Can renal Doppler sonography replace diuretic radionuclide renography in infants with hydronephrosis?

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Reliable differentiation between obstructive and non-obstructive hydronephrosis is decisive for the further therapeutic management in infants. The results of renal Doppler sonography were compared with diuretic radionuclide renography and with the follow-up results in 33 patients (range: 21 to 98 days). In Doppler sonography, a resistive index (RI) of >0.9 was considered to be abnormal in the sense of an obstruction. In diuretic renography, a T½ value (time until a 50% decrease in activity in the kidneys was observed after injection of furosemide) of >20 min was appraised as obstructive hydronephrosis. In six patients an obstructive (T½ >20 min) and in 27 patients a non-obstructive (T½ <20 min) hydronephrosis was found. All patients with obstruction in diuretic renography showed an abnormal RI (>0.9) in Doppler sonography. In addition, all patients with surgery and obstruction in diuretic radionuclide renography showed an improvement in hydronephrosis. However, seven patients had a false-positive result in Doppler sonography. All patients with non-obstruction in diuretic radionuclide renography showed no worsening of hydronephrosis without surgery in the follow-up. We found a RI of 0.84±0.07 in the non-obstructive group and of 0.96±0.05 (p=0.018) in the obstructive group. Doppler sonography showed discrepant results compared to diuretic radionuclide renography and therefore cannot replace this method.

Key words: *diuretic radionuclide renography, renal Doppler sonography, hydronephrosis, resistive index.*

A common reason for renal failure in infants is an unrecognized obstructive hydronephrosis. A general prenatal screening by sonography was thus introduced to detect these abnormalities because the timely and adequate therapy of obstructive hydronephrosis in newborns is of central importance. While the postnatal kidney is extremely sensitive to increased backpressure from the renal pelvis, the kidneys also have a pronounced ability to regenerate their function after removal of the damaging agent. The most decisive criterion for the therapeutical management of hydronephrotic diseases is the differential diagnosis between obstructive and non-obstructive hydronephrosis. The effects of chronic obstruction are easily recognized in the form of hydronephrosis, parenchymal atrophy, and impaired renal function[1]. In children with a congenital obstruction, the pelvic pressure is directly proportional to the rate of urinary flow, the duration of the diuresis, and the degree of obstruction[2]. Loss of renal function is proportional to the magnitude and the duration of the rise in intrapelvic pressure[3]. A complete obstruction which persists for more than one week produces permanent deterioration of glomerular and tubular function[4]. In patients with severe obstruction, a rapid and progressive reduction in renal blood flow and glomerular filtration was observed[5]. But congenital obstruction is rarely complete[6], and the elasticity of the collecting system protected the nephron from the full effect of the elevated pressure[7].

Sonography is a sensitive method of detecting dilation of the renal collecting system, but its use in the diagnosis of acute renal obstruction is limited when dilation has not developed[8]. Recent works have suggested that Doppler sonography may be used to distinguish between an obstructed and non-obstructed dilated collecting system by changes in the arterial Doppler waveform[9]. In 1978 Arima et al.[10] identified an alteration in arterial blood flow pattern in renal allograft undergoing rejection measured by the Doppler technique. The alteration was characterized by an increase in renal arterial resistance, which resulted in a decrease in diastolic blood flow in comparison to systolic flow. The introduction of the resistive index (RI), defined as [(peak systolic velocity – end diastolic velocity)/ peak systolic velocity], allowed a quantitative determination of the arterial resistance. Many studies have shown the usefulness of the RI in the differentiation between obstructive and non-obstructive hydronephrosis[8,9,12-16]. When using Doppler sonography in children, it is important to note the age dependency of the RI[13]. It is generally accepted that a RI > 0.9 in children younger than six months is borderline obstructive hydronephrosis[17-19].

Material and Methods

The study included 33 children (9 girls, 24 boys) with abnormal results in pre- or postnatal renal sonography and unilateral hydronephrosis. Patients were aged from 21 to 98 days. All patients underwent diuretic radionuclide renography and a Doppler sonography within one week before or after renography. All patients had a follow-up with sonography and/or diuretic radionuclide renography with a maximum observation period of two years (irregular intervals).

Diuretic radionuclide renography was performed with 20 MBq of Tc-99m-mercapto-acetyltriglycil (MAG3) (in the first patients we used 37 MBq, but this was later changed to 20 MBq). One hour prior to the study hydration was initiated (10 ml/kg body weight, BW). Scintigrams were recorded in supine position using a gamma camera (Genesys, ADAC Laboratories, Milpitas, CA). To reduce movement of the children, Velcro straps were applied. If possible, the child lay directly on the collimator surface[20]. The recording protocol was 180 frames at a rate of 1s/frame and 126 frames at a rate of 20s/frame. In all patients, furosemide was injected 20 min after the start of the investigation to achieve forced diuresis. We used an age-related dosage of furosemide (1.0 to 2.0 mg/kg BW) considering a possible lack of response to furosemide due to the immature renal function in this age group. At the end of the investigation, split renal function, MAG_3-clearance and the T½ after furosemide were calculated. The T½ was defined as the time until a 50% decrease in activity in the kidneys was observed after injection of furosemide. An obstructive hydronephrosis was assumed at T½ >20 min[21].

Doppler sonography was performed by a standardized protocol which included a baseline sonography and then repeated sonography after the infusion of normal saline (10 ml/kg BW) given over 30 min, followed by an injection with furosemide (1 ml/kg BW). Doppler sonography was performed 10 min, 30 min, 60 min and 90 min after injection of furosemide. The infusion of normal saline was continued during the entire investigation. Doppler sonographic evaluation of interlobar arteries was carried out with an Acuson 128 XP scanner (Acuson, Mountain View, CA) using a linear 5.0 MHz transducer. In all patients the renal RI was calculated from sonographic waveforms obtained from interlobar branches of the renal arteries of both kidneys. The RI was calculated using the formula (peak systolic velocity – peak diastolic velocity/peak systolic velocity). The RI of each kidney was determined as an average of five uniform appearing waveforms. All investigations were performed by the same experienced observer. A RI >0.9 was defined as an abnormal result.

Statistical Analysis

Data are presented as mean data±standard deviation. We used the paired Student's t-test. Two-tailed p values <0.05 were considered to indicate statistical significance. Sensitivity and specificity were calculated with the diuretic radionuclide renography as gold standard.

Results

Based on diuretic radionuclide renography, six patients had an obstructive hydronephrosis (T½ after furosemide >20 min) (Fig. 1) and 27 patients a non-obstructive hydronephrosis (T½ after furosemide <20 min) (Table I). All patients with obstruction in diuretic radionuclide renography (T½ after furosemide >20 min) also had an abnormal result in Doppler sonography (RI >0.9). Accordingly,

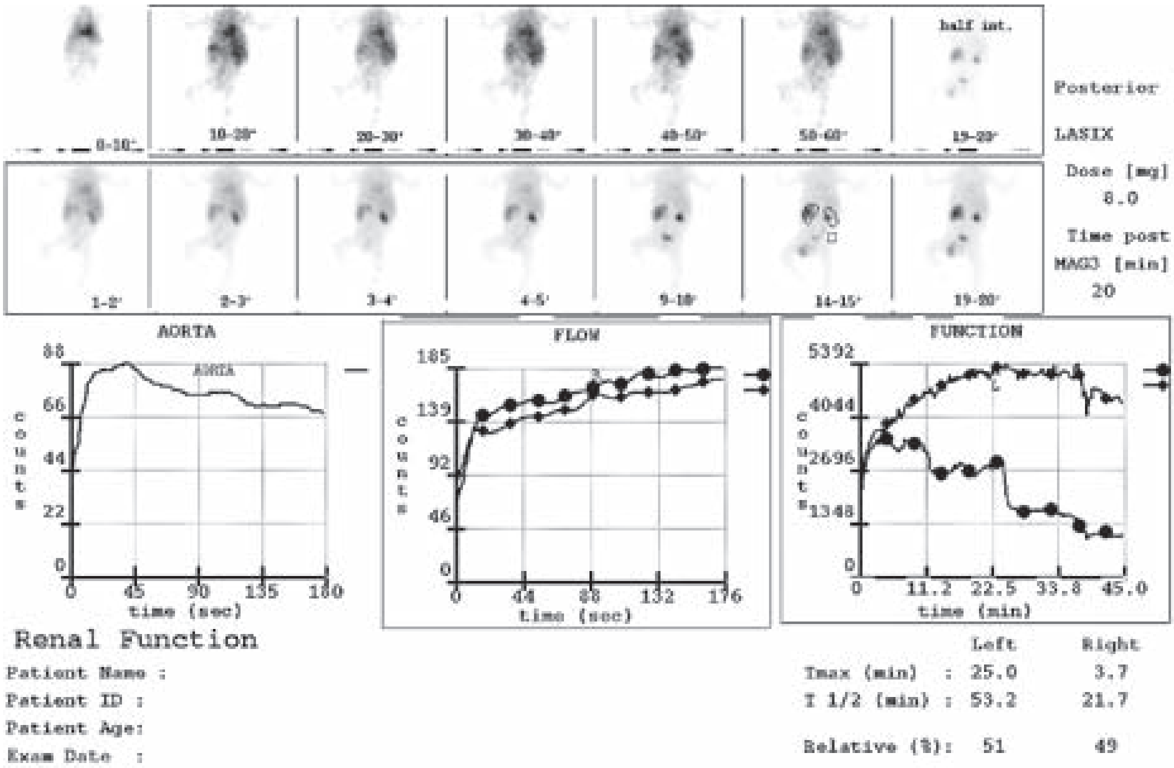

Fig. 1. Infant (59 days old) with obstruction in diuretic renography (T½ after furosemide >25 min).

Table I. Results of Diuretic Renography and Doppler Sonography in 33 Infants

Renography	Doppler Ultrasound: Pathologic RI >0.9	Doppler Ultrasound: Normal RI<0.9	Summary
obtructive	6		6
non-obtructive	7	16	23
normal		4	4
summary	13	20	33

the sensitivity for Doppler sonography was 100%. However, there were seven patients with non-obstruction on diuretic radionuclide renography and a RI >0.9, thus giving a specificity of 74% (Figs. 2, 3). Five of these seven patients had an improvement in diuretic radionuclide renography with a decrease of T½ after furosemide or an increase in split renal function (Fig. 4), and the other two patients had no worsening of hydronephrosis in renal sonography in the follow-up.

None of the 27 patients with a non-obstructive hydronephrosis in diuretic radionuclide renography showed a worsening of the hydronephrosis in renal sonography or diuretic renography. There were no false-positive results in diuretic radionuclide renography in comparison to the follow-up with a maximum of 2½ years. However, we observed seven false-positive results in the Doppler sonography in the follow-up.

The Doppler sonography showed a RI of 0.96±0.05 in patients with obstruction and of 0.84±0.08 in patients with non-obstruction in diuretic renography, and this difference was statistically significant (p=0.018).

Discussion

Diuretic radionuclide renography and sonography are the most common imaging examinations used in patients with hydronephrosis. With the introduction of Doppler sonography, an extension of the diagnostic management seemed possible. In percutaneous pressure flow studies in children younger than one year, a correlation between increased renal pelvis pressure and RI was observed[22]. The age-dependency of the RI of the renal artery in healthy children is well

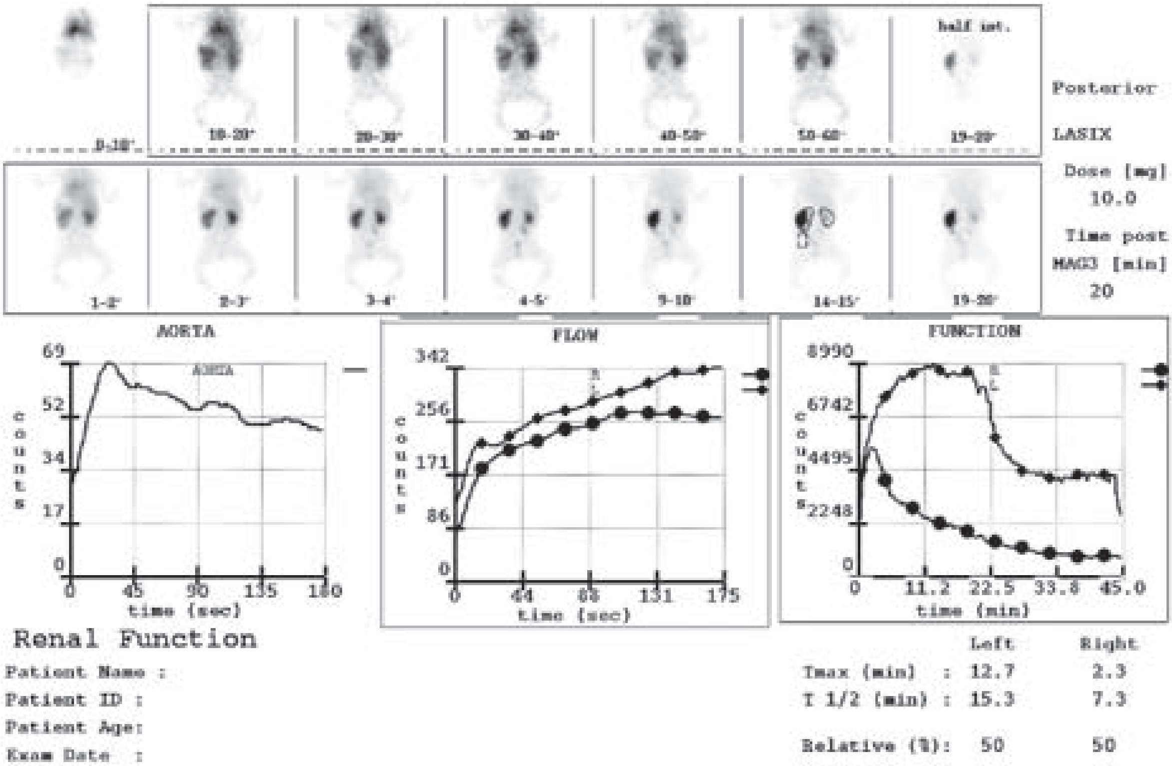

Fig. 2. Infant (28 days old) with non-obstruction in diuretic renography (T½ after furosemide=4.3 min) and a uretero-pelvic junction in the urography.

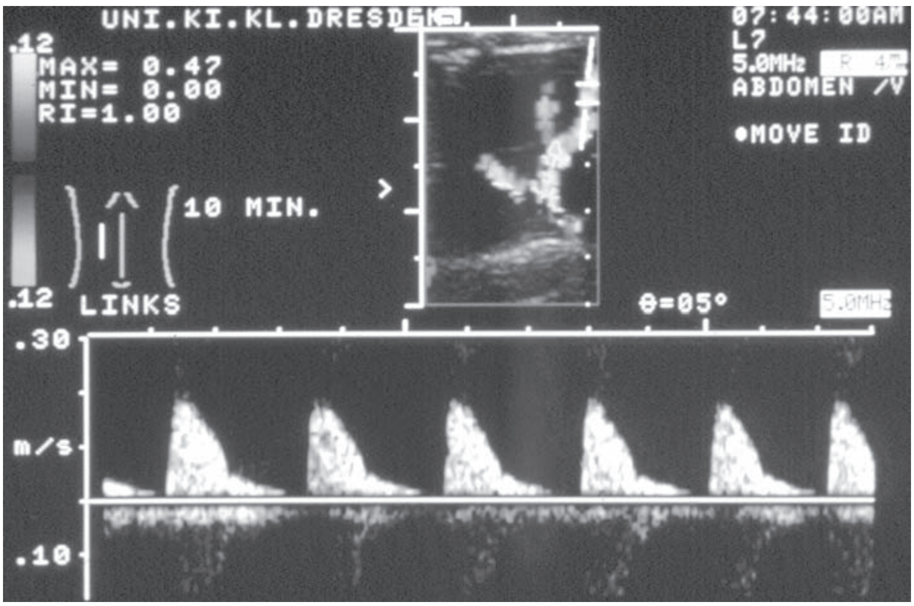

Fig. 3. The same infant as in Figure 2 with false-positive, abnormal finding in renal Doppler sonography (RI=1.0).

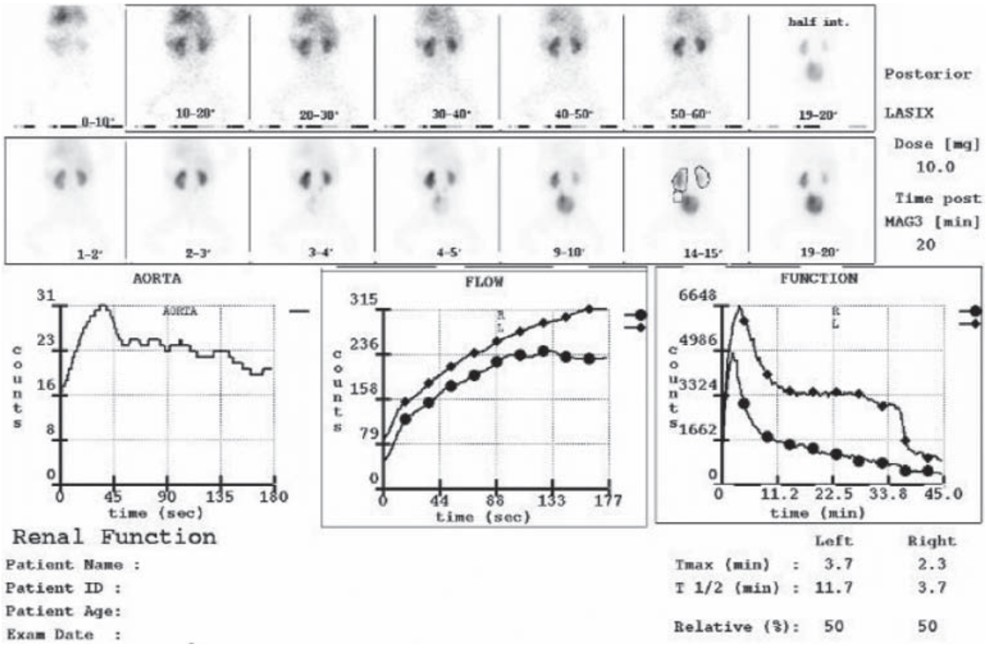

Fig. 4. Radionuclide renography in the same infant as in Figure 2 performed 12 months later without interventional procedures shows improvement.

known[12,23,24], with an overall decreasing trend with increasing age, especially in the first year of life. In our study, we used the normal value of Deeg[18] and evaluated a RI >0.9 as pathologic in the sense of obstructive hydronephrosis. Other authors[25] rated a cutoff RI of 0.7 as not conclusive in making a distinction between obstruction and non- obstruction. In comparison to diuretic radionuclide renography, we found a sensitivity of 100% and a specificity of 74% for Doppler sonography. Other papers showed a sensitivity of 76% - 92% and a specificity of 81%-88% for Doppler sonography[26–28]. Further authors discussed the results of Doppler sonography more critically. Lee et al.[14] found a sensitivity of only 20% in unilateral obstruction; however, it was 80% in the subgroup with acute symptoms. They concluded that Doppler sonography had limitations as a screening method in obstruction, but that it can be useful in selected cases of acute and severe obstruction. Vade et al.[29] postulated from their results that Doppler sonography in infants has no value in differentiating obstructive from non-obstructive hydronephrosis.

Several studies regarding renal hemodynamic response to ureteral obstruction described a tri-phasic renal vascular and ureteral pressure response to obstruction[11,30,31]. The initial phase, occurring in the first 1.5 hours after obstruction, is characterized by a transient rise in renal blood flow. The pressure in the ureter and renal parenchyma is increased, but renal vascular resistance is reduced. The second phase (1.5 to 5 hours) is characterized by elevated renal vascular resistance, decreased renal blood flow, and elevated ureteral pressures. The third phase, beginning after five hours of obstruction, then shows an elevation in pre-glomerular resistance and a marked elevation of renal vascular resistance. In animal studies using rabbits with a partial ligature of the ureter, an increase in the RI was reported within three days[32], but the RI subsequently decreased seven days after the partial obstruction. These results can be extrapolated to humans to only a limited extent, but it might be an explanation for the different results in the different papers.

In evaluating the follow-up results of children with hydronephrosis, Shokeir et al.[33] described a sensitivity and specificity of 100% and 94% for diuretic radionuclide renography and 82% and 63% for Doppler sonography, respectively. In 23 children with abnormal results in diuretic radionuclide renography six months after pyeloplasty, the T½ after furosemide in diuretic radionuclide renography was normal, but in three patients the Doppler sonography was again abnormal[13]. In our study, all of the 27 patients with non-obstruction in diuretic radionuclide renography in the follow-up showed no worsening of hydronephrosis, and therefore there were no false-negative results in diuretic renography. All patients with obstruction in diuretic radionuclide renography and surgery showed an improvement in subsequent diuretic radionuclide renography or no worsening of hydronephrosis in renal sonography.

Given the lower specificity of Doppler sonography, this method cannot replace diuretic radionuclide renography in the differentiation of obstructive and non-obstructive hydronephrosis.

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