MAG_3-F_0 Scintigraphy in Decision Making for Emergency Intervention in Renal Colic After Helical CT Positive for a Urolith

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Patients with renal colic are evaluated with clinical, laboratory, and imaging methods for stratification for emergency decompression, medical treatment, or discharge and follow up. The current standard practice is heavily based on unenhanced helical CT for detecting uroliths. However, the presence of a urolith does not necessarily mean that the kidney is obstructed and requires emergency decompression. In this study, technetium-mercaptoacetyltriglycine (MAG_3) diuretic scintirenography was used to detect obstruction in patients with renal colic. The contribution of this test to patient management after positive findings from helical CT was also studied. **Methods:** Diagnostic criteria were established on the basis of previous experience with 60 patients who had renal colic and had undergone radiography of the kidneys, ureters, and urinary bladder (KUB) and diuretic Tc-MAG_3 scintirenography and were followed up to correlate scintigraphic findings with clinical outcome. Subsequently, 80 patients with renal colic underwent scintigraphy within 12 h of presentation in the emergency room, after abdominal helical CT showed findings positive for calculus and suggestive of obstruction. After therapeutic oral or intravenous hydration and analgesics, diuretic dynamic renal scintigraphy (flow, function, delayed imaging) was performed after intravenous injections of 10 mCi (370 MBq) ^{99m}Tc-MAG_3 and 40 mg furosemide (at zero time, or F_0). Results were available soon after completion of the study and were considered in patient management. Four characteristic patterns of scintirenography, essential in patient stratification and treatment, had been standardized and were used for interpretation of the studies: the unobstructed kidney; the partially obstructed kidney, proximally or distally obstructed, with mild to severe obstruction and impairment of function; the totally obstructed kidney, with arrested renal function; and the unobstructed but dysfunctioning kidney after decompression, or stunned kidney. **Results:** Among the 80 patients with positive helical CT findings, 56.5% were found to have obstruction by scintigraphy (32.5% partially, 24% completely); the remaining 43.5% did not have obstruction (21% without an indication of recent obstruction and 22.5% with stunned kidneys after spontaneous decompression). Occasionally, findings of preexistent urine extravasation or infection were present. Patients who, by scintigraphy, never had obstruction or had experienced spontaneous decompression did not require admission or emergency intervention; those with complete or severe obstruction required admission and decompression for relief of pain or restoration of function, whereas those with mild obstruction were treated variably with forced fluids, analgesics, or, less frequently, elective surgery. Outcome information from clinical examination, imaging, and interventional findings indicated that this stratification was successful. The test caused no side effects. **Conclusion:** For renal colic, clinical selection, KUB radiography, and even positive helical CT findings were all found to have a low positive predictive value for obstruction (in this study, 35%, 32%, and 56% respectively). Anatomic studies, including helical CT, should be followed by diuretic MAG_3-F_0 scintirenography to diagnose and quantify or exclude obstruction, detect spontaneous decompression, and appropriately stratify patients for emergency intervention, observation and medical therapy, or further work-up and discharge with referral to the clinic.

Key Words: mercaptoacetyltriglycine; renal colic; stone disease; helical CT; obstruction; postdecompression; kidneys, ureters, and bladder

J Nucl Med 2000; 41:1813–1822

Patients presenting in the emergency room with a clinical and laboratory picture suggestive of renal colic (acute flank pain radiating toward the genitals and hematuria) need diagnostic proof of a urolith and confirmation that, by obstructing the drainage system, it is indeed causing the pain. If conservative treatment, such as analgesics and forced diuresis, is not effective and significant obstruction persists, hospital admission and emergency intervention under general anesthesia are required to prevent renal damage by decompressing the kidney or removing the stone. For small stones causing a mild obstruction, vigorous hydration usually results in palliation of pain and spontaneous passage of the stone; otherwise, elective decompression may be needed. When the kidney is not obstructed or spontaneously decompresses, the patient is referred to the clinic (*1*). However, not infrequently, acute flank pain may not be caused by ureteral obstruction, even in the presence of a calculus (*1*). In addition, pain may stop with or without relief of the obstruction, or, while some symptoms persist,

Received Oct. 12, 1999; revision accepted May 16, 2000.

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obstruction may resolve spontaneously after passage or change of position of the calculus.

In patients whose clinical presentation suggests renal colic, radiographic methods, sonography, and, more recently, unenhanced helical CT have been used to detect uroliths or related findings (*2,3*). Traditionally, abdominal radiography of the kidneys, ureters, and urinary bladder (KUB) followed by intravenous urography (IVU), performed on an emergency basis without patient preparation, has provided anatomic and functional information on the presence of a calculus and obstruction (*2*). However, radiographic contrast studies are contraindicated in some patients because of renal insufficiency or hypersensitivity, and on many occasions, IVU may not be diagnostic of a calculus or an obstruction. In those cases, renal scintigraphy may be used to obtain reliable functional information (*1,4*). Helical CT has reportedly been more sensitive than KUB and IVU in detecting uroliths and obstruction (*3*). Findings such as a calculus at the site of symptoms and hydronephrosis, hydroureter, perinephric fat stranding, relative renal enlargement, or a perinephric fluid collection cause helical CT to be positive for renal obstruction (*3*). However, as for KUB and IVU, helical CT findings of a stone or related abnormalities may not necessarily indicate the existence of obstruction or its severity. The positive predictive value of positive helical CT findings for obstruction is not certain.

Diuretic renal scintigraphy, although indicated for the study of congenital or chronic renal obstruction, has not been used systematically for the evaluation of patients with colic (*5*). Reported studies have compared scintigraphy with IVU favorably (*6,7*). However, most of the studies were performed with ^{99m}Tc-diethylenetriaminepentaacetic acid, a glomerular imaging agent with a 20% renal extraction rate. In addition, the literature does not describe the scintigraphic signs of a decompressed kidney after the passage or dislodgment of a stone. The renal imaging agent ^{99m}Tc-mercaptoacetyltriglycine (MAG_3) (Mertiatide, Mallinckrodt, Inc., St. Louis, MO) is considered optimal for revealing obstructions (*5*) because of both the physical properties of ^{99m}Tc and the tubular excretion biologic properties of the carrier molecule. For Mertiatide, the kidney exhibits an extraction rate of 40%–60%, and up to 70% of the dose is excreted in the urine within 30 min of injection in the normal state.

At our nuclear medicine laboratory, MAG_3 imaging with simultaneous injection of furosemide (MAG_3-F_0) (*8*) has been used selectively in patients with renal colic to seek evidence of obstruction and its effect on renal function. Encouraging preliminary results prompted the clinical use of MAG_3-F_0 imaging for stratification of 2 groups of patients with renal colic, the first before and the second after the introduction of helical CT.

The purpose of this article is to present the diagnostic patterns observed with diuretic MAG_3-F_0 imaging in patients with a clinical diagnosis of renal colic, to correlate the patterns with clinical outcome and helical CT findings, and to describe the contribution of scintigraphy in stratification for emergency intervention, observation, or discharge.

MATERIALS AND METHODS

Before the introduction of helical CT, a total of 60 patients (38 males, 22 females; age range, 30–73 y; median age ± SD, 45 ± 6 y) with acute pain clinically considered to be renal colic underwent diuretic MAG_3-F_0 imaging so that obstruction could be diagnosed or excluded (*9*). The studies were performed within 1–8 h of the patients' presentation in the emergency room or clinic. All patients underwent KUB radiography, and in 31 the findings suggested urolithiasis. Many patients had specific contraindications to contrast injection, such as a history of allergy to iodine contrast material or elevated levels of serum creatinine (>2 mg/dL) (*9*). In this group of patients, 4 patterns of scintigraphic results were identified (Table 1). Outcome data were compiled from 1 mo to 1 y after the acute episode and focused on the clinical history at the time of the colic, other imaging findings, decompression findings, and follow-up for verification of the scintigraphic findings. In this group of patients, the effort was to verify the patterns of scintigraphy (Table 2). Normal findings were verified by patient observation only, with pursuit of the cause of pain and long-term follow-up. Abnormal studies of the stunned pattern after decompression were verified by the presence of passed stones in the urine or dislodged stones in the ureters or bladder and by follow-up scintirenography for some patients. Diagnoses of obstruction were verified during intervention for removal of calculi and, sometimes, through follow-up studies indicating a return to normal (*9*).

TABLE 1
MAG_3-F_0 Patterns in Renal Colic

		Parenchymal function		Drainage system				
Diagnostic pattern	Blood flow	Accumulation	Discharge	Visible	Intensity	Drained	Stasis	Renogram
No obstruction	Normal*	Normal*	Normal*	Yes	Normal	Yes	No	Normal*
Partial obstruction	Decreased (moderate)	Reduced (moderate)	Delayed	Yes	High	Partial†	Yes	P/D/R
Complete obstruction	Decreased (severe)	Reduced (severe)	Rising	No	None	No	No	R
Stunned kidney	Decreased (variable)	Reduced (variable)	Delayed	Yes‡	Low	Yes	No	R/P/D

*If function of kidney was normal, results were normal. Otherwise, results were reduced or delayed.
†If partial obstruction was very severe, drainage was seen late (1–2 h).
‡In stunned kidney, drainage system may be faint and need enhancement.
P = plateauing graph; D = late peaking and declining renogram; R = continuous rising renogram up to 22 min.

TABLE 2
Results of MAG_3-F_0 and Outcome in 60 Patients with Clinical Diagnosis of Renal Colic and KUB

Scintirenographic findings		No intervention needed	Spontaneous resolution of obstruction	Intervention/decompression
No obstruction				
Positive KUB findings	16*	11		5†
Negative KUB findings	15‡	15		0
Partial obstruction§	11		5	6‖
Complete obstruction§	10¶		1	8#
Stunned kidney§,**	8		8††	0
Total	60	26	14	19

*Discharged and evaluated as outpatients.
†Elective decompression to remove Staghorn calculi.
‡Lack of obstruction, and alternative diagnosis was reached (infection, injury, gynecologic, gallbladder).
§Five in each category were positive for stones on KUB.
‖Elective decompression for large stones.
¶One patient left against medical advice.
#Emergency decompression.
**Patients either found stones in urine or follow-up studies over 6 days showed gradual resolution of cortical dysfunction.
††Decompression occurred before scintigraphy.
Clinical diagnosis of renal colic had positive predictive value of 35%. KUB had sensitivity of 48%, specificity of 46%, negative predictive value of 48%, and positive predictive value of 32%.

After the introduction of helical CT, 80 patients (51 males, 29 females; age range, 12–73 y; median age, 44.5 y) with acute flank pain and screening helical CT findings suggestive of renal stone obstruction (based on the criteria already described (*3*)) underwent MAG_3-F_0 imaging 1.5–12 h after helical CT. Referral for scintigraphy occurred when emergency room physicians consulted with the urology team and decided that information about the presence and severity of obstruction was needed. Selection of patients for this test was random and based on the previous experience of the emergency room or urology team. The results were used for decision making and influenced patient care (*10*).

Scintirenography was performed using a gamma camera with a large field of view and a low-energy high-efficiency collimator, in upright (if possible) or supine posterior projection. The patients were already hydrated and medicated with analgesics, as part of an effort to promote passage of a stone. ^{99m}Tc-MAG_3, in a dose of 10 mCi (370 MBq), was injected intravenously and followed immediately (at zero time, or F_0) by 40 mg intravenous furosemide (Lasix; Aventis Pharmaceuticals Inc., Parsippany, NJ). If the creatinine level was greater than 2 mg/dL, 80 mg were administered. The furosemide was given to promote diuresis and empty the unobstructed drainage system even when cortical dysfunction was present. The study was recorded as a dynamic 1-min flow (1 frame/sec) and a 22-min function-drainage phase (1 frame/30 s) and was concluded with a 2-min static image after the patient voided or stood up. If the cortex or the collecting system was not empty at 25 min or was not adequately visualized during this study, a delayed (1- to 2-h) 2-min static image was also acquired (*8*).

Data were grouped into 3-s images for review of the flow and into 2-min images for review of the function-drainage phase. The computer program incorporated the flow data into the first function-drainage image, which was thus descriptive of the 2-min parenchymal phase (before visualization of the drainage system in normal kidneys). The 2 frames at 1–2 min (30 s each) were grouped and used to calculate the split renal function. Renograms were generated for the cortex and the entire kidney, including the pelvis, using the original data (30-s frames). Semiquantitative analysis included the peak time, the time to one half of peak activity ($T_{1/2}$), and the residual activity at 20 min (percentage of counts at 20 min/counts at peak).

The scintigraphic data were reviewed by 2 experienced nuclear medicine physicians working together. They were told that the patient had renal colic and a helical CT scan positive for stones, and they were told the side of the abnormality. The grouped images were initially evaluated visually using a computer monitor and display software that allowed reduction of background or enhancement of low counts by adjustment of the intensity scale. Subsequently, the renograms were reviewed for their shape, and semiquantitative data were then considered.

Criteria for the final scintigraphic diagnosis were based on absolute kidney visualization, visualization relative to the contralateral kidney, time-related changes in the intensity of renal flow (3-s images), parenchymal activity (2-min images and split renal function), the drainage system, and renography findings (Table 1). The final scintigraphic diagnosis was also based on the 4 distinct diagnostic patterns (Table 1): no obstruction; partial obstruction; total obstruction; and dysfunction after decompression, or the stunned pattern, the last indicating recent passage of a calculus or a dislodged calculus. These 4 diagnostic patterns with MAG_3 and simultaneous injection of furosemide showed differences in 1 or more of the flow, parenchymal, and drainage system criteria.

No-Obstruction Pattern

In kidneys with good function, the no-obstruction pattern (Fig. 1) is characterized by normal flow and function (visually or by split renal function) in proportion to the size of the renal parenchyma. Filling and emptying of the cortex are timely. Visualization of the pelvis and ureters is faint and not persistent; they may become temporarily visible with activity (4–10 min) but later empty (10–20 min). Renograms are sharp and exponential, peaking at 3 min and dropping rapidly ($T_{1/2} < 15$ min from injection), and residual activity is less than 20% of peak activity (*8*).

When overall function is reduced, as in cases of renal insufficiency, flow and function are delayed and reduced, the cortex fills and empties more slowly, and the renograms may be flat. The intrarenal drainage system is visible, larger, and, at times, more pronounced than in normal kidneys, but no retention or stasis is present (Fig. 2A, left kidney) and the 2 kidneys appear similar. In cases of renal insufficiency and failure, especially in patients with a preexistent dilated collecting system or with a single functioning kidney, urine activity seen in the collecting system late because of diminished cortical function is sometimes difficult to differentiate from that caused by low-grade obstruction. The best criterion for obstruction is persistent activity in the intrarenal drainage system that is substantially more intense than the activity in the renal parenchyma.

Partial-Obstruction Pattern

This pattern (Fig. 2) is characterized by a mild to moderate ipsilateral relative decrease in flow and function, with consideration given to the size of the kidneys. Filling of the cortex is slow,

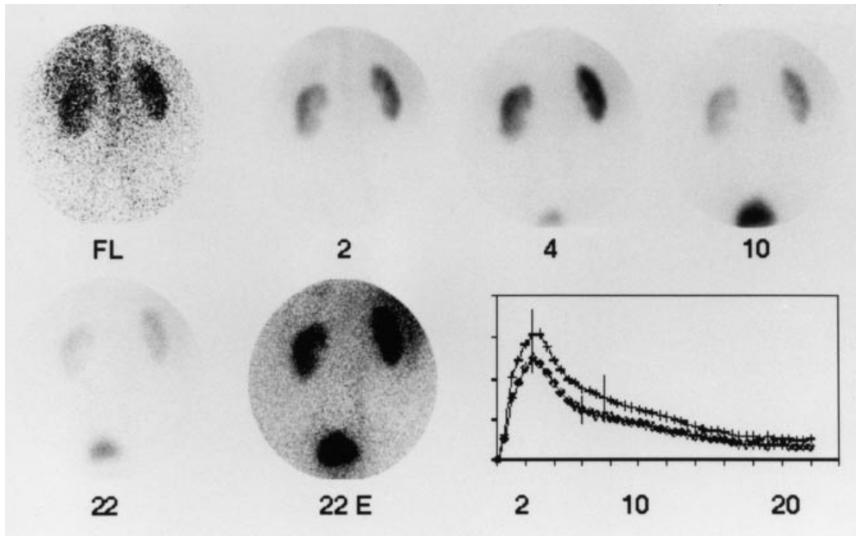

FIGURE 1. No obstruction, selected images, posterior views. Numbers indicate minutes after injection when 2-min images were obtained and also time points on renogram. E = intensity-enhanced image; FL = first-pass flow (3-s image).

and then the cortex (parenchyma) is persistently active. Filling of the drainage system is delayed and slow, and the drainage system empties partially and shows a persistent prominence substantially more intense than the parenchymal activity (stasis). In proximal obstruction (ureteropelvic junction) (Fig. 2A), stasis is observed within the pelvis alone. In more distal obstruction (along the ureter, usually at the ureterovesical junction) (Fig. 2B), stasis is observed in a portion of the ureter in addition to within the pelvis. This

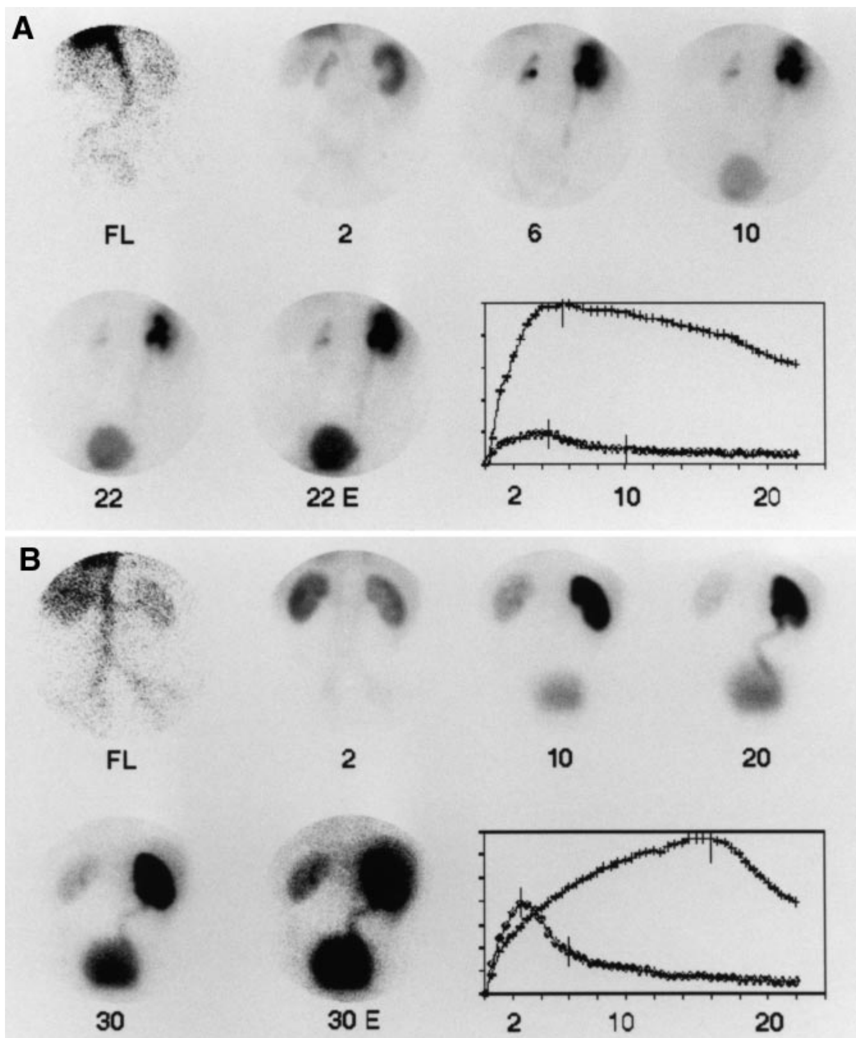

FIGURE 2. (A) Partial obstruction, proximal (ureteropelvic junction), moderate. Hydronephrosis (2 min), late filling, and then retention (stasis) are seen within pelvis of right kidney (6–22). Ureter is seen intermittently without stasis. Cortical retention is mild. Left kidney is small and hypofunctioning (atrophic) but drains normally despite some activity that is more prominent than usual activity in pelvis. Because of size discrepancy, abnormalities in relative flow and function of kidneys cannot easily be seen. (B) Partial obstruction, distal (ureterovesical junction), severe. Decreased flow and function of right kidney and cortical retention of activity are evident. Delayed (20 min) and persistent high-intensity activity (stasis) is seen in pelvis and ureter. E = intensity-enhanced image; FL = first-pass flow (3-s image).

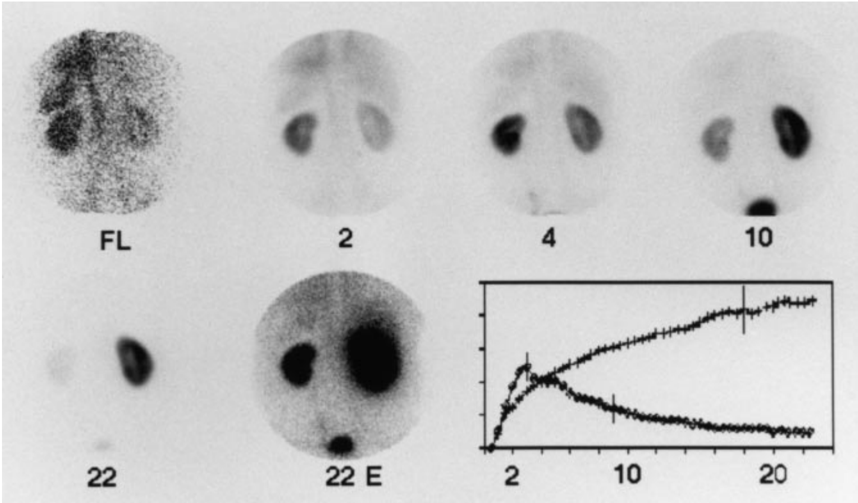

FIGURE 3. Acute, total obstruction. Severe impairment of flow and function in right kidney, persistent cortical nephrogram, no visualization of drainage system even after enhancement (22E), and rising renogram are seen. Nonvisualization of right ureter even after enhancement (22E) is critical in differentiating total obstruction from stunned kidney (Fig. 4). E = intensity-enhanced image; FL = first-pass flow (3-s image).

retention of activity continues until the point of obstruction, distal to which the drainage is normal, that is, not persistent but faint and intermittent visualization. Renograms are slow to peak (>3 min) and to fall ($T_{1/2} > 15$ min), and the residual activity is increased. In partial obstruction, the renal parenchyma shows slow filling and emptying and cortical renograms show retention. To determine the level of obstruction accurately, delayed images obtained at 1–2 h or later are often necessary.

Total-Obstruction Pattern

The pattern of total or complete obstruction (Fig. 3) is characterized by a severe ipsilateral decrease in renal blood flow and function, continuous slow accretion and retention of activity by the renal parenchyma (persistent and intensifying cortical nephrogram), and no visualization of the intra- or extrarenal drainage system, even after computer enhancement. In patients with pyelectasis from previous episodes or with long-standing complete obstruction, a central photopenic area associated with thinned parenchyma may be present. Renograms rise continuously when the obstruction is acute. They become flat and the kidney undergoes atrophy in the chronic state. The level of obstruction cannot be determined on the basis of scintigraphic findings, because the collecting system is not visualized. Delayed images serve to confirm the nonvisualization of the drainage system. Because very late images are not acquired, such a pattern is considered diagnostic of either total or nearly total obstruction.

Dysfunction After Decompression, or Stunned-Kidney Pattern

This pattern (Fig. 4) has been recognized at our center (*9*). It is caused by cortical or parenchymal dysfunction remaining after passage or dislodgment of a stone (stunned kidney). The pattern is characterized by a variable ipsilateral decrease in renal flow and function, relatively severe retention of cortical (parenchymal) activity (persistent cortical nephrogram), and, normal drainage (without retention) of usually faintly radioactive (dilute) urine. Such urine activity in the pelvis is not always visible because of the highly active parenchyma; however, the ureter is visualized, and this is the main feature distinguishing this pattern from complete obstruction (Fig. 4). The ureter is often only faintly visible, frequently intermittently, and computer enhancement of the images is required for visualization. The shape of the renogram varies but reflects only cortical or parenchymal abnormality. Immediately after the passage of a stone, flow and function are markedly

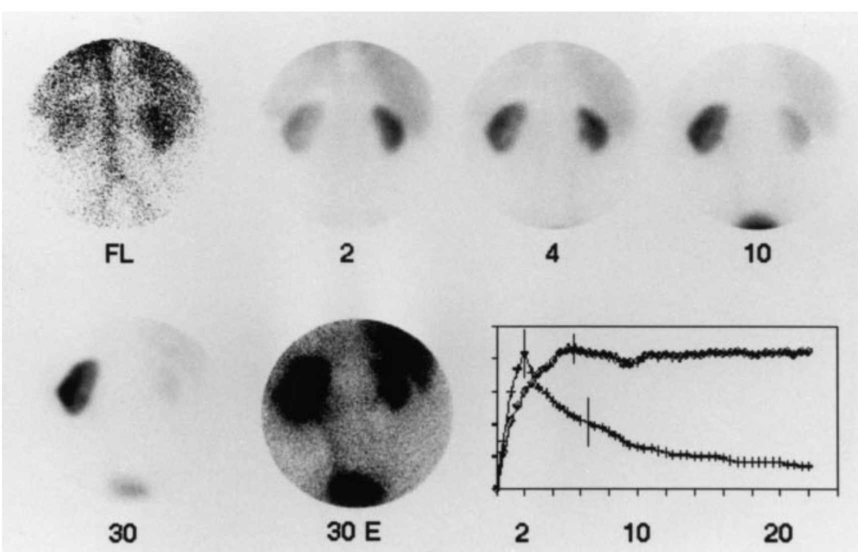

FIGURE 4. Dysfunctioning kidney after decompression, or stunned kidney, is seen on left, a few hours after passage of calculus. Flow and function are decreased (2 min). Cortical nephrogram is persistent, and drainage system is visualized (10 min) and empties normally (without retention, 30 min). Ureter is visible after enhancement. Renogram is plateauing. In more recent decompression (after minutes), flow and function may be more severely reduced and renogram may even be rising, but still, ureter is visible after enhancement, thus separating stunned kidney from total obstruction (Fig. 3). E = intensity-enhanced image; FL = first-pass flow (3-s image).

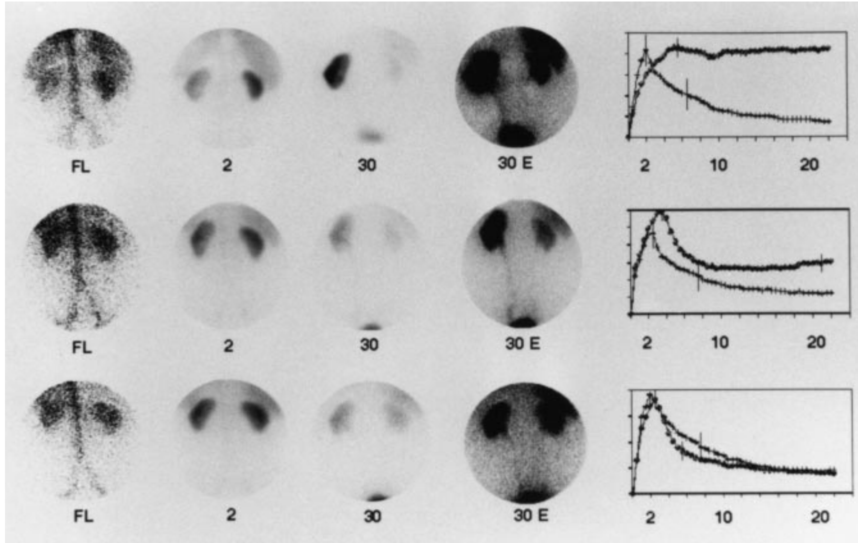

FIGURE 5. Recovery of stunned kidney in same patient as in Figure 4. First row shows recent decompression (few hours). Second row was obtained at 48 h. Third row was obtained at 6 d. Left cortex retains activity (30 min), drainage system appears normal, and gradual return to normal is seen with recovery of flow and function (2 min) and normalization of renogram. E = intensity-enhanced image; FL = first-pass flow (3-s image).

reduced and the renogram may even rise; however, over time (days sometimes), normal kidney function returns (Fig. 5). Delayed images help confirm the faint visualization of the ureter.

The results of the masked reading were compared with the original interpretation at the time of imaging. They were also correlated with the helical CT findings for stone size, location, and other characteristics and with the time elapsed between the 2 imaging studies.

RESULTS

Among the 80 patients with helical CT findings positive for calculus, 35, or 43.5%, had no evidence of renal obstruction at the time of MAG_3-F_0 and 45, or 56.5%, had complete or partial obstruction. More precisely, 17 patients, or 21%, had an unobstructed pattern, and follow-up disclosed that obstruction was not present, although calculi were diagnosed. All but 1 of these patients did not need or undergo emergency decompression and either were treated medically (analgesics, forced fluids, antibiotics) or underwent elective removal of the stone (Table 3). In addition, findings characteristic of parenchymal dysfunction and a normal drainage pattern, also known as the stunned kidney, were seen during the review session for 18 (22.5%) of the 80 patients with positive helical CT findings; of these, 16 received an appropriate diagnosis at the time of study completion. Of the 16 patients, 15 were discharged without intervention; the other patient had persistent pain. Recurrence of colic and obstruction, requiring emergency intervention, occurred in 3 of these patients days to weeks later. Two of the 18 studies showing stunned kidneys were originally misinterpreted as showing complete obstruction, resulting in unnecessary emergency decompression. These were the only studies for which the 2 readings disagreed.

Among the 80 patients with positive findings on helical CT, 26 (32.5%) were found to have partial obstruction, either proximal (16 patients) or distal (10 patients), with varying severity. Identifying the exact site of partial obstruction was difficult; if the ureter was not dilated and was severely obstructed, the images did not always reveal the level of distal obstruction. Review of the results of helical CT helped clarify questionable cases. The results of other imaging modalities and the findings during interventions and follow-up supported the diagnosis. Some patients with severe obstruction needed emergency intervention. Others, with mild obstruction, were treated medically and released to clinical follow-up or underwent elective decompression (Table 3). In addition, 19 (24%) of the 80 patients total were stratified into the complete-obstruction group by scintigraphy (Table 3). The level of obstruction could be determined

TABLE 3
Results of MAG_3-F_0 Scintigraphy and Outcome in 80 Patients with Abnormal H-CT

Scintirenographic findings		No intervention	Intervention/ decompression: Emergency	Intervention/ decompression: Elective or delayed
No obstruction	17	13	1*	3†
Partial obstruction	26	11‡	10	5
Complete obstruction	19	4§	15	0
Stunned kidney	18	14	3‖	1‡
Total	80	42	29	9

*One patient who had intractable pain needed intervention.
†One patient was treated because of new colic with obstruction; 2 patients were treated to relieve stone complicating pyelonephritis.
‡One patient in each category had recurrent pain 2 days later.
§One of 2 HIV-positive patients on indinavir sulfate, who had nonradioopaque stones, and 2 other patients with 2- and 3-mm stones at ureteropelvic junction were relieved after vigorous hydration; 1 patient left against medical advice.
‖Condition of 2 patients was incorrectly interpreted by on-call nuclear physician as complete obstruction, and 1 patient had intractable severe pain.
Positive predictive value of helical CT for obstruction was 56% (based on results of scintigraphy).

by KUB, IVU, or helical CT or during intervention. The determination of complete obstruction was useful to clinical management, because 15 of the 19 patients underwent emergency intervention. Some patients with small stones in the ureterovesical junction passed the stones through overhydration, and 2 left against medical advice. The scintigraphic findings of total obstruction correlated with severe obstruction in 100% of the cases for which intervention occurred.

Most patients had some decrease in renal function, but the scintigraphic criteria were applicable. No patients with renal failure were studied in this group. All patients had unilateral colic at the time of the study, although some previously had contralateral or ipsilateral colic from bilateral stones (Fig. 6).

Delayed images obtained according to the protocol for most patients with abnormal results were helpful in confirming the impression of the dynamic and postvoiding part of the study, especially in the case of the stunned kidney.

In general, 35 (43.5%) of the 80 patients with clinical renal colic and positive helical CT findings had no obstruction associated with the current episode of pain (no-obstruction or stunned kidney, Table 3). Thus, in this group of patients and for this study, when scintigraphy was considered the gold standard for diagnosis of obstruction, the positive predictive value, which equals true positive/(true positive + false-positive), was 56% for helical CT in showing obstruction. This value, as expected, was higher than that for KUB (32%) or for the clinical diagnosis of colic (35%) in the first group of 60 patients (Table 2). The data did not allow calculation of the sensitivity, specificity, or negative predictive value of helical CT in the diagnosis of obstruction.

Finally, all 4 scintigraphic patterns were present regardless of the passage of time from the clinical and helical CT evaluations, although a longer time favored obstruction. No strong association between obstruction and other helical CT criteria was noticed, although the stones tended to be smaller in cases of complete obstruction (ureter) and in spontaneously decompressed kidneys.

DISCUSSION

The advent of unenhanced helical CT demands that urologists and other clinical decision makers embrace a new perspective on how patients with urinary lithiasis should be evaluated. Unenhanced helical CT offers excellent anatomic information, better than that from KUB or IVU, for detecting uroliths and related renal parenchyma and drainage system anatomy (*11–13*). Unfortunately, and as the data presented above also indicate, the technique does not offer sufficient information about renal function, particularly the existence and degree of obstruction. Unquestionably, pain relief and patient comfort are therapeutic goals, but the issue of obstruction is of considerable importance because physiologic and immunohistochemical studies indicate that significant renal changes consistent with parenchymal damage may occur when a renal unit experiences prolonged partial or complete obstruction (Fig. 6) (*14–23*). However, helical

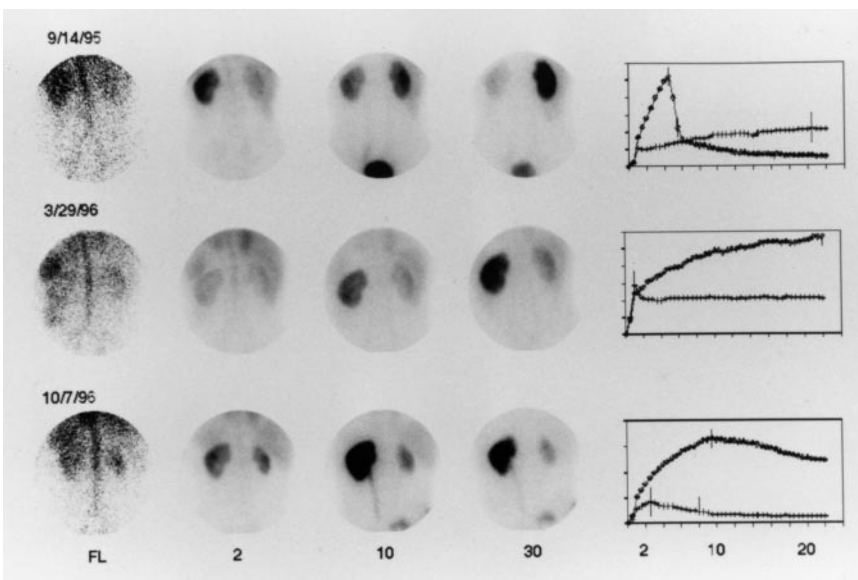

FIGURE 6. Chronic effects of obstruction on renal function and anatomy shown by 3 studies from same patient. On 9/14/95, right kidney was totally obstructed for several days, resulting in hydronephrosis and decreased flow and function. Left kidney had good function and drainage. Patient did not accept decompression. On 3/29/96, right kidney was still totally obstructed and barely functioning, whereas left kidney was acutely and completely obstructed. Patient was anuric. Bilateral decompression followed this study. On 10/7/96, patient had new left colic from stone, which induced left partial distal obstruction; left kidney had recovered much of its function since 3/29/96 because of decompression soon after obstruction. Right kidney had undergone atrophy because of persistent obstruction from 9/14/95 until 3/29/96, but drainage was normal. Studies were obtained after administration of 10 mCi MAG_3 and 40 mg furosemide. Selected pictures, from left to right, show flow study; images at 2 min, 10 min, and 30 min; and renograms. FL = first-pass flow (3-s image).

CT findings that are positive for calculus, even with other findings suggestive of obstruction, do not necessarily confirm the diagnosis of obstruction and the need for emergency intervention under general anesthesia. They do not verify that obstruction was or is present, and they may not indicate the severity of persistent obstruction and its impact on renal function. Among our study population, who had renal colic and positive helical CT findings at the time of critical decision making, slightly fewer than half either never had obstruction or had experienced spontaneous decompression. Likewise, in patients who had positive helical CT findings, using persistent pain as a criterion for emergency intervention appears useful, but considering persistent pain alone may lead to a wrong decision about patient management: on the one hand, cessation of pain, especially after analgesics, does not necessarily mean that decompression by passage or dislodgment of the calculus occurred, and such an assumption may lead to kidney damage from untreated obstruction; on the other hand, persistence of symptoms does not always mean that severe obstruction in need of emergency intervention is present (*24*). In addition, the lack of a strong correlation between the time elapsed after the helical CT examination and the finding of a stunned kidney suggests that, at least in some patients, decompression may have occurred even before the helical CT was performed.

Making the final decision requires an objective criterion such as a noninvasive test that reliably shows whether obstruction is or was the cause of the pain, whether obstruction is still present and how severely it affects renal function, and whether spontaneous decompression has occurred. Such a test, in conjunction with the helical CT results, will facilitate patient stratification into 3 groups. The first will receive further work-up or be discharged to outpatient follow-up before final diagnosis and possible elective intervention (no obstruction or a postdecompression pattern). The second will receive diuretic and analgesic therapy and may finally undergo elective decompression (mild or partial obstruction). The third will be admitted to the hospital for emergency removal of the calculus or for decompression to avoid irreparable renal damage (severe or total obstruction). MAG_3-F_0 scintigraphy appears to qualify as this noninvasive test.

In our study, on the basis of reported results about the sensitivity of helical CT for stone detection, patients with negative findings were considered to be experiencing pain from causes other than renal colic and were stratified accordingly. However, confirmation of the sensitivity of helical CT through prospective MAG_3-F_0 scintigraphy may be useful in patients with negative helical CT findings, which indirectly suggest that renal obstruction is not the cause of their pain.

The 4 characteristic patterns of diuretic ^{99m}Tc-MAG_3 scintirenography correlate with well-known pathophysiologic changes that occur in patients with total or partial obstruction and in acutely decompressed kidneys (*25*).

All patients with obstruction, and most patients with a stunned kidney, had ipsilaterally decreased renal flow and function and increased 20-min cortical retention of activity. The dependence of these findings on the severity and duration of obstruction and on the time elapsed after decompression concurs with the experimental findings (*25*). All patients were studied several hours after the onset of obstruction, when decreased blood flow and function had already been established (*25*).

When the drainage system in cases of obstruction was considered, total and partial obstruction differed fundamentally, again in concordance with experimental findings. When obstruction was complete, the intrarenal and extrarenal drainage systems were not visualized but a continuous slow cortical accumulation with a rising cortical renogram was visualized in the acute phase of obstruction. The tubular cells are less severely affected and slowly (decreased blood flow) but continuously accumulate MAG_3 (rising graphs), and because of the lack of urine flow the activity remains in the parenchyma, inside the tubular cells, or in the tubular lumen.

In contrast to the nonvisualization of the drainage system in complete obstruction, in the partially obstructed kidneys the drainage system was visualized in addition to slow and persistently active parenchyma. Visualization often occurred late. A delayed and then persistent, prominent image of the pelvis (substantially more intense than the renal parenchyma) and ureter was seen in cases of distal obstruction because the highly concentrated radiopharmaceutical was retained in the urine within the portion of the drainage system proximal to the level of ureteral obstruction (Figs. 2A and B).

In spontaneously decompressed, postobstruction, stunned kidneys, renal blood flow and function progressively improve and normalize with time (Fig. 5). Unless decompression is recent, a relative (to obstruction) preservation of renal blood flow is present, associated with a variable, delayed, and persistent cortical nephrogram. Conversely, a faintly visualized drainage system empties promptly because of a normal flow of dilute urine (*25*) after injection of a potent diuretic. Despite substantial urine flow, only small portions of the MAG_3 taken up by the tubular cells appear to be soon excreted into the lumen of the tubules; the severe tubular dysfunction keeps most of the activity in the parenchyma of the kidney (acute tubular necrosis–like stunning). As a result, the urine has a low concentration of activity, the intrarenal drainage system is not usually visible against a dense hyperactive cortex, and the ureter often requires image enhancement to become visible (Figs. 4 and 5). Visualization of the drainage system is the most convincing finding for differentiating between a stunned kidney and complete obstruction. Appreciation of this finding during the test interpretation is often difficult, and indeed, 2 misinterpretations occurred in cases of stunned kidney. The on-call readers interpreted these cases as complete obstruction (Table 3).

The unilateral nature of the abnormality and the history can help distinguish renal dysfunction after obstruction from other conditions that induce similar dysfunction (e.g., acute tubular necrosis, toxicity, vascular problems, and nephrotic syndromes). However, this pattern suggests simply that obstruction has been relieved and not necessarily that a calculus has passed into the bladder. The stone may change position and cease causing obstruction. KUB radiography or helical CT may still show the stone, although scintigraphy will show lack of obstruction; of course, obstruction may recur, as it did in some of our patients. Whether this pattern follows decompression of all obstructed kidneys or occurs in severe or prolonged obstruction is not known. Experimental data indicate a certain relationship with severity and duration of obstruction (*25*).

The postobstruction state as shown by IVU has been described (*26*). This state was reported for 10 patients, and the following 4 signs were emphasized : no delay in passage of contrast material, decreased density of contrast material in the ureter, hazy visualization of the ureter, and dilatation of the ureter. This complex of signs, which are similar to MAG_3-F_0 findings, was then explained as a result of dilute urine diuresis after obstruction. However, findings on IVU are not easily recognizable.

In this study, the use of diuretics did not aggravate the pain of patients who were already undergoing forced diuresis and did not induce any complications in these 2 groups of patients. On the contrary, the diuretic effect may have helped the radiopharmaceutical empty from the unobstructed units (Figs. 1, 5, and 6), thus separating patients without obstruction and patients with spontaneous decompression from those with partial or complete obstruction. The diuretic effect helped in identifying the location of the obstruction by underlining activity proximal to the obstruction compared with the contralateral kidney, which emptied promptly (Fig. 2). When furosemide is injected intravenously, its diuretic effect begins at 7 min and 90% of its peak action is manifested by 10 min. The drainage system is thus emptied by 20 min in the absence of obstruction (*5,8*). Two cases of preexistent forniceal rupture were diagnosed when urine leakage was shown to begin at 4–6 min after injection, before the diuretic action of furosemide had taken effect.

The results presented in this article are clinical because the study was not double-masked to accurately assess the impact of scintigraphy on patient management. Previous experience at this center (including our initial group of 60 patients) overwhelmingly supported the accuracy of the test regarding obstruction; therefore, ethical issues did not allow us to perform a masked study and to deprive patients of the benefit of using the test for making decisions about their treatment. However, follow-up indicated that the test appropriately stratified most of the 80 patients (Table 3).

CONCLUSION

Diuretic (F_0) ^{99m}Tc-MAG_3 scintirenography can effectively determine the presence or absence of obstruction and may differentiate between very severe or complete obstruction and partial obstruction. This imaging method may provide information about the severity of, and indicate the anatomic level in, partial obstruction. The functional character and tubular properties of the method allow recognition of renal dysfunction after decompression, or the stunned kidney, the image of the kidney after passage or dislodgment of a urolith. This test should be used for routine evaluation of patients with renal colic to stratify them for emergency intervention (complete or severe obstruction), for medical therapy and elective intervention (mild partial obstruction), or for further work-up and follow-up (no obstruction or spontaneous decompression). Such stratification is needed after clinical selection, after KUB radiography, and even after positive results on helical CT, all of which have a low positive predictive value for obstruction.

ACKNOWLEDGMENTS

This study was presented in part at the annual meeting of the Society of Nuclear Medicine, Denver, CO, June 3–5, 1996, and Los Angeles, CA, June 6–10, 1999; the World Congress of Endourology, Melbourne, Australia, November 11–16, 1996, and Rhodes, Greece, September 2–5, 1999; the annual meeting of the American Urological Association, New Orleans, LA, May 1997; and the Basic Research Symposium of Shock Wave Lithotripsy, Rhodes, Greece, September 2–5, 1999.

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