# Whitaker Test: Differentiation of Obstructive From Nonobstructive Uropathy

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**The Whitaker test, a urodynamic study, combined with antegrade pyelography has been used recently to evaluate persistent upper urinary tract dilatation after operative correction of obstruction. This test will differentiate patients with residual or recurrent obstruction from those with dilatation secondary to permanent changes in the musculature. It is useful in evaluating patients with questionable ureteropelvic or ureterovesical junction obstruction, or primary defects in the ureteral musculature, such as prune-belly syndrome. It also will establish when urinary diversion safely can be discontinued in postoperative patients.**

**Percutaneous puncture of the renal pelvis is performed or an indwelling nephrostomy tube is used. The upper urinary tract is then perfused at a constant rate of 5–10 ml/min with saline or diluted contrast media, and a serial pressure recording is made in the renal pelvis and bladder. The high flow rate used will be tolerated easily in a nonobstructed system without a progressive rise in renal pelvic pressure. In obstructed systems abnormally high pressure above 12 cm water or a constant rise in pressure will be recorded. Videotaping of ureteral peristalsis and spot films of the upper urinary tract complete the evaluation.**

The Whitaker test, a urodynamic study, combined with antegrade pyelography has been used recently to evaluate persistent upper urinary tract dilatation after operative correction of obstruction [1–3]. The principle of the test is to perfuse the upper urinary tract at a constant flow rate with saline or contrast medium in an antegrade manner while simultaneously monitoring renal pelvic and bladder pressures. This test will differentiate patients with residual or recurrent obstruction from those with dilatation secondary to permanent changes in the musculature. It also is useful in evaluating patients with questionable ureteropelvic or ureterovesical junction obstruction [4, 5] or primary defects in the ureteral musculature, such as prune-belly syndrome [2, 3]. We present the results of 17 Whitaker tests in 12 patients to illustrate the utility of this study, which has not been emphasized in the radiologic literature.

## Materials and Methods

At our institution the procedure is performed after initial sedation of the patient and catheterization of the bladder. The patient is then placed prone on our special procedures table. If a nephrostomy tube is not available, the location and depth of the renal pelvis is determined either using ultrasound, review of previous uroradiologic studies, or under direct fluoroscopic observation after intravenous injection of contrast media. Percutaneous puncture of the renal pelvis is then performed. We initially used 22 gauge Chiba needles, but now use a 14-cm-long 18 gauge needle with flexible outer radiopaque Teflon catheter (Deseret Pharmaceuticals, Salt Lake City). A smaller needle and catheter may be used for infants and small children. Urine is obtained for culture.

The nephrostomy tube, needle, or catheter within the renal pelvis and bladder catheter are connected to pressure transducers (fig. 1). After the baseline pressures have been recorded, perfusion is begun with a 50% dilution of Hypaque 50 at a flow rate of 5 ml/min in infants and small children, and 10 ml/min in older children and adults. A standard angiographic injector or infusion pump may be used for accurate delivery at specified flow rates.

Received December 20, 1978; accepted after revision August 15, 1979.

Presented at the annual meeting of the Society for Pediatric Radiology, Denver, September 1978.

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*AJR* 134:9–15, January 1980
0361–803X/80/1341–0009 $00.00

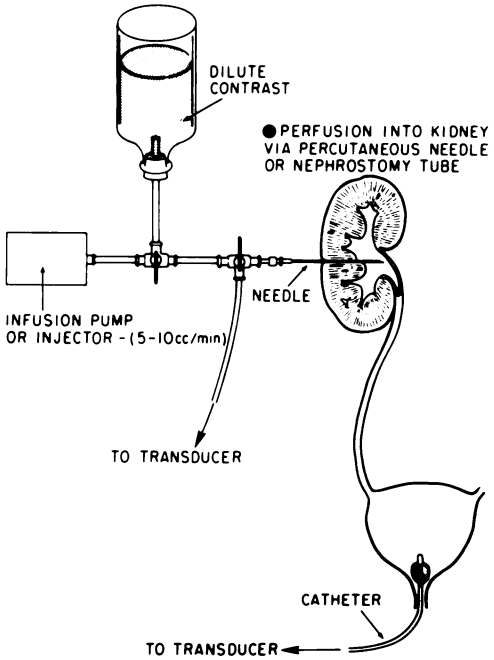



Fig. 1.—Whitaker procedure. Absolute pressure difference across ureteral orifice is obtained by subtracting bladder pressure from renal pelvic pressure, canceling out intraabdominal pressure.

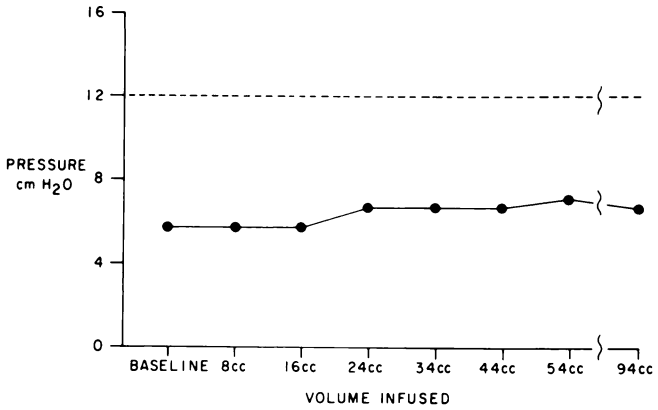



Fig. 2.—Absolute pressure difference across ureteral orifice obtained at time of Whitaker procedure in 5-year-old-boy. Baseline pressure is normal, and there is no pressure rise during infusion initially at 8 ml/min, then 10 ml/min.

This high flow rate is chosen to put maximal stress on the urinary tract system. The normal renal pelvis and ureter will tolerate this flow easily with no or only minimal rise in pressure. At this high flow rate, the contribution to the total flow produced by the kidney, about 0.25–0.5 ml/min, is insignificant.

Serial pressure measurements are made during infusion of dilute contrast material. The bladder is allowed to drain during the procedure. The catheter within it reflects intraabdominal pressure. By subtracting bladder pressure from renal pelvic pressure, the pressure difference between the two can be obtained, and cancels out the intraabdominal pressure that is otherwise a variable factor. Patency of the system is confirmed by a sharp increase in pressure when the patient is asked to cough or the abdomen is pressed. Videotaping of ureteral peristalsis and 105 mm spot films of the upper urinary tract complete the evaluation.

A pressure of less than 12 cm water across the ureteral orifice and not showing progressive rise during infusion is normal. In obstructed systems abnormally high pressures, often greater than 15–20 cm water, or a constant rise in pressure will be recorded [1–6]. Figure 2 illustrates a normal pressure tracing in a nonobstructed system. The pressure remains relatively constant within the renal pelvis during infusion.

## Case Reports

*Case 1*

A 5-year-old boy with several operative procedures for hydronephrosis noted shortly after birth was doing well on regular follow-up visits. Excretory urography (fig. 3A) revealed bilateral hydronephrosis unchanged from serial studies over the previous 6 months. Two months later, he underwent a right-to-left pyelopyelostomy with tapering of his solitary left ureter and reimplantation into the bladder. Follow-up excretory urography 2 months later revealed markedly decreased function on a comparable film when compared with the preoperative study. A Whitaker test revealed an abnormally high opening pressure, a progressive rise in renal pelvic pressure with infusion (fig. 3B), and demonstrated complete obstruction of the distal left ureter at its entrance into the bladder (fig. 3C). The catheter was left temporarily in the left renal collecting system for drainage and 2 days after the study a nephrostomy was performed.

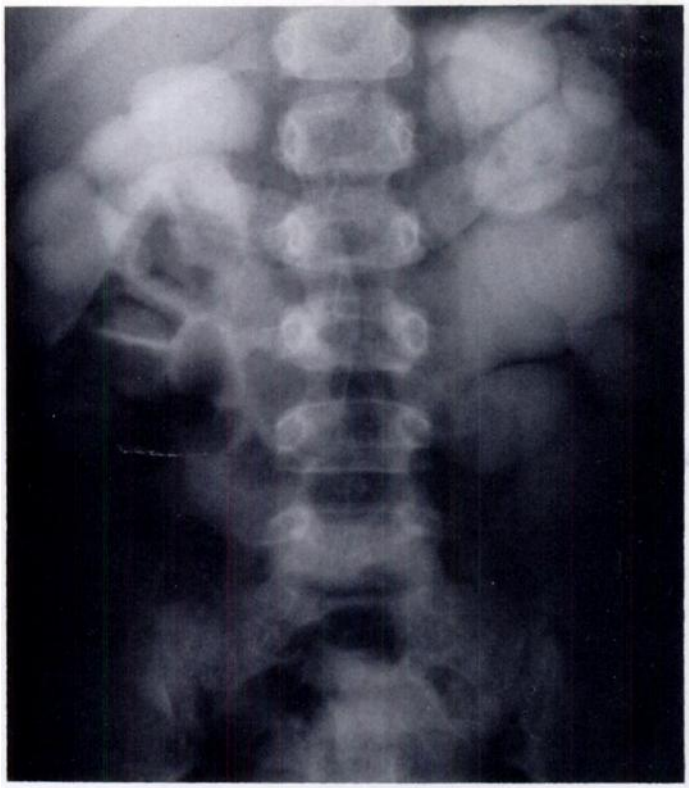
*Comment.* The abnormally high opening pressure was in itself diagnostic of obstruction. We now believe that it was not appropriate to continue the infusion to a pressure of 75 mm Hg, as the possibility of inducing pyelotubular backflow and sepsis may be high in such instances. It is recommended that the study be terminated when the renal pelvic pressure reaches 30 cm $H_2O$.

*Case 2*

A 7-year-old boy had a left-to-right ureteroureterostomy, placement of an ileal conduit connecting the proximal right ureter to the bladder with tapering of the ileum, and implantation of the ileum into the bladder with an antireflux procedure [7]. Excretory urography 3 years later (fig. 4A) revealed bilateral hydronephrosis unchanged over 8 months. Follow-up excretory urography 9 months later demonstrated increased hydronephrosis on a comparable radiograph. Retrograde pyelography demonstrated probable right ileoureteral obstruction (fig. 4B). A Whitaker procedure revealed a patent ureteroureterostomy and obstruction of the midright ileoureter (figs. 4C–4E). At operation the obstruction was confirmed with lysis of the ileoureteral adhesions and intraperitonealization of the ileoureter. Repeat Whitaker test 5 months after operation demonstrated a more normal appearance to the solitary ileoureter (fig. 5A). Figure 5B shows the pressure measurements made at the tme of both Whitaker procedures.

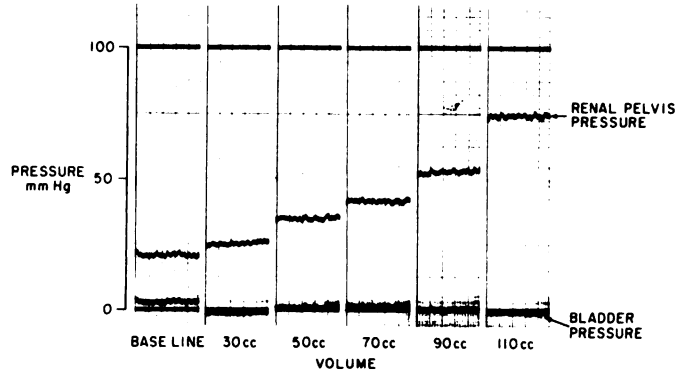
*Case 3*

An 8-year-old boy was well 4 years after bilateral ureteral reimplantation for severe reflux and hydronephrosis. Excretory urography (fig. 6A) demonstrated hydronephrosis unchanged from serial studies dating back 2 years. Follow-up excretory urography 2 years later revealed decreased concentration on a comparable film. Voiding cystourethrography showed moderately severe right reflux and minimal left reflux. Left retrograde pyelography demonstrated features suggestive of left ureteral obstruction with dilatation of the



A

C




B

Fig. 3.—Case 1, 5-year-old boy with several operative procedures for hydronephrosis. **A,** Excretory urogram. Bilateral hydronephrosis unchanged from serial studies over previous 6 months. Excretory urogram 4 months later demonstrated markedly decreased function. **B,** Unretouched pressure tracing obtained at time of Whitaker procedure. Elevated baseline pressure (22 mm Hg) and progressive rise in renal pelvic pressure during infusion at rate of 10 ml/min. (In unretouched tracings, pressure is in mm Hg; pressure in cm $H_2O$ is obtained by multiplying by 1.36.) **C,** Antegrade pyelogram. Complete obstruction of solitary distal left ureter at entrance into bladder.

proximal left ureter and more normal appearance to the distal ureter (fig. 6B). A Whitaker procedure revealed less than 5 cm $H_2O$ pressure gradient across the ureteral orifice. A spot film confirmed a widely patent left ureter (fig. 6C).

*Case 4*

A 6½-year-old boy had severe bilateral reflux documented on voiding cystography. One week later, excretory urography revealed bilateral hydronephrosis and hydroureter on a 24 hr radiograph (fig. 7A). He underwent bilateral ureteral reimplantation with bilateral ureteral tapering. Follow-up excretory urography 2½ months after operation revealed no change in his severe hydronephrosis and hydroureter but demonstrated decreased concentrating ability on a comparable 24 hr radiograph. A Whitaker procedure revealed no evidence of obstruction with less than 6 cm $H_2O$ pressure gradient across each ureteral orifice. Spot films demonstrated patent ureters (figs. 7B and 7C).

## Discussion

Our experience with the Whitaker test confirmed its usefulness in differentiating obstructive from nonobstructive uropathy. In nine patients the test was used to evaluate a change in the excretory urogram in the postoperative patient. The use of dilute contrast material resulted in an excellent antegrade pyelogram and improved visualization of hydronephrotic collecting systems and dilated ureters. Pressure measurements during infusion permitted more ac-

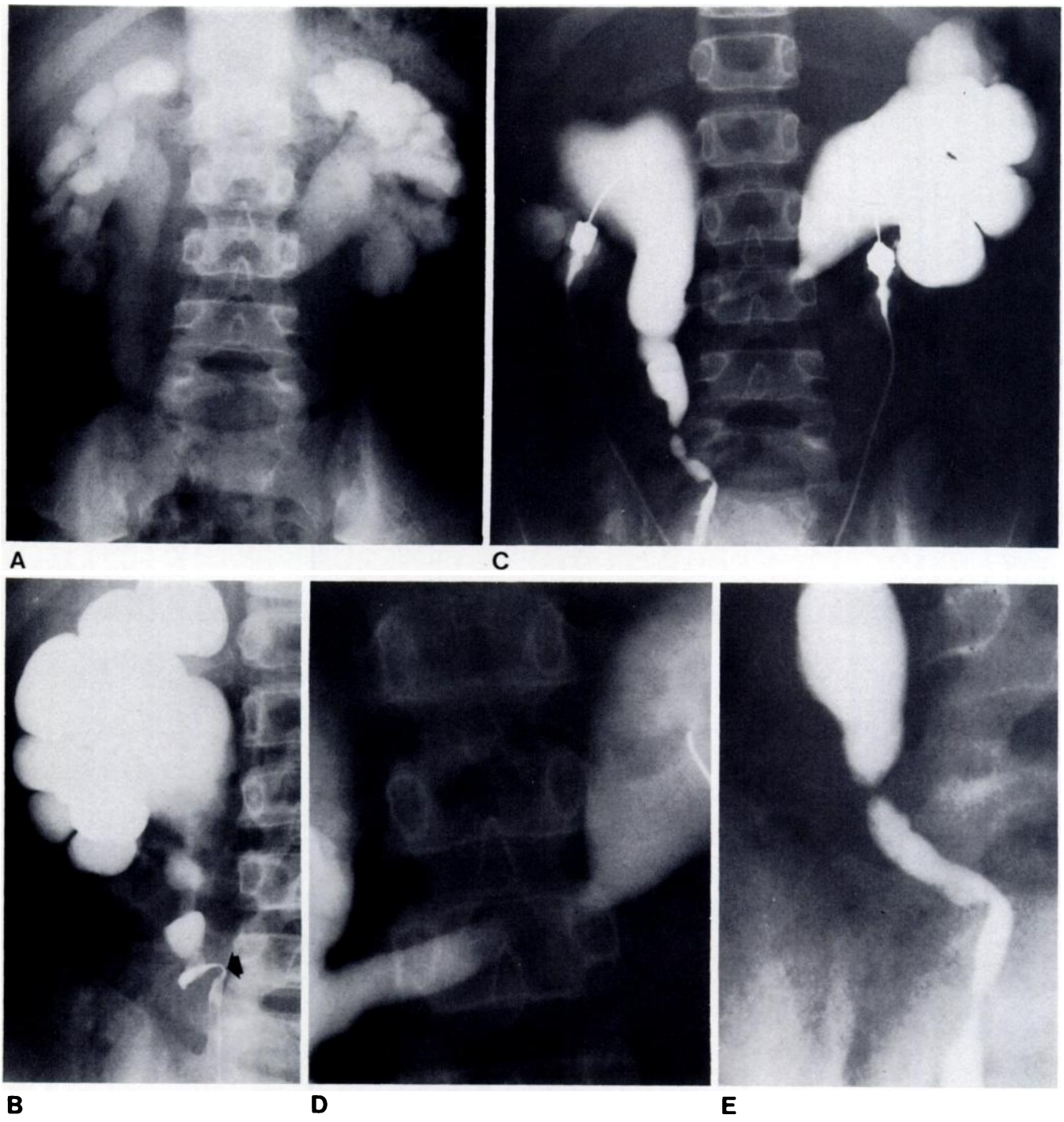
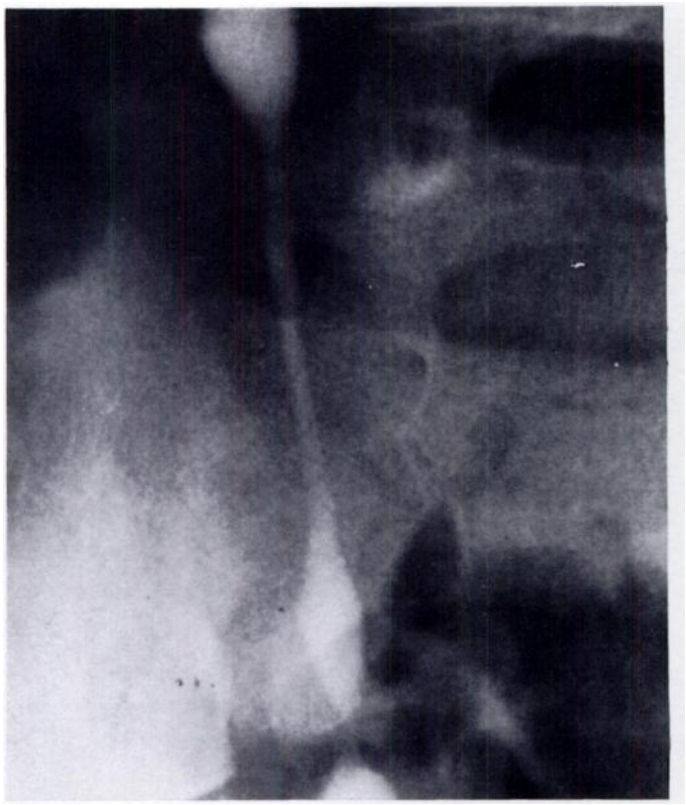



Fig. 4.—Case 2, 7-year-old boy with left-to-right ureteroureterostomy and placement of a tapered ileal conduit connecting upper urinary tracts to bladder with an antireflux procedure performed 3 years earlier. **A,** Excretory urogram. Bilateral hydronephrosis unchanged from radiographs 8 months earlier. Urogram 9 months after **A** demonstrated increased hydronephrosis. **B,** Retrograde pyelogram. Probable right ileoureteral obstruction (*arrow*). **C,** Antegrade pyelogram obtained at the time of Whitaker procedure. Chiba needles in both right and left renal pelvis. Ureteroureterostomy is patent. Right ileoureteral obstruction. **D,** Close-up of patent ureteroureterostomy. **E,** Close-up of right ileoureteral obstruction.

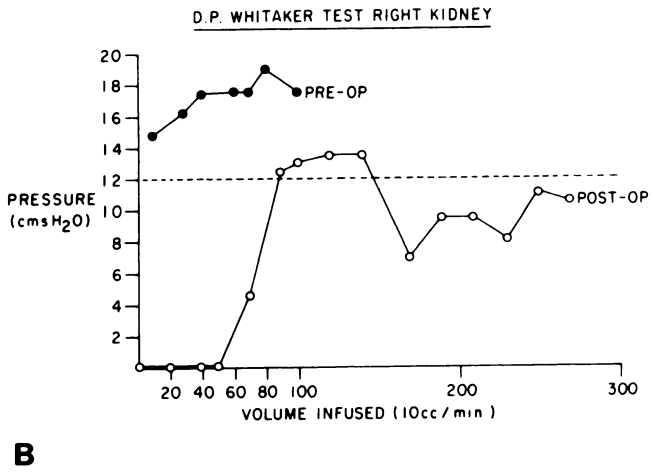
curate evaluation of stenotic ureteral segments and identified patients with postoperative ureteral dilatation secondary to defects in the ureteral musculature. In patients with nonobstructive postoperative ureteral dilatation, fluoroscopy with videotaping usually revealed impaired peristalsis [1].

In two patients, antegrade pyelography and urodynamic measurements excluded questionable ureteropelvic junction obstruction.

In another patient with recent repair of ureteropelvic junction obstruction, a Whitaker test through the indwelling

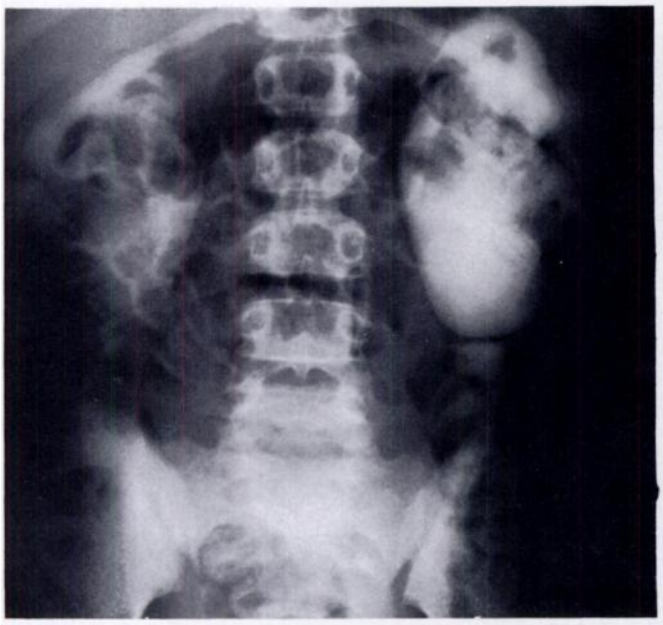


A




B

Fig. 5.—Case 2. **A,** Antegrade pyelogram 5 months after repeat operation. More normal appearance of solitary ileoureter. **B,** Absolute pressure difference across ureteral orifice. Progressive rise in pressure during infusion from obstruction of solitary ileal ureter. After reoperation, pressure tracing is normal with pressures below 12 cm $H_2O$.



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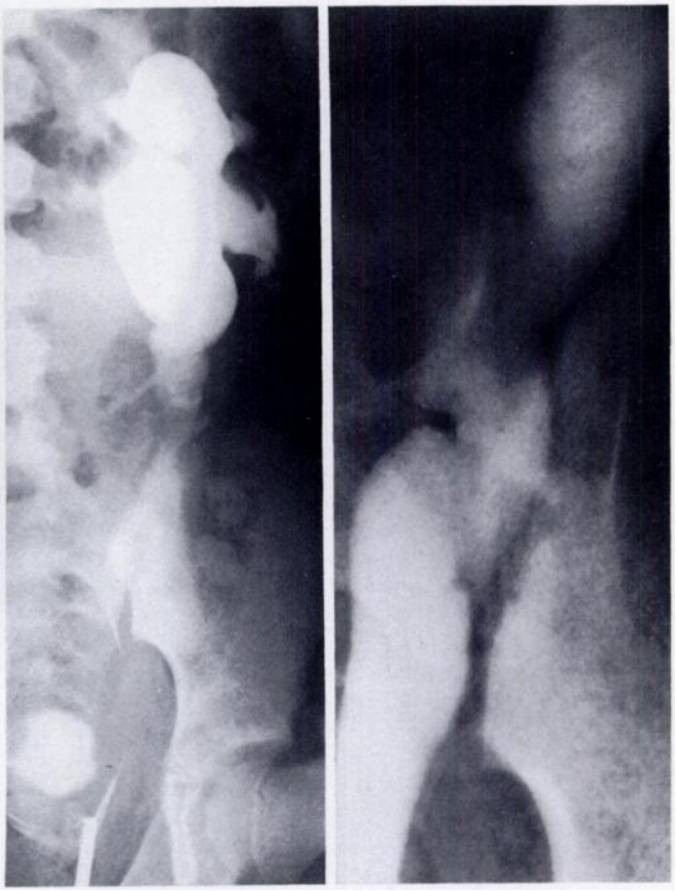
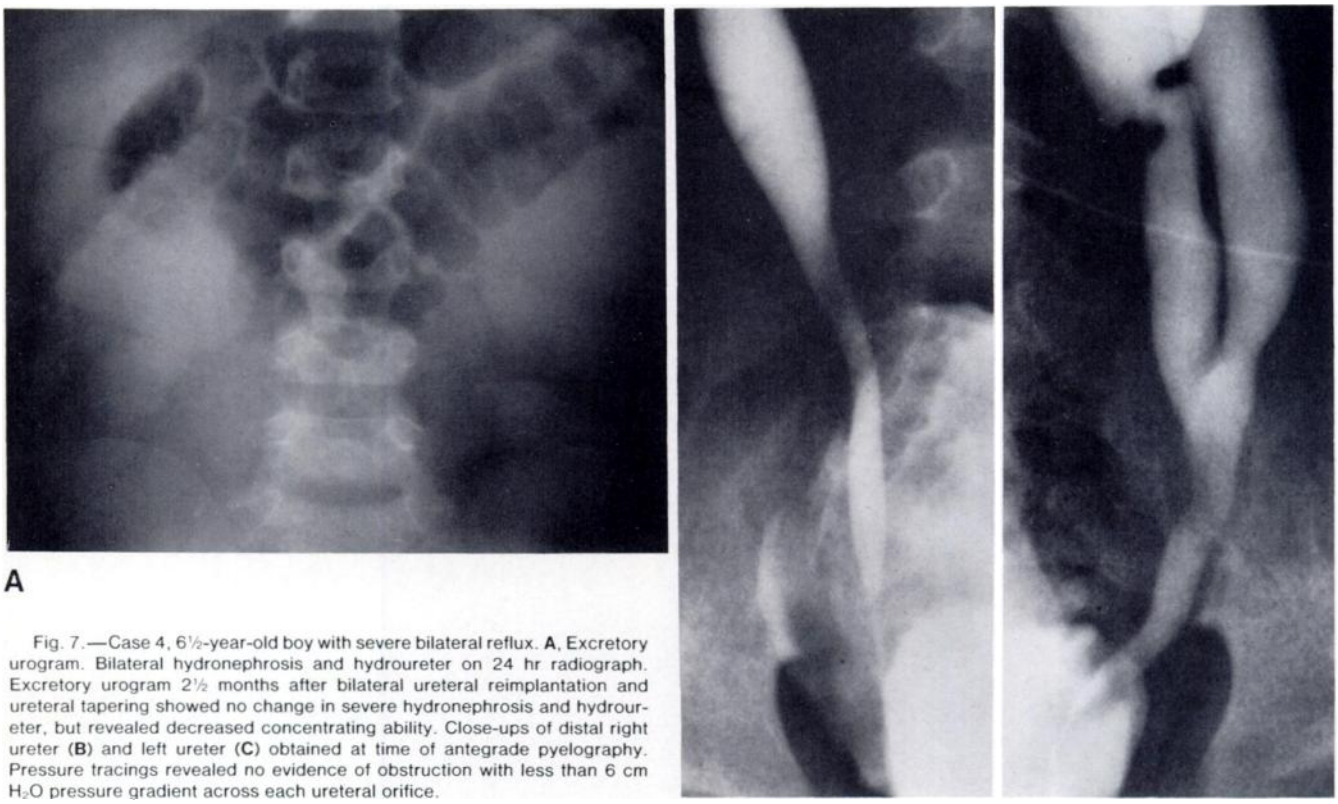


B

Fig. 6.—Case 3, 4-year-old boy, 4 years after operative bilateral ureteral reimplantation for severe reflux and hydronephrosis. **A,** Excretory urogram. Bilateral hydronephrosis unchanged from serial studies during previous 2 years. Urogram 2 years later revealed decreased concentrating ability. **B,** Left retrograde pyelogram. Features suggestive of left ureteral obstruction with dilatation of proximal left ureter and more normal appearance to distal ureter. **C,** 105 mm spot film obtained at time of antegrade pyelography. Widely patent left ureter. Less than 5 cm $H_2O$ pressure gradient across ureteral orifice.



A

B

Fig. 7.—Case 4, 6½-year-old boy with severe bilateral reflux. **A**, Excretory urogram. Bilateral hydronephrosis and hydroureter on 24 hr radiograph. Excretory urogram 2½ months after bilateral ureteral reimplantation and ureteral tapering showed no change in severe hydronephrosis and hydroureter, but revealed decreased concentrating ability. Close-ups of distal right ureter (**B**) and left ureter (**C**) obtained at time of antegrade pyelography. Pressure tracings revealed no evidence of obstruction with less than 6 cm $H_2O$ pressure gradient across each ureteral orifice.

nephrostomy tube demonstrated no evidence of obstruction and established that urinary diversion could be discontinued. In an 8-year-old boy with apparent neuromuscular disease, several excretory urograms suggested obstruction of the right collecting system when the bladder and rectum were distended. The Whitaker test performed with the bladder empty, then filled to 200 ml, confirmed this finding.

The test has also proven useful in evaluating patients with primary defects in the ureteral musculature. In Whitaker's study [2] of 15 patients with primary megaureter, some patients had a pressure drop across the ureteral orifice of less than 10 cm $H_2O$ while in others the drop was 20–30 cm $H_2O$. In other patients the ureter could not tolerate 10 ml/min at pressures less than 100 cm $H_2O$.

The test has proved useful in evaluating patients with colon loop diversion of the urinary tract. In a study of 57 patients, Yoder and Pfister [6] performed 11 antegrade pyelograms and eight urodynamic studies in nine patients and found six ureters with fixed obstruction. Pressures across the ureteral orifice in these obstructed patients were greater than 15 cm $H_2O$. In five ureters, no obstruction was present with pressures less than 10 cm $H_2O$.

On the basis of our early experience and review of the urologic literature, the Whitaker test is useful for evaluation of: (1) persisting upper urinary tract dilatation after operative correction of obstruction [1–4] (the Whitaker test can accurately differentiate patients with residual or recurrent obstruction from those with defects secondary to permanent changes in the musculature); (2) apparent obstruction at the ureteropelvic or ureterovesical junction [4, 5] (the study can accurately determine the degree of obstruction); (3) patients after recent urinary tract reconstruction or reimplantation procedures to establish when urinary diversion can safely be discontinued [8]; (4) patients with primary defects in the ureteral musculature [2, 3]; and (5) the influence of bladder volume and intravesical pressure on ureteral dynamics [8, 9].

The test is simple to perform with equipment readily available in any hospital catheterization laboratory. Water manometers may be used in place of pressure transducers and pressure measurements can be read directly [3].

Urine obtained from the renal pelvis at the time of percutaneous puncture is sent for culture. Sepsis is a potential complication [3] and identification of any organisms at the time of study may prove useful in patient management. Subcapsular or parenchymal hematoma, intraabdominal bleeding, and peripelvic urinoma are possible complications. A small peripelvic hematoma was the only complication encountered in this series.

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