The scintigraphic imaging modality of choice in the evaluation of renal infections is renal cortical scintigraphy utilizing [99mTc]dimercaptosuccinic acid (DMSA). This technique is able to demonstrate upper tract involvement with infection and to assess for the presence of renal cortical scarring following a urinary tract infection (UTI). There are recent publications advocating its use to determine which patients need to proceed to further investigation with cystography. It is also being utilized in the evaluation of different treatment regimes used in patients with UTI. Fluorodeoxyglucose (FDG)-PET and leukocyte scanning have only a minor role in the diagnosis of renal infection. Their main application is in the diagnosis of renal cyst infections in patients with polycystic renal disease.

KEY WORDS: Radionuclide imaging - Kidney diseases - Infection.

Urinary tract infection (UTI) is a common clinical problem. It accounts for more than 7 million visits to physicians annually in the U.S.A. In women aged 20-40 years, 25-35% give a history of symptoms diagnosed by their doctor as a UTI. One of the most common bacterial infections in women is UTI—at least 10% of women experience a symptomatic UTI in their lifetime. In children, approximately 3.5% of girls and 1.2% of boys have had a symptomatic infection at some time in their lives. In Australia, UTI accounts for approximately 1.2% of all general practitioners patient encounters. In Sweden, the cumulative incidence of symptomatic UTI at 7 years of age was 7.8% for girls and 1.6% for boys. UTI may be complicated or uncomplicated. A complicated UTI is characterized by the presence of complicating factors such as obstruction, calculi, vesico-ureteral reflux, septicemia or systemic diseases, like diabetes and immunosuppression. Imaging of the renal tract is recommended in adults suspected of complicated UTI. The investigation of UTI in children has been the subject of debate and controversy for many years. It is generally agreed that the primary goal of investigating children with UTI is to identify patients at risk (such as those with renal tract malformation, vesico-ureteric reflux [VUR] and established renal damage), to prevent further infections and to prevent progressive renal damage.

Clinical features that may identify a child at risk include recurrent UTI, bacteremia, a sick infant requiring hospitalization, an unusual infective organism, i.e. non-

Escherichia coli in origin, clinical signs such as a poor urinary stream or palpable kidneys, slow response to treatment, prenatal ultrasound (US) diagnosis of a renal/urinary tract abnormality and recurrent cystitis in a girl usually older than 3 years of age.

Ultrasound examination

There is much debate in the literature as to whether all children with UTI require imaging or whether only
patients assessed to be at risk require evaluation. Despite this, most workers in the field agree that the first imaging modality to be used when investigating UTI is US examination.7, 11, 13 This technology does not utilize ionizing radiation, is inexpensive and non-invasive, has the potential to provide useful information of the kidneys and urinary tract and can be performed at the bedside to diagnose infectious emergencies, such as renal abscess and pyohydrenephrosis with or without renal calculi.14 US may identify acute pyelonephritis, although it is acknowledged to be less sensitive than renal cortical scintigraphy.15 Ultrasound is undertaken to exclude the presence of hydronephrosis, hydroureteronephrosis or obstruction, to exclude structural abnormalities, such as small kidneys and ureteroceles and exclude the presence of renal calculi.

Renal cortical imaging utilizing technetium-99m dimercaptosuccinic acid

For the detection of renal infection or its sequela of scarring, dimercaptosuccinic acid (DMSA) is the radiopharmaceutical of choice.16 DMSA is an excellent renal cortical imaging agent with approximately 40% of the administered dose accumulating in the distal tubular cells, providing excellent visualization of the renal cortex, after background activity has cleared. Dynamic tracers with high excretion rates such as [99mTc]mercaptoacetyltriglycine (MAG 3) give less accurate information on renal cortical abnormalities and constitute only second-choice tracers. Guidelines have been published for the performance of this investigation.17 The recommended minimum dose is 15-20 MBq, with a maximum adult dose of 100-110 MBq. The administered dose should be scaled on a body surface basis. Images should be acquired 2 to 3 h after tracer injection, but if significant hydronephrosis exists, late images (4-24 h) or frusemide injection may be helpful. Images should include at least a posterior view acquired for a minimum of 200 000 counts or 5 min using high-resolution parallel-hole collimator and both posterior oblique views. Many experts advocate the addition of pinhole images using a 2 to 4 mm aperture insert. Pinhole views are acquired for 100 000 to 150 000 counts or for 10 min.

Some workers add single photon emission computed tomography (SPECT), which may provide useful information, but can increase the number of false-positive results and is more technically demanding during both acquisition and analysis. Motion artifact constitutes a problem in SPECT related to the long acquisition time. Pinhole imaging is more easily repeated than is a SPECT study. Several workers recommend the addition of either pinhole or SPECT imaging to the planar studies to increase the level of certainty with which renal cortical scintigraphy is interpreted.

A normal DMSA study exhibits homogeneous cortical uptake throughout the kidneys except for a lower concentration in the region of the collecting system (Figure 1). The consensus report confirmed the variety that can be found in normal images, including flattening of the superolateral aspect of the upper pole of the left kidney caused by splenic impression and prominent cortical columns of Bertin, resulting in heterogeneous uptake.16 Differential function calculation can be undertaken on the posterior planar view. Depth correction using geometric mean data from the anterior view may also be obtained, although the need for depth correction has been questioned.16 Renal length measurements also can be obtained and normal ranges have been established.18 DMSA studies are used either early to make the diagnosis of acute pyelonephritis or late to detect the presence of renal cortical scarring.19 If the DMSA study is undertaken to assess for the presence of chronic damage after UTI, the study should not be performed <3 months from the time of UTI. There is much debate in the literature as to the time period between UTI and

Figure 1.—Normal DMSA study with anterior and posterior planar views in the upper row and posterior and posterior oblique pinhole views of both kidneys in the lower row. A normal DMSA study is identified by uniform uptake in the renal cortex with reduced uptake centrally in the medulla and collecting system. DMSA: dimercaptosuccinic acid.
scanning. The minimum period is 3 months, although some workers have advocated waiting 6 months or 12 months to ensure that all reversible findings caused by resolving infection have occurred.16 The accuracy of the DMSA study in the diagnosis of acute pyelonephritis and chronic renal cortical scarring has been established in the piglet model. Rushton et al. confirmed that the changes present on the DMSA study at the time of acute pyelonephritis do correspond to acute infective foci histologically.20 Their findings were soon confirmed by Parkhouse et al., who also validated the sensitivity of the DMSA study in the detection of acute pyelonephritis using the piglet model.21 Histological confirmation of the DMSA findings of chronic renal cortical scarring in the pig model was obtained by Rossleigh et al.22

**Acute pyelonephritis**

There are three patterns of DMSA scan abnormality identified at the time of acute pyelonephritis: unifocal or acute lobar nephronia, multifocal and diffuse. Scan features to suggest acute changes include focal decreased or absent cortical uptake without cortical or volume loss, in which the renal cortical contour remains intact 23, 24 (Figure 2).

Some recent publications have concluded that the presence of acute pyelonephritis in infants or children presenting with UTI is critical in the planning of further investigations and treatment. Hansson et al. advocate that the use of DMSA scintigraphy performed within 3 months of the acute infection may replace micturating cystourethrography (MCU) for the detection of VUR as part of the primary work-up of children with UTI. In their initial study, there were 7 of 80 children with a normal DMSA scan that had grade III VUR, but whose follow-up was uneventful without recurrent UTI and with spontaneous regression of VUR, with only one developing a scarred kidney. On the basis of these results, it was argued that, in the presence of normal DMSA scintigraphy, MCU was not necessary.25

In their subsequent prospective study of 290 consecutive infants <1 year of age presenting with their first diagnosed symptomatic UTI, renal ultrasound and DMSA scintigraphy was performed within 2 months.26 They found that DMSA scintigraphy was abnormal in all 27 infants with dilating VUR except 1. This single false-negative finding needed to be compared with 140 unnecessary MCU performed in the presence of a normal DMSA study. Their findings supported their hypothesis that DMSA scintigraphy is abnormal in the presence of dilating VUR and that a normal DMSA made MCU unnecessary in the primary investigation of infants with UTI.

Moorthy et al. concluded that because only 16% of their children with VUR had an abnormal kidney, the presence of VUR did not identify a susceptible population with an abnormal kidney on DMSA.27 In the context of a normal US, MCU contributed little to the management of children younger than the age of 1 with a UTI, because there was no correlation between VUR demonstrated on MCU and renal scarring identified on DMSA performed 3 to 6 months after UTI. In this context, a normal DMSA study reinforced the redundancy of cystography. On the basis of their data, their recommendation for children with UTI younger than the age of 1 year, when the US was normal was that DMSA should be the next imaging investigation. Where US is normal, MCU is only indicated if the DMSA is abnormal. The aim to reduce the number of MCU in children is welcome, because it is an...
unpleasant procedure requiring urethral catheterization and has a risk of introducing infection and a radiation burden associated with it.

In some centers, the acute DMSA study is undertaken to determine antibiotic therapy for UTI. An abnormal DMSA study will require the child to have more intensive antibiotic therapy. This approach has not been adequately validated in the literature, although there is some evidence to support it. 

Levtchenko et al. assessed the efficiency of 7 days of intravenous antibiotics compared with 3 days of intravenous antibiotics, both followed by an oral agent in children with acute pyelonephritis. In children treated for 7 days with intravenous antibiotics, the percentage of patients with chronic renal cortical scarring on the delayed DMSA study was the same whether the children presented early or the diagnosis and treatment was delayed for > 1 week. However, in the group treated for 3 days with intravenous antibiotics, there was a significantly greater incidence of sequelae, with renal cortical scarring on the delayed DMSA study in the group of children with a delay in diagnosis and treatment of > 1 week.

Levtchenko et al.’s findings were not confirmed in a subsequent publication. Doganis et al. found that there was no significant difference in the incidence of subsequent renal cortical scarring in infants with acute pyelonephritis confirmed on DMSA scintigraphy performed at the time of acute UTI when treatment was commenced early or late.

Montini et al. showed that treatment with oral antibiotics was as effective as parenteral then oral treatment in the management of the first episode of clinical pyelonephritis in children. The incidence of scarring and response to treatment was the same in both groups.

In approximately 10% of children of any age with a clinical diagnosis of acute pyelonephritis, urine cultures are found to be either equivocal or negative. In this group of children, the acute DMSA study can be undertaken to confirm the clinical diagnosis and result in an appropriate management plan. Without the DMSA study, the child would remain with the diagnosis of a fever of unknown origin.

### Chronic renal cortical scarring

Some workers use DMSA studies to assess for chronic sequelae once acute infective changes have resolved in the kidney. A number of workers have demonstrated that the incidence of residual scarring following an abnormal early DMSA study ranges from 15% to 40%. The scintigraphic features that suggest chronic scarring on a DMSA study are defects in uptake associated with cortical thinning and volume loss resulting in a localised deformity of the renal outline.

If the acute DMSA is normal, the risk of chronic scarring at 6 months is 0%. Hoberman et al. advocate urine cultures and cystograms alone as the only investigations to determine whether antibiotics or antimicrobial prophylaxis is prescribed. This is not an approach supported by others. The recent NICE guidelines advocate the use of ultrasonography in children of all ages with atypical UTI to identify structural abnormalities of the urinary tract; DMSA scan 4-6 months after the acute infection to detect renal cortical scarring in children < 3 years with atypical and/or recurrent UTI and not to perform routine imaging to identify VUR.

### The role of fluorodeoxyglucose positron emission tomography and leukocyte scanning in the diagnosis of renal infection

Fluorodeoxyglucose positron emission tomography (FDG PET) and leukocyte scanning has only a small role in the diagnosis of renal infection. As
opposed to DMSA scintigraphy, which is well established in the literature as the imaging modality of choice in the diagnosis of renal infection, there are only case reports advocating the utility of FDG PET or leukocyte scanning for this purpose. One role where DMSA scintigraphy would be unhelpful, but FDG PET or leukocyte scanning would be useful is in the diagnosis of renal cyst infections. Bleeker-Rovers et al. describe the use of FDG PET scan in 3 patients with adult polycystic kidney disease in localizing the site of infection. There are two separate case reports describing the utility of leukocyte scanning in polycystic renal disease. Gilbert et al. describe the localization of a unilateral renal abscess using [111In]oxine-labeled autologous leukocytes in a febrile patient with polycystic renal disease, after other non-invasive imaging procedures failed to identify a source of infection. Bretan et al. reported a similar case. FDG PET has been utilized in the investigation of a renal transplant patient with sepsis where the infective focus was localised to a native kidney. Sebrehcts et al. warned of the limitations of 11In leukocyte scanning in febrile renal transplant patients due to the marked nonspecificity of renal, pulmonary and other sites of focal leukocyte accumulation that occur in this group of patients in distinct contrast to the experience with this diagnostic modality in non-transplant patients.

Conclusions

DMSA renal cortical scintigraphy is the scintigraphic imaging modality of choice in the evaluation of renal infections. FDG PET and leukocyte scanning have only a minor role with their main application being in the diagnosis of renal cyst infections.

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