M. Meola[a]
G. Giuliano[b]
E. Morelli[a]
A. Cupisti[a]
G. Barsotti[a]

[a] Chair of Nephrology, Istituto di Clinica
Medica I, Università di Pisa and
[b] Istituto di Fisiologia Clinica, CNR,
Epidemiologia e Biostatistica, Pisa, Italy

Ultrasound Diagnosis of Suspected Urinary Tract Obstruction Using a Stimulated Diuresis Test

Abstract

The aim of this study was to evaluate whether a stimulated diuresis test associated with ultrasound is able to differentiate pelvic dilation due to atonicity from pelviureteric junction obstruction (PUO). 42 patients (25 f, 17 m) with minimal or moderate renal pelvis dilation revealed by sonography were selected for the test. Three different measurements of the anteroposterior diameter (APD) of the renal pelvis were done at the renal hilus level, by using a transversal ultrasound scan: the first under spontaneous diuresis conditions, the second after hydration with 1.5 liters of water, and the third with a full bladder 15 min after intravenous injection of 20 mg frusemide. All the patients underwent pyelography. Baseline APD (bAPD) linearly correlated with the PAD both after hydration and frusemide (r = 0.89 and r = 0.84, respectively). A descriptive evaluation of the frequency distribution of the bAPD suggested the possibility that the data samples could belong to three populations with different underlying pathophysiological conditions. Correspondence analysis between bAPD distribution and PUO suggested that the best grouping of data was: group 1 (11 patients) bAPD < 13 mm, group 2 (14 patients) 13 ≥ bAPD ≤ 20 mm, group 3 (17 patients) bAPD > 20 mm (likelihood ratio χ^2 46.36; d.f. = 2). Standard intravenous pyelography showed an increase in pelvis size compatible with PUO in 2 patients from group 2 and in all patients from group 3. At the end of the test, in group 3 APD increased by 20.9 ± 5.6 mm while in group 2 and group 1 the increase, though significant, was moderate (respectively, 7.3 ± 4.6 and 7.3 ± 4.9 mm) and the APD never exceeded 30 mm. In conclusion, the stimulated diuresis test is an important tool for sonographic diagnosis of pelvic dilations. It may be regarded as a valid alternative for pyelography and other urodynamic tests, particularly for children and for patients with a suspected obstruction of the upper urinary tract.

Introduction

A high urinary flow in the presence of an obstruction of the upper urinary tract leads to an increase of intrapelvic pressure and slows down ureteral flow [1]. This concept is the basis of dynamic tests usually used in obstruction diagnosis, i.e. Withaker's test [2], diuresis renography [3, 4], and DTPA parenchymal transit time [5, 6].

The sonography is the first choice screening technique for the diagnosis of hydronephrosis, due to its sensitivity, availability and safety [7]. Its main application is in the antenatal and pediatric diagnosis of congenital urinary obstruction [8, 9], but it is also useful for the adult with suspected urinary tract obstruction. The sensitivity of this technique for anatomical assessments is nearly 100% [10, 11]. When the sonography is positive for hydronephrosis, a further evaluation must be performed to diagnose urinary tract obstruction.

The aim of this study was to evaluate the possibility of distinguishing between a simple dilation of renal pelvis

Dr. Mario Meola
Istituto di Clinica Medica 1
Università di Pisa
Via Roma 67
I-56100 Pisa (Italy)

Table 1. Clinical data of the 42 patients undergoing the test

Parameters		Number
Patients studied		42
Sex	male	17
	female	25
Mean age, years		36.9 (SD = 13.0)
Clinical indications for sonography		
Renal cholics, loin pain with or without microhematuria		12
UTI		6
Lithiasis, past or in progress		3
Hypertension		3
Others		14

UTI = Urinary tract infection.

due to atonicity in the absence of obstruction, and a pelvis dilation caused by pelviureteric junction obstruction (PUO) by using a dynamic test [stimulated diuresis with overhydration and intravenous (i.v.) injection of 20 mg frusemide].

Patients and Methods

42 patients (25 female, 17 male, age 36.9 ± 13.0 years) undergoing renal sonography during the period of 1990–1992 were selected on the basis of sonographic evidence of minimal or moderate pelvis dilation with normal hydration and empty bladder [7]. Minimal dilation was diagnosed when a well-defined renal pelvis (funnel- or irregularly shaped anechoic band) was present within the central echogenic renal complex. Moderate dilation was defined by a larger anechoic area (pelvis) with or without collecting system dilation.

Patients with congenital malformations of the upper urinary tracts, horseshoe kidney, polycystic kidney disease, acute and chronic renal failure and renal artery stenosis were excluded. Clinical data of patients are reported in table 1. All patients had a normal renal function (serum creatinine lower than 1.2 mg/dl). The dilation was bilateral in only 2 patients. The renal parenchyma structure was regular with a good differentiation between cortex and medulla. No patients had evidence of parenchymal or peripelvic cysts. At the time of testing no patients had urinary tract infection.

Renal sonography was performed with a sonolayer apparatus (Toshiba Medical Systems Sal 77-A). Longitudinal and transversal scans were obtained using an electronic sector-convex probe of 3.75 MHz. The *stimulated diuresis test* was performed by measuring the renal pelvis anteroposterior diameter (APD) (1) at normal hydration, (2) after hydration with 1.5 liters water and (3) with a full bladder after the i.v. injection of 20 mg frusemide. On the day of the test, the

initial measurement was taken in the morning after overnight fasting with an empty bladder. The patients were asked to drink approximately 1.5 liters of water in 1 h. The renal pelvis APD was measured with a full bladder about 2 h from the beginning of hydration, considering urgency of the miction stimulus. Without delay we then proceeded to i.v. inject 20 mg frusemide. The last measurement of APD was taken 15 min after injection. The overall duration of the test was 2.5 h. At the initial measurement, the contralateral renal pelvis was in a collapsed state in all except 2 patients. Standard i.v. urography for comparative anatomical assessment of the renal pelvis was performed in all patients. Urographic data were unknown to the sonographist.

Statistical evaluation was performed using regression, correlation, variance (ANOVA) and correspondence analysis. Differences were considered significant when $p < 0.05$. Multiple comparison of the mean group values was performed using the Scheffé F test. Results were expressed as mean ± standard deviation. The sensitivity and specificity of the test were determined at different APD values, both after hydration and frusemide; the correspondent receiver operator characteristic (ROC) curves were elaborated [12]. For the selected cutoff points the correspondent efficacy was calculated [13].

Results

A positive linear relationship was found between baseline APD (bAPD) of renal pelvis and APD after both steps of the test [hydration (hAPD) and frusemide (fAPD); fig. 1]. Correlation r was 0.89 and 0.84, respectively (see formulas at the bottom of fig. 1). Linear interpolation of the data explained about 79% of the total variance of the measurements obtained after hydration and about 71% after frusemide.

The detection of different bAPD values and test results suggested the existence of different underlying urodynamic conditions. Descriptive evaluation of the frequency distribution of bADP suggested a three-modal pattern. After grouping of bAPD into three classes, correspondence analysis between bAPD distribution and PUO showed that the best grouping of the patients was group 1: 11 patients (5 m, 6 f), with bAPD < 13 mm, group 2: 14 patients (5 m, 9 f) with 13 ≤ bAPD ≤ 20 mm, and group 3: 17 patients (8 m, 9 f) with bAPD > 20 (x^2 of likelihood ratio = 46.36; d.f. 2). The three groups differed significantly in the value of hAPD and fAPD as demonstrated by the analysis of variance (F = 51.27, d.f. 2,39, $p < 0.0001$; F = 102.88, d.f. = 2,39, $p < 0.0001$, respectively) and by comparison of the mean group values using the Scheffé F test. Furthermore the increase of APD both after hydration and after frusemide was significantly different (F = 11.38, d.f. 2,39, $p < 0.0001$, and F = 35.39, d.f. 2,39, $p < 0.0001$, respectively) even if it was attributable only to group 3 which differed significantly from group 1 and 2 (fig. 2).
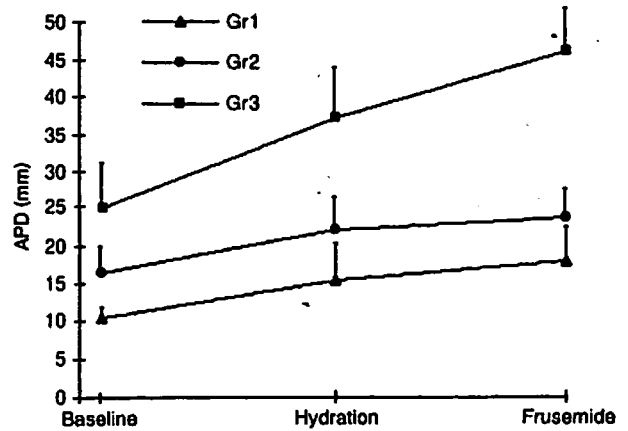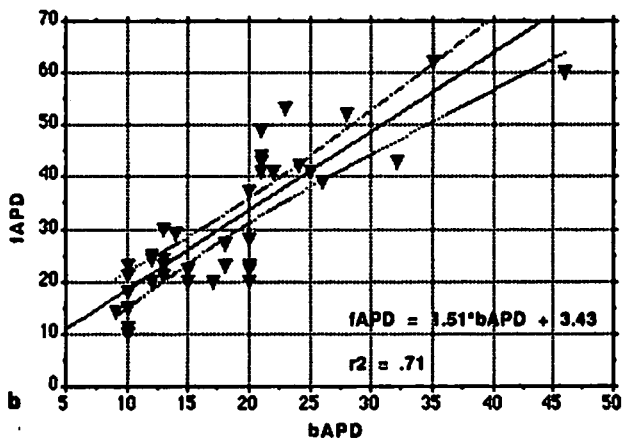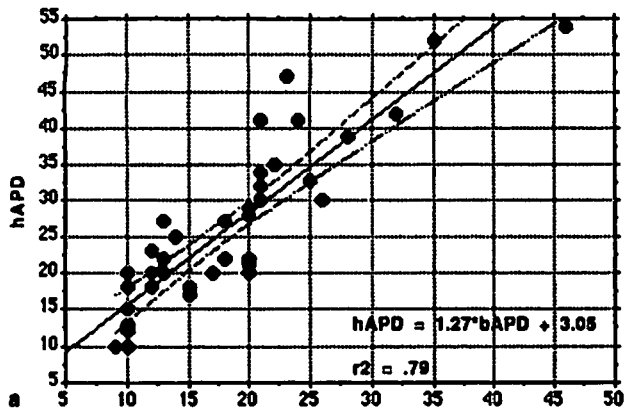
Meola/Giuliano/Morelli/Cupisti/Barsotti   Stimulated Diuresis Test

Fig. 1. Linear correlation between bAPD and hAPD (a) and fAPD (b). 95% confidence limits of the mean values are outlined while the regression functions are shown at the bottom of each graph.

Fig. 2. Mean variation of APD (mm) before and after hydration and frusemide administration in the three groups (Gr) of patients.

The mean bAPD in group 1 was 10.5 ± 1.0 mm. APD increased to 15.4 ± 4.7 mm after hydration and reached the mean value of 17.8 ± 5.2 mm after i.v. frusemide. Mean variation of APD after the test was 7.3 ± 4.6 mm. No patients of this group showed features of stenosis with i.v. pyelography. The mean bAPD in group 2 was 16.4 ± 3.0 mm. It increased to 22.1 ± 3.4 mm after hydration and to 23.7 ± 3.4 mm after i.v. frusemide. The mean variation of ADP after the test was 7.3 ± 4.9 mm. At i.v. pyelography, 2 patients of this group showed a pelvic renal morphology compatible with PUO. Group 3 had a mean bAPD of 24.2 ± 6.9 mm. It increased to 37.2 ± 7.9 mm after hydration and to 46.1 ± 71 mm after frusemide injection. All the patients of this group had clear pyelographic features of PUO. In 4 patients the longitudinal diameter of the renal pelvis was greater than the APD. After testing, 9 patients in group 3 complained of intense loin pain (with renal cholic characteristics) which rapidly disappeared after micturation; 5 of these patients underwent pyeloplasty.

In order to evaluate the diagnostic value of the test, sensitivity and specificity were elaborated considering every cross tabulation derived at each APD measurement. At first, pyelography was tested against bAPD and fAPD in order to establish the APD value corresponding to 100% sensitivity and maximum specificity, which was 91.3% when hAPD was 25 mm and 100% when fAPD was 29 mm. Such cutoff points were used to establish correspondent values for bAPD. ROC curves were then determined between APD values at different test conditions (fig. 3, 4). By testing APD measurements versus PUO detected by pyelography, 100% sensitivity was reached when (1) bAPD was equal or greater than 13 mm, (2) hAPD was equal or greater than 25 mm, and (3) fAPD was equal or greater than 29 mm. Such cutoff points corresponded, respectively, to a specificity of 47.8, 91.3, 100% and a total efficacy of 71.4, 95.2, 100%.
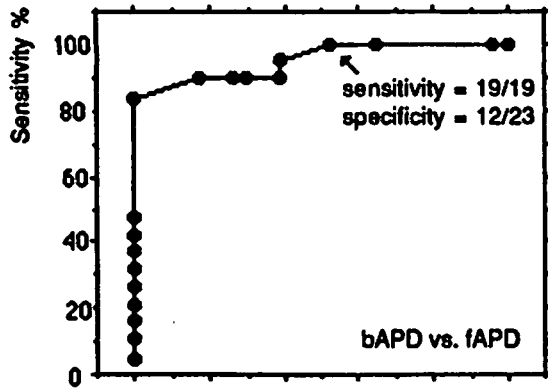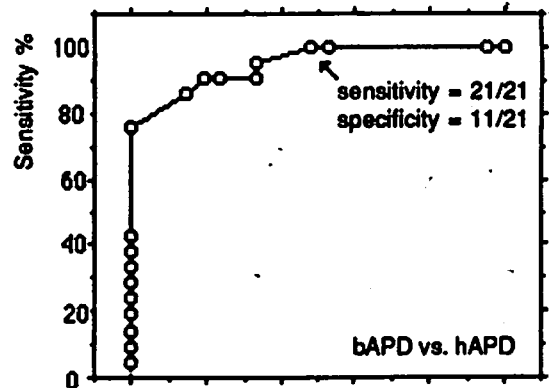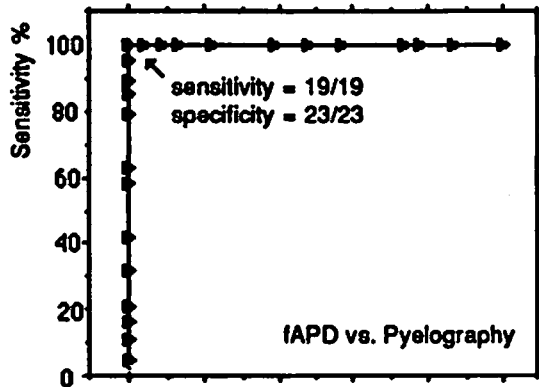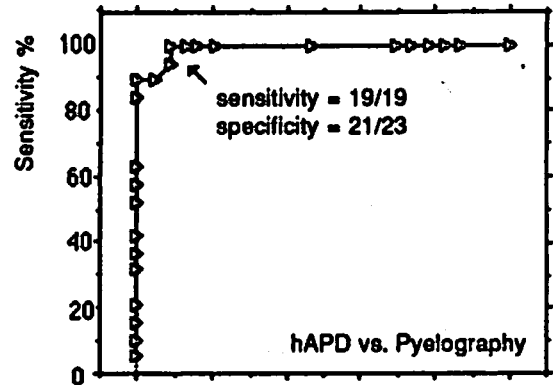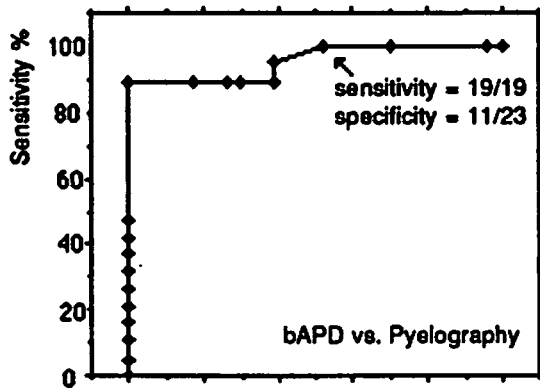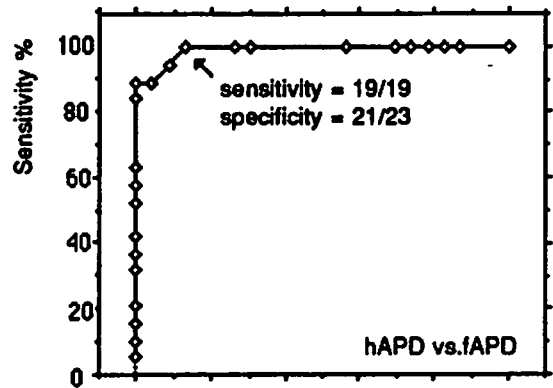
Fig. 3. ROC curves relating PUO detected by pyelography versus fAPD (b) and at bAPD (c). The cutoff points (arrows) detected in b is used to elaborate (a). The sequence of the three curves follows the diagnostic reasoning.

Fig. 4. ROC curves relating PUO detected by pyelography versus hAPD (b). The cutoff points (arrows) detected in b and in figure 3b are used to elaborate (c) and (a).
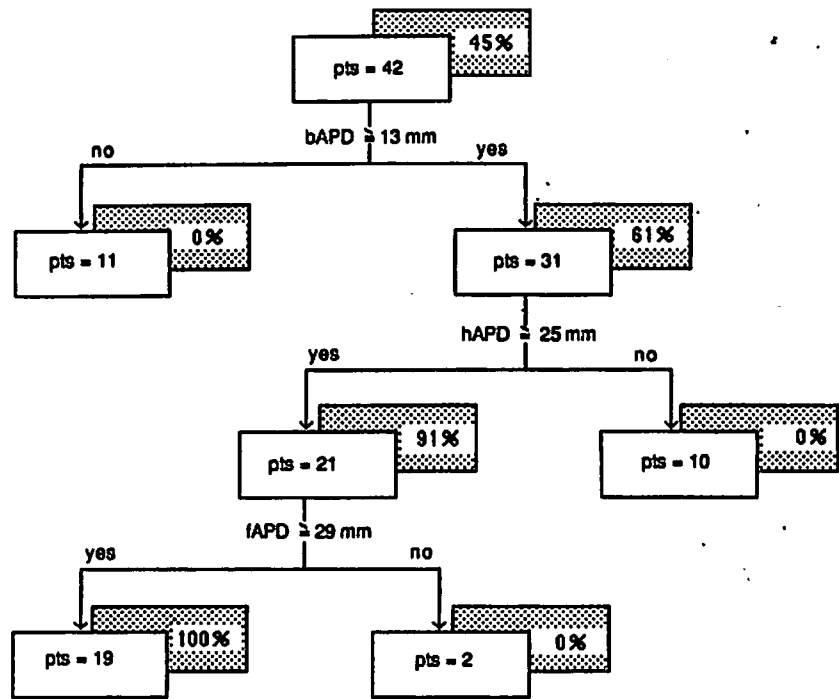
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Fig. 5. Algorithm for sonographic diagnosis of PUO using the stimulated diuresis test. For each step, shaded rectangles report the percentage of patients with PUO detected by pyelography.

Discussion

Standard intravenous urography was and still is the gold standard to assess the anatomic features of the upper urinary tract. The urographic findings of a pelvis dilation in a patient with loin pain makes necessary the decision of whether or not to perform a pyeloplasty, to prevent progressive kidney damage due to obstructive uropathy. In these circumstances, a dynamic diagnostic assessment can be helpful to distinguish between a renal pelvis atonicity and a PUO.

At a high urinary flow, an obstruction leads to an increase of intrapyelic pressure and a decrease of ureteral urine flow [1]. This physiological concept is the basis of percutaneous pressure flow studies (Whitaker's test) [2] and of the diuresis renography [3, 4]. Obstruction, when present for more than 24 h, also causes a decrease of the renal blood flow and of the glomerular filtration rate [14]. Such abnormalities, together with an increase of sodium tubular absorption, cause a slowing down of parenchymal transit, leading to the hypothesis that the measurement of the parenchymal transit time of a nuclear agent can be useful in the diagnosis of PUO [15].

The role of sonography in the diagnosis of upper urinary tract obstruction is briefly examined. The renal pelvic volume and pressure vary according to urinary flow rate and urine content of the bladder. At normal urinary flow or with an empty bladder, the upper urinary tract (calyces, renal pelvis) are in a collapsed state and, therefore, not visible through ultrasound. At high urinary flow or with a full bladder, renal pelvic pressure increases slightly, and pyeloureteral peristalsis allows an adequate urine flow [16]. In these conditions, the collecting system is outlined in the echogenic central renal complex, and the funnel-shaped renal pelvis may appear completely or partially in the renal sinus. The ureter remains in a collapsed state and is not visible with ultrasound.

Sonography can reveal moderate or severe hydronephrosis (grade 2-3) with a sensitivity of about 100% [10]. However, the sonographic evidence of pelvicalyceal dilation, under normal hydration, does not necessarily indicate the presence of an obstruction. The false-positive and false-negative sonographic rate is, respectively, 6-26 and 5-11% [11].

A further problem may be due to the lack of standard measurements enabling an objective comparison. As clearly shown by our results, APD may be considered as such. The physiological basis for the dynamic tests usually employed to detect PUO is also valid for sonography. At high urinary flow, the upper urinary tract capacity is sub-

jected to acute stress. In this condition the sonography becomes a dynamic test permitting to reveal an increase of renal pelvis APD which is compatible with PUO.

The patients studied were selected on the basis of a minimal or moderate increase of renal pelvis APD under normal urinary flow. During the test, all the patients showed an increase of APD directly proportional to bAPD so that the data can be linearly interpolated. This is in agreement with the principle that the rapid increase of urinary flow, at full bladder, facilitates the dilation of the urinary tracts. The mean variation of APD after hydration and frusemide was significantly different in both conditions ($F = 11.38$, d.f. 2,39, $p < 0.0001$, and $F = 35.39$, d.f. 2,39, $p < 0.0001$, respectively). Group 3 differed significantly from groups 1 and 2 (fig. 2). Standard i.v. pyelography showed an increase in pelvis size compatible with PUO in 2 patients from group 2 and in all patients from group 3. At the end of the test, in group 3 APD increased by 20.9 ± 5.6 mm while in group 2 and group 1 the increase, though significant, was moderate (respectively, 7.3 ± 4.6 and 7.3 ± 4.9 mm) and the APD never exceeded 30 mm.

Our results demonstrate that sonography may be a useful tool for evaluation of PUO. ROC curves clearly suggest the cutoff points in the evaluation of suspect patients. In order to draw some clinical conclusions from our study, we propose the following diagnostic algorithm, which is shown in figure 5. (1) Each patient with a bAPD equal or greater than 13 mm should undergo a dynamic test. The proportion of PUO in this subgroup rises from 0.45 to 0.61 without false negatives. (2) When hAPD is equal or greater than 25 mm, an obstruction should be highly suspected. The proportion of PUO in our subgroup rises to 0.91 with no false negatives. (3) When the fAPD is equal or greater than 29 mm, an obstruction should be considered as quite certain. In our sample the proportion of patients with PUO was 1.0 with no false negatives. In our experience, loin pain complained about during the stimulated diuresis test supports the indication for surgical correction.

Stimulated diuresis testing can give useful information in patients with loin pain and/or upper urinary tract dilation, to indicate pyeloplasty, and in patients who underwent pyeloplasty. The dynamic test may be useful in the screening of pediatric hydronephrosis. Finally the simplicity and noninvasiveness could make the test an important alternative to standard urography in pre- and post-surgical checks.

In conclusion, the urographic or sonographic findings of upper urinary tract dilation do not necessarily indicate obstruction, while pelvic APD changes after a forced diuresis test make it possible to distinguish between pelvic atonicity and PUO. At present following our results, we suggest the use of the sonographic stimulated diuresis test besides pyelography at least for the differential diagnosis of the most equivocal cases.

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