with large amounts of intestinal gas [8,9,27].

The results of recent studies suggest that patients with RC should be evaluated with color Doppler imaging of the kidneys instead of gray-scale sonography alone. These studies showed that the renal resistive index (RI), one of the variables assessed with this method, is elevated in the presence of hydronephrosis, and the index also displays clear correlation with the degree and duration of the urinary tract obstruction [7,10,28,29].

The objectives of the present prospective study were to determine whether, in patients with unilateral RC, the RI can predict the onset of hydronephrosis and if so, whether its predictive value is time-dependent.

Materials and methods

The study population comprised 54 patients admitted to the ED with unilateral RC. Inclusion criteria were: 1) patient history, clinical findings, and laboratory data all negative for medical nephropathy, obstructive uropathy, cardiovascular disease, and metabolic disease; 2) age 20–50 years; 3) no drugs administered before the first observation; 4) symptom onset less than 4 h before enrolment.

At the time of the first observation (time point [tpI]) all patients had: 1) blood drawn for laboratory studies; 2) an ECG and cardiologic examination; 3) plain film of the urinary tract; 4) abdominal US; 5) bilateral color Doppler ultrasound (CDUS) with measurement of the renal RIs. All patients were treated according to the same protocol, which provided for intramuscular injections of ketoprofen 100 mg every 12–24 h, intravenous hydration (2000 ml over 24 h at a constant rate of 83 ml/h), and ciprofloxacin 500 mg p.o.).

Six (tpI), 12 (tpII), 18 (tpIV), 24 (tpV), 36 (tpVI), and 48 (tpVII) hours after the first observation, urinary tract sonography and CDUS with bilateral measurement of the RI were repeated. The RI was expressed as follows: (peak systolic velocity – end diastolic velocity)/peak systolic velocity. Forty-eight to sixty hours after admission, all

patients underwent CT of the urinary tract without contrast enhancement (the reference method). Each patient was examined sonographically by the same examiner. Examinations were done with the patient in the supine and lateral decubitus positions using the same machine (Philips EnVisor HD) and a convex transducer (3.5–5 MHz). CDUS measurement of the RI (excluding aliasing phenomena and other artifacts) was carried out in the upper, middle, and lower portion of each kidney, between the interlobar arteries and the arcuate arteries. If the mean of the three measurements in the symptomatic kidney was greater than 0.70, the test was regarded as indicative of obstruction. This finding is referred to hereafter as mean RI positivity (mRI+).

Based on data collected at the various time-points in the study, the patients were divided into two groups: those who presented signs of dilatation (group A) and those who did not (group B). The data were subjected to statistical analysis to identify: 1) possible differences between groups A and B; 2) the relation between mRI+ and the time of onset of hydronephrosis; 3) possible correlation between the mRI+ and the level, degree, and duration of ureteral obstruction; 4) the sensitivity, specificity, positive and negative predictive values, accuracy, and efficiency of the method.

Results

The demographic and clinical features of the 54 patients investigated in this study are shown in Tables 1 and 2. Tables 3 and 4 show, respectively, the number of mRI+ recorded and the number of cases of hydronephrosis observed in the two groups (A and B) at each time point. There were no statistically significant differences between groups A and B in terms of demographic or clinical features. In 51/54 cases (94.4% of the patients), the RC was attributed to ureteral calculosis on the basis of CT findings; in the other 3 cases, no cause was identified.

In the diagnosis of hydronephrosis, ultrasonography displayed excellent sensitivity, specificity, accuracy, PPV, and

Table 1 Demographic and clinical features of the study population.

<i>Demographic features</i>		
Sex	Males 35 (64.8%) Females 19 (35.2%)	M/F = 1.8:1
Age	Mean: 36.6 years	Range 22–50 years
<i>Clinical features</i>		
Symptoms	Pain	Right flank 23/54 (42.6%) Left flank 31/54 (57.4%) Duration 4–38 h (mean 7.2)
	Nausea – vomiting	37/54 (68.5%)
	Dysuria	41/54 (75.9%)
	Gross hematuria	18/54 (33.3%)
	Fever	11/54 (20.4%)

Table 2 Results of diagnostic procedures performed in the study patients.

<i>Laboratory analyses</i>			
Leukocytosis		43/54 (79.6%)	
Microhematuria		51/54 (94.4%)	
Bacteriuria		14/54 (25.9%)	
Crystalluria		33/54 (61.1%)	
<i>Plain radiography of the urinary tract</i>			
Radiopaque images consistent with the presence of calculi	Presumed location: kidney	35/54 (64.8%)	
	Presumed location: ureter	37/54 (68.5%)	
	Presumed location: bladder	1/54 (1.85%)	
<i>Ultrasonography</i>			
Calculosis	Kidney	47/54 (87%)	
	Proximal ureter	17/54 (27.8%)	
	Mid-distal ureter	13/54 (16.7%)	
	Bladder	3/54 (5.5%)	
Hydronephrosis	Unilateral	29/54 (53.7%)	
	Bilateral	0/54 (0%)	
	Grade I	5/29 (17.2%)	
	Grade II	8/29 (27.6%)	
	Grade III	16/29 (55.2%)	
<i>CT</i>			
Calculosis	Kidney	47/54 (87%)	
	Proximal ureter	31/54 (57.4%)	
	Mid-distal ureter	20/54 (37%)	
	Bladder	2/54 (3.7%)	
Hydronephrosis	Unilateral	29/54 (63.7%)	
	Bilateral	0/54 (0%)	
	Grade I	4/29 (13.8%)	
	Grade II	11/29 (37.9%)	
	Grade III	14/29 (48.3%)	

Table 4 Number of cases of hydronephrosis observed at different time-points.

Time point	No. cases hydronephrosis (%)	
tpI (admission)	0	0
tpII (6 h after admission)	0	0
tpIII (12 h after admission)	3/54	5.5
tpIV (18 h after admission)	14/54	25.9
tpV (24 h after admission)	10/54	18.5
tpVI (36 h after admission)	2/54	3.7
tpVII (48 h after admission)	0	0
Total	29/54	53.7%

NPV (all 100%), but its performance declined in the identification of obstructing and nonobstructing calculosis in the two groups (sensitivity 72.4%, specificity 64%, accuracy 68.5%, PPV 70%, and NPV 66.7%) (Table 5).

CDUS with calculation of the mRI+ was of substantial value in diagnosing the onset of hydronephrosis (sensitivity 100%, specificity 84%, accuracy 92.6%, PPV 87.9%, NPV 100%, and efficiency 84%) (Table 5). In group A, mRI+ was always observed before the onset of hydronephrosis (100% of the cases) in an apparently time-dependent manner (an example is shown in Fig. 1); in particular, the interval between mRI+ and detection of hydronephrosis was 6 h in 19/29 cases (65.5%), 12 h in 8/29 cases (27.6%), and 18 h in 2/29 cases (6.9%). Positive mRIs were also observed in 4/25 (16%) patients in group B, and all were recorded at tpII. (An example is provided in Fig. 2.) In all four patients, the mRI observed at the next tp was already within the normal range.

No significant correlation was found between mRI values and the level of ureteral obstruction, the degree of

Table 3 Number of mRI+ observed in groups A and B at the different time-points in the study.

Time point (tp)	Group A		Group B
	No. cases (%)	No. cases – hours before onset of hydronephrosis	No. cases (%)
tpI (admission)	0	0	0
tpII (6 h after admission)	7/29 (24.1%)	1 case – 18 h 3 cases – 12 h 3 cases – 6 h	4/25 (16%)
tpIII (12 h after admission)	16/29 (55.1%)	5 cases – 12 h 11 cases – 6 h	0
tpIV (18 h after admission)	5/29 (17.2%)	1 case – 18 h 4 cases – 6 h	0
tpV (24 h after admission)	1/29 (3.4%)	1 case – 6 h	0
tpVI (36 h after admission)	0	0	0
tpVII (48 h after admission)	0	0	0
Total	29/29 (100%)	2/29 cases – 18 h (6.9%) 8/29 cases – 12 h (27.6%) 19/29 cases – 6 h (65.5%)	4/25 (16%)

Table 5 Sensitivity, specificity, accuracy, PPV, NPV, and efficiency of ultrasonography in the diagnosis of hydronephrosis and calculosis and of CDUS in predicting onset of hydronephrosis.

	Ultrasonography		RI at CDUS
	Diagnosis of hydronephrosis	Diagnosis of ureteral calculosis	Prediction of onset of hydronephrosis
Sensitivity	100%	72.4%	100%
Specificity	100%	64%	84%
Accuracy	100%	68.5%	92.6%
PPV	100%	70%	87.9%
NPV	100%	66.7%	100%
Efficiency	100%	36.4%	84%

dilatation, the size of the obstructing calculus (≤ 6 mm in 11 cases, >6 mm in 18), or the duration of the pain (range 4–38 h).

In all of the patients in group A, the RI promptly returned to normal once the obstruction had resolved. Resolution occurred spontaneously in [12/29 (41.4%)] cases; in the other cases it was achieved with extracorporeal lithotripsy (10/29, 34.5%); removal of the stone with the aid of a Dormia basket (1 case, 3.4%).

Discussion

There are numerous reports in the literature showing that CDUS with measurement of the RI is useful in the diagnosis of acute urinary tract obstruction in patients with recent onset (6–48 h) unilateral RC [7,29–31]. The RI is easy to calculate; it can even be provided automatically by the scanner itself. It represents an indirect estimate of the resistance present in the intrarenal vessels [32]. An acute urinary tract obstruction can increase the RI because this parameter is directly correlated with the pressure within the collection system. Indeed, dilation of the excretory ducts causes progressive compression of the renal parenchyma and renal vessels, and resistance within these vessels increases [30,32].

Early clinical studies produced contradictory results regarding the value of the supplementary information furnished by CDUS (compared with gray-scale ultrasound alone) and by measurement of the RI itself in the diagnosis of acute urinary tract obstruction [30,33].

In the 1980s Platt [30] and Sauvain [33] reported that RIs > 0.70 were indicative of acute ureteral obstruction; since then, numerous studies conducted in animals and humans have confirmed this finding and attributed more or less high sensitivity and specificity to CDUS measurement of the RI [7,28,29,31,32].

In our study, the RI was found to predict the onset of acute dilatation with higher sensitivity, specificity, accuracy, and diagnostic efficiency than gray-scale US. In view of these findings and the temporal advantage it offers, we feel that the RI could be a useful prognostic

marker for planning and monitoring responses to treatment for acute urinary tract obstruction. If an RI of >0.70 is indicative of obstruction with increased intrarenal pressures, patients with indexes in this range need prompt urinary tract decompression (via medical therapy, extracorporeal lithotripsy, endourologic procedures) to prevent irreversible damage, as confirmed by the more or less rapid RI normalization seen in our cohort and others once the obstruction has been eliminated [30,32,33].

Despite the encouraging results that emerged from our study and others, it is important to recall that this method has certain limitations. Above all, the RI has been shown to be influenced by a number of factors, including the patient's age, plasma renin levels, and the concomitant presence of diabetes, hypertension, heart disease, and many renal disorders. These factors can cause the RI to rise even in the absence of renal obstruction [10]. The population we studied was selected to minimize the effects of these variables. It was characterized by a well-defined age range and the absence of metabolic, cardiologic, renal, and urological disease.

It is also important to stress that the sensitivity and specificity of the RI varies in cases of partial obstruction. Data in the scientific literature confirm that this marker is more sensitive in the diagnosis of complete rather than partial obstructions [31,34,35]. de Toledo et al. [36], for example, reported a sensitivity of 91.8% in patients with complete obstruction but only 48.1% in those with partial obstruction. In the latter case, the intraureteral pressure is not high enough to increase intrarenal vascular resistance [35,36]. These considerations might also explain the cases of false positivity observed in our study: in all probability, these cases were characterized by partial and/or transient obstruction that caused only a temporary increase in the intraluminal pressure (and consequently of the RI as well), which was not sufficient to produce permanent dilation.

Some authors have found that the RI increase associated with acute urinary tract obstruction is time-dependent [29,36]. Opdenakker [29], for example, showed that the sensitivity of the RI decreases substantially 48 h after symptom onset. Platt [30] found that in patients whose obstruction had been present for 12 h, the RI is not significantly higher than that observed in the presence of more recent obstruction. On the other hand, de Toledo [36] reported that the RI was significantly higher in patients whose renal colic had lasted at least 24 h. These differences may be related to the duration of the obstruction and the clinical course. We found that in all patients who developed hydronephrosis, the rise in RI occurred before the onset of dilation (at least 6–12 h in 93% of the cases).

In accordance with the findings of Shokeir [31] and other authors, we found no significant correlation between the RI and the level of ureteral obstruction, whereas de Toledo [36] reported that proximal obstructions were associated with higher RIs than distal obstructions.

Other authors have observed a relation between the RI and the magnitude of dilation [31,35]. In our cohort, the RI exhibited no significant correlation with the degree of dilation or with the duration of the colic.

Figure 2 Example 2: Male patient admitted for left renal colic. Panels a and b: At time point (tp) I, sonography revealed a calculus at the level of the distal ureter, near the bladder (white arrow in panel a). This finding was later (48 h after admission) confirmed by urinary tract CT without contrast enhancement. Panel c: At tpII, sonography shows no evidence of hydronephrosis, but CDUS reveals mRI+. Panel d: At tpIII, there is still no evidence of dilation on sonography. CDUS shows normalization of the RI even though the calculus has not been expelled. (It was expelled spontaneously one week later.)

Conclusions

CDUS with measurement of the RI is a simple, noninvasive method that furnishes acceptably precise information on the evolution of obstructive urinary tract lesions in patients with unilateral RC. In our study, this method effectively predicted the onset of acute dilatation with levels of sensitivity, specificity, accuracy, and diagnostic efficiency that were superior to those of sonography. Routine use of CDUS in the ED should be a useful supplement to ultrasonography, especially when there are contraindications for methods that involve radiation exposure (pregnancy,

allergies, renal failure, etc.) or intravenous administration of iodinated contrast material (urography, CT).

Conflict of interest

The authors have no conflict of interest to disclose.

Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.jus.2012.10.003>.

Figure 1 Example 1: Male patient admitted for right renal colic. Panels a and b: At time point (tp) II, sonography revealed a calculus in the proximal ureter (white arrow in panel a) with no signs of hydronephrosis. At the same tp, CDUS showed mRI+. Panels c and d: At the next time point (tpIII), sonography confirmed the presence of the ureteral calculus (white arrow in panel c) and revealed grade III hydronephrosis; CDUS confirmed mRI+. Panels e, f, and g: Forty-eight hours after admission, CT of the urinary apparatus without IV contrast enhancement confirmed both the grade III hydronephrosis (white arrow in panel a) and the ureteral calculus (white arrow in panels f and g). Panels h and i: A ureteral stent was inserted (three white arrows), and the post-procedural sonogram shows resolution of the dilation, whereas CDUS reveals normalization of the RI.

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