AJR FOCUS ON:

Imaging in Pediatric Urinary Tract Infection: A 9-Year Local Experience

Wing Hang Luk[1]
Yip Hin Woo
Andrea Wai San Au-Yeung
James Chi Sang Chan

OBJECTIVE. Urinary tract infection (UTI) is a common disease entity in children, and a number of imaging options are offered for these patients. The purpose of our study was to retrospectively describe the ^{99m}Tc-labeled dimer captosuccinic acid (DMSA) renal scintigraphy, ultrasound, and micturating cystourethrography (MCU) findings over a 9-year period.

MATERIALS AND METHODS. All children younger than 10 years old who presented to a local hospital in Hong Kong between July 1, 1997, and June 30, 2006, with culture-confirmed UTI and who subsequently underwent DMSA scintigraphy, ultrasound, and MCU were identified. For the purpose of this study, patients with underlying major congenital urinary tract abnormalities were excluded. DMSA scintigraphy was regarded as the gold standard for the diagnosis of renal scarring. DMSA scintigraphy, ultrasound, and MCU findings and clinical outcomes were reviewed and analyzed.

RESULTS. A total of 583 children were included in the study. Of these, 432 children (74.1%) had normal findings on ultrasound and on MCU. Only 13 children (3%) of this group had renal scarring as shown on DMSA scintigraphy. The overall negative predictive value (NPV) for excluding renal scarring of combined ultrasound and MCU reached 97%. The NPV was 97.7% in the subgroup of patients 0 to 2 years old.

CONCLUSION. For children younger than 2 years with UTI in the absence of underlying major congenital urinary tract abnormalities, we recommend that DMSA scintigraphy may be withheld if findings on both ultrasound and MCU examinations are normal.

Urinary tract infection (UTI) is a common febrile illness in children. Although most will recover with an excellent prognosis, a minority will have long-term complications such as hypertension, chronic renal insufficiency, and end-stage renal failure. These potential complications are the grounds for the timely investigation, prompt treatment, and tailored follow-up of UTI in children [1].

Urinary tract imaging is appropriate in children after the first onset of UTI. Imaging may entail renal ultrasound for the detection of congenital abnormalities, obstruction, and scarring; micturating cystourethrography (MCU) for the identification of vesicoureteric reflux; and ^{99m}Tc-labeled dimer captosuccinic acid (DMSA) renal scintigraphy for the determination of scarring. Depending on the clinical scenario, one or more of these examinations may be performed after a child's first episode of UTI; indeed, in many cases, all three investigations are performed. In 1991, the Working Group of the Research Unit of the Royal College of Physicians (RCP) established a series of guidelines for managing acute UTI in children [2]. With regard to urologic imaging in particular, the RCP recommended that ultrasound be considered in all cases and that it should be supplemented with a late DMSA scintigraphy in children up to the age of 7 years and with MCU in those younger than 1 year. Nevertheless, the adoption of these recommendations remains variable, and implementation is complicated by regional variations in local policies and practices [3].

Although UTI is a common childhood occurrence that affects up to 10% of children by the teenage years [4, 5], only approximately 4% will have renal parenchyma defects as a result of UTI that are visible on DMSA scintigraphy scans. An even smaller proportion will develop the feared long-term sequelae of hypertension, renal impairment, and end-stage renal failure [6]. A blanket approach using all

Keywords: cystourethrography, pediatric imaging, renal scarring, renal scintigraphy, ultrasound, urinary tract infection

DOI:10.2214/AJR.08.1869

Received September 25, 2008; accepted after revision December 16, 2008.

[1]All authors: Department of Diagnostic Radiology and Organ Imaging, United Christian Hospital, Hong Kong B1/F, Block S, United Christian Hospital, 130 Hip Wo St., Kwun Tong, Kowloon 0852, Hong Kong. Address correspondence to W. H. Luk.

AJR 2009; 192:1253–1260

0361–803X/09/1925–1253

three renal imaging techniques is therefore neither realistic nor practical.

DMSA scintigraphy is a relatively invasive test involving IV cannulation and injection of radionuclide and commonly requires sedation or restraint of pediatric patients, which involves several hours of hospital stay and radiation to the body including the gonads. The whole process is psychologically traumatic to the child and is also stressful to the parents [7]. Some authors question the need for and cost-effectiveness of performing this test in all children with UTI to detect uncommon complications [8].

Consequently, in a number of studies [9–11], investigators have examined the findings of ultrasound, MCU, and DMSA scintigraphy scans to determine the respective efficacy of each in predicting renal scarring and hence the risk for future comorbidity. However to our knowledge, none has specifically compared the results of ultrasound and MCU in combination with the results of DMSA scintigraphy, the gold standard. Here, we report the first study of this kind to date. We aimed to evaluate the potential role of combined ultrasound and cystourethrography as first-line imaging tests in predicting renal scarring using DMSA scintigraphy as the gold standard.

Materials and Methods

This retrospective study was approved by the local institutional review board.

Subjects

All children younger than 10 years old who underwent DMSA scintigraphy in a local hospital in Hong Kong from July 1, 1997, to June 30, 2006, because of culture-confirmed UTI were identified.

Definition

UTI was defined as a urine culture showing bacterial growth of more than 10^5 colony-forming units per milliliter of urine collected by an appropriate method including the clean-catch method, suprapubic tap, catheterized urine, or mid-stream sampling.

Guidelines

There are no established local guidelines in the United Christian Hospital about which tests to perform to examine children with UTI. Traditionally, ultrasound, MCU, and DMSA scintigraphy studies are routinely performed in children younger than 6 years. Of children older than 6 years, only those with complicated features are referred for DMSA scintigraphy in addition to ultrasound and MCU.

With respect to the timing of the investigations, DMSA scintigraphy is generally performed a minimum of 3 months after the onset of UTI. MCU is performed after the current episode of UTI has subsided. In our center, ultrasound and MCU are typically performed the same day for the convenience of the patients and their families.

Exclusion Criteria

All children without laboratory-proven UTI as defined earlier were excluded from the study. For the purpose of the study, we did not include patients with major congenital urinary tract abnormalities such as horseshoe kidney, cross ectopia, duplex kidney, and single kidney. We excluded those patients because the threshold for DMSA scintigraphy would normally be low in any case for these patients who are anatomically predisposed to recurrent UTIs and therefore at higher risk of long-term renal damage. Other exclusion criteria included failure to complete all three investigations and early DMSA scintigraphy performed less than 3 months from the onset of UTI.

Imaging Studies

In our center, ultrasound was performed by a qualified radiologist with a minimum of 2 years of radiology experience using a curvilinear probe (8C4 probe and Acuson Sequoia 512, Siemens Medical Solutions; or C7-4 probe and ATL HDI 5000 system, Philips Healthcare). Renal images

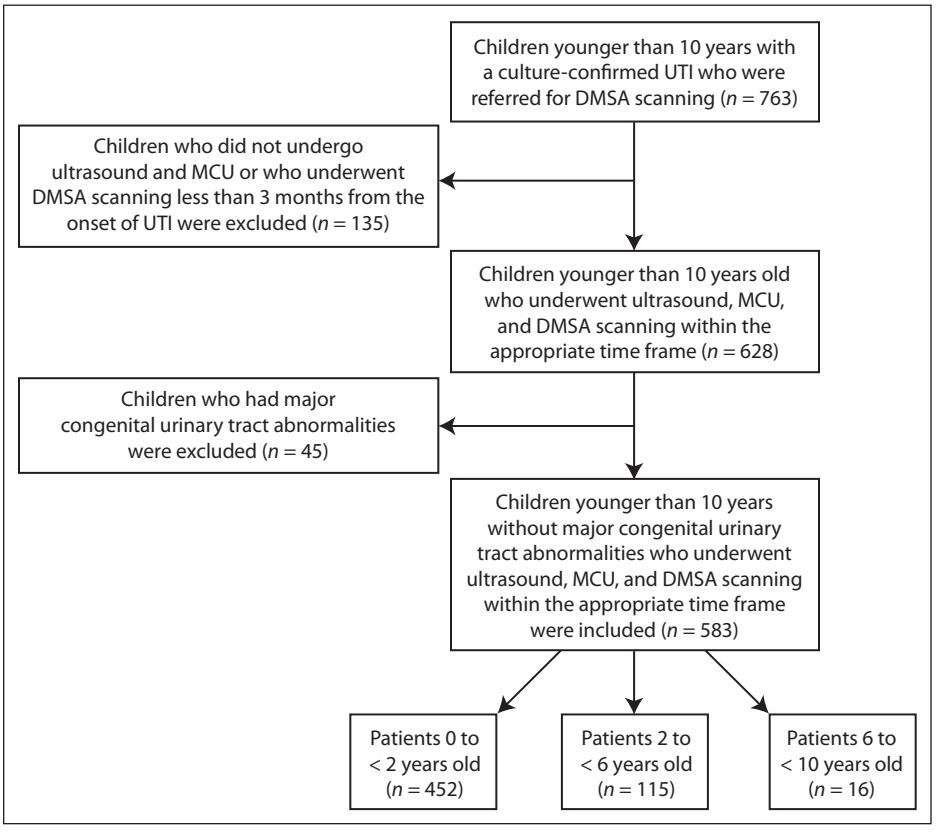


Fig. 1—Flowchart illustrates selection of children with urinary tract infections (UTIs) recruited to our study. DMSA = ^{99m}Tc-labeled dimer captosuccinic acid renal scintigraphy, MCU = micturating cystourethrography.

were obtained with the patient in the supine, oblique, or prone position with sagittal and transverse views.

MCU images were obtained during bladder filling, when the bladder was full, and during voiding after injection of iothalamate meglumine (Conray 30, Covidien Imaging) via a urinary catheter and under fluoroscopy (Diagnost 76 Plus system, Philips Healthcare). Both frontal and bilateral oblique views were obtained to assess the vesicoureteric junctions.

DMSA scintigraphy images were acquired 2 hours after IV administration of a weight-adjusted dose of ^{99m}Tc up to a maximum of 80 MBq. Images were obtained using a SPECT protocol, three degrees per step, and a 15-second acquisition for each step in the continuous mode with a matrix of 128 × 128 (Prism 1000 system, Picker International).

Methodology

Patients were divided into three groups on the basis of their age at presentation: < 2 years old, 2 to < 6 years old, and 6 to < 10 years old. All their medical records and investigation reports were reviewed. The DMSA scintigraphy scans were regarded as the gold standard for the diagnosis of renal scarring. A renal scar was defined as a photopenic area in the renal parenchyma not caused by lobulation. Combined ultrasound and MCU studies were regarded as the potential first-line investigations in the identification of patients who were at risk of developing renal scarring.

Ultrasound was regarded as positive if terms such as scarring, pelviureteric dilatation, hydronephrosis, large or small kidney, renal swelling, increased or decreased echogenicity, prominence of pyramids, or loss of corticomedullary differentiation were used in the report. Images of these positive ultrasound studies were subsequently reviewed blindly by a radiologist with 12 years of experience. MCU was regarded as positive if vesicoureteric reflux was seen.

Statistical Analysis

Through a comparison of the ultrasound, MCU, and DMSA scintigraphy findings, the prevalence of vesicoureteric reflux and the prevalence of renal scarring were obtained. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were determined by constructing a 2 × 2 table in which the combined first-line examinations (i.e., ultrasound and MCU) were compared against the gold standard examination, DMSA scintigraphy. Correlation between ultrasound-detected renal abnormalities, MCU-detected vesicoureteric reflux, and DMSA scintigraphy–detected renal scarring was then evaluated by the chi-square test (SAS software, version 9, SAS Institute). The 2 × 2 tables for DMSA scintigraphy against ultrasound alone, DMSA scintigraphy against MCU alone, and DMSA scintigraphy against combined MCU and ultrasound studies were tabulated. A p value of less than 0.05 was considered statistically significant.

Results

From our database, a total of 763 patients with culture-confirmed UTI who underwent DMSA scintigraphy were identified. After exclusion of the patients who did not meet the stated criteria, 583 children (76.4%) were recruited into our study. Of these, 388

TABLE 1: Sex Distribution of Patients Excluded From and Included in the Study

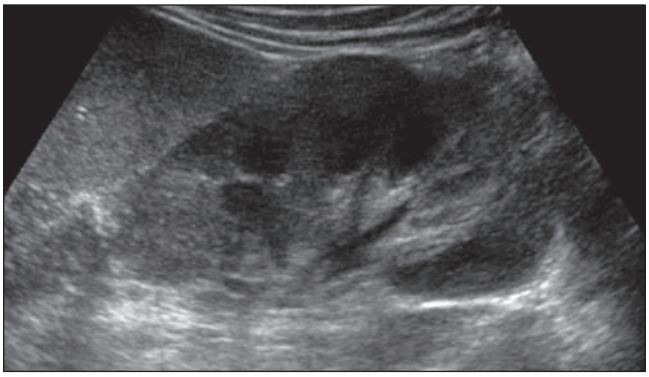
Patients	Total No. of Patients	No. (%) of Patients	
		M	F
Included because patient was < 10 years old and presented with a urinary tract infection during the study period	763	480 (62.9)	283 (37.1)
Excluded because patient had an underlying congenital urinary tract abnormality	43	27 (62.8)	16 (37.2)
Excluded because patient did not undergo all three imaging examinations	135	74 (54.8)	61 (45.2)
Included in the study	583	388 (66.6)	195 (33.4)

TABLE 2: Age and Sex Distributions of Patients Included in the Study

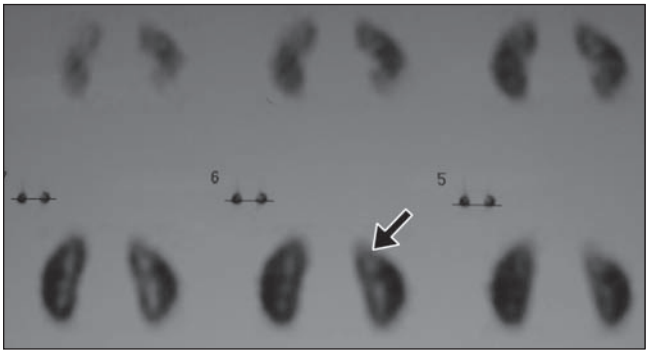
Age Group	Total No. (%) of Patients	No. (%) of Patients	
		M	F
0 to < 2 y	452 (77.5)	314 (69.5)	138 (30.5)
2 to < 6 y	115 (19.7)	66 (57.4)	49 (42.6)
6 to < 10 y	16 (2.7)	8 (50.0)	8 (50.0)
Total	583	388 (66.6)	195 (33.4)

TABLE 3: Comparison of Ultrasound Findings and Dimer Captosuccinic Acid (DMSA) Renal Scintigraphy Findings by Patient Age Group

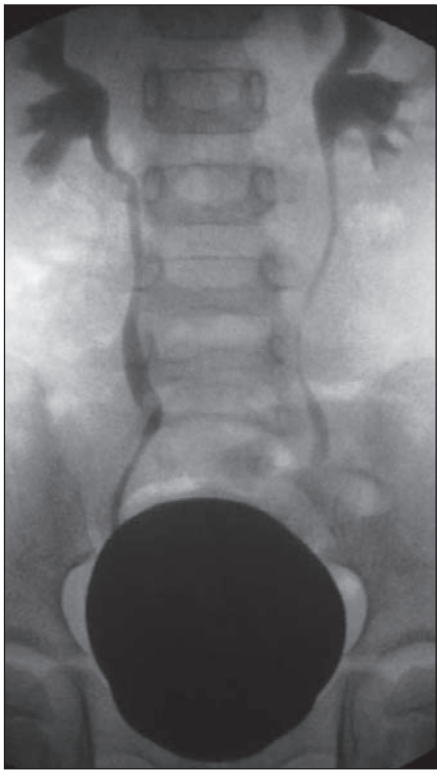
DMSA Findings	No. (%) of Patients with		Total No. of Patients
	Abnormal Ultrasound Findings	Normal Ultrasound Findings	
Abnormal (scarring)			
Age 0 to < 2 y	7 (26.9)	19 (73.1)	26
Age 2 to < 6 y	8 (33.3)	16 (66.7)	24
Age 6 to < 10 y	1 (20.0)	4 (80.0)	5
All ages	16 (29.1)	39 (71.0)	55
Normal (no scarring)			
Age 0 to < 2 y	15 (3.5)	411 (96.5)	426
Age 2 to < 6 y	7 (7.7)	84 (92.3)	91
Age 6 to < 10 y	1 (9.1)	10 (90.9)	11
All ages	23 (4.4)	505 (95.6)	528
Total			
Age 0 to < 2 y	22 (4.9)	430 (95.1)	452
Age 2 to < 6 y	15 (13.0)	100 (87.0)	115
Age 6 to < 10 y	2 (12.5)	14 (87.5)	16
All ages	39 (6.7)	544 (93.3)	583



A

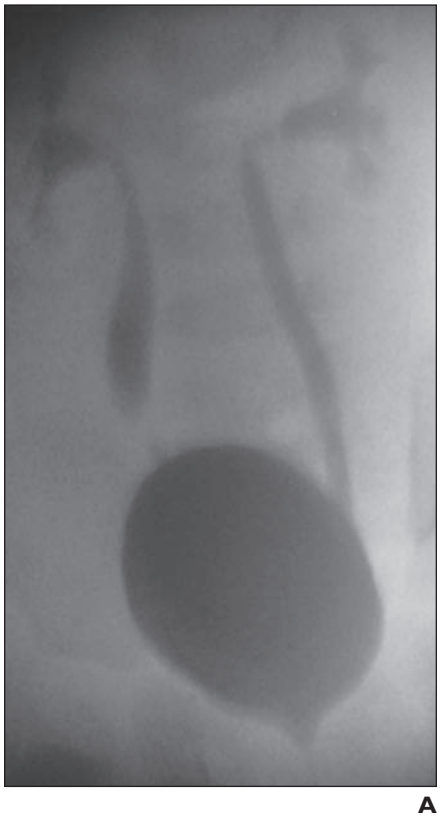


C



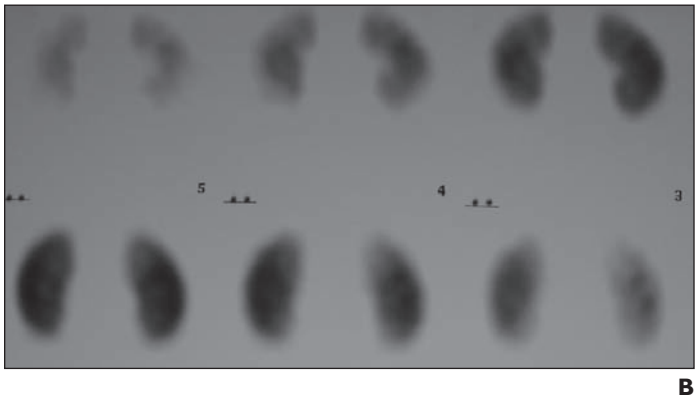
B

Fig. 2—2-month-old boy who presented with fever and irritability and was subsequently diagnosed with urinary tract infection. Follow-up imaging was performed.
A and **B,** Ultrasound findings (**A**) were found to be normal; however, bilateral vesicoureteric reflux into renal pelvis was shown at micturating cystourethrography (**B**).
C, Left upper renal cortical scar was then confirmed by coronal SPECT dimer captosuccinic acid renal scintigraphy image (*arrow*). This case illustrates that normal ultrasound does not reliably exclude renal scarring.



A

Fig. 3—4-month-old girl who presented with fever and poor feeding.
A and **B,** Urine culture grew *Escherichia coli* and urinary tract infection was diagnosed. Renal ultrasound findings were reported to be normal; however, grade 3 vesicoureteric reflux was found at micturating cystourethrography (**A**). Subsequent dimer captosuccinic acid renal scintigraphy scan (**B**) shows no scarring in both kidneys. This case shows that not all vesicoureteric reflux leads to renal cortical scarring.



B

(66.6%) were boys and 195 (33.4%) were girls (Fig. 1 and Tables 1 and 2).

In total, 39 ultrasound (6.7%), 135 MCU (23.2%), and 55 DMSA scintigraphy (9.4%) scans of the 583 cases were abnormal (Figs. 2 and 3). The most common abnormal ultrasound findings included hydronephrosis, hydroureter scarring, and small kidney. Vesicoureteric reflux was the principal abnormality identified on MCU.

TABLE 4: Comparison of Micturating Cystourethrography (MCU) Findings and Dimer Captosuccinic Acid (DMSA) Renal Scintigraphy Findings by Patient Age Group

DMSA Findings	No. (%) of Patients With		Total No. of Patients
	Abnormal MCU Findings	Normal MCU Findings	
Abnormal (scarring)			
Age 0 to < 2 y	18 (69.2)	8 (30.8)	26
Age 2 to < 6 y	19 (79.2)	5 (20.8)	24
Age 6 to < 10 y	4 (80.0)	1 (20.0)	5
All ages	41 (74.5)	14 (25.5)	55
Normal (no scarring)			
Age 0 to < 2 y	73 (17.1)	353 (82.9)	426
Age 2 to < 6 y	19 (20.9)	72 (79.1)	91
Age 6 to < 10 y	2 (18.2)	9 (81.8)	11
All ages	94 (17.8)	434 (82.2)	528
Total			
Age 0 to < 2 y	91 (20.1)	361 (79.9)	452
Age 2 to < 6 y	38 (33.0)	77 (77.0)	115
Age 6 to < 10 y	6 (37.5)	10 (62.5)	16
All ages	135 (23.2)	448 (76.8)	583

TABLE 5: Comparison of the Combined Ultrasound and Micturating Cystourethrography (MCU) Findings with Dimer Captosuccinic Acid (DMSA) Renal Scintigraphy Findings by Patient Age Group

DMSA Findings	No. (%) of Patients With		Total No. of Patients
	Abnormal Ultrasound or MCU (Group A)	Normal Ultrasound and MCU (Group N)	
Abnormal (scarring)			
Age 0 to < 2 y	18 (69.2)	8 (30.8)	26
Age 2 to < 6 y	20 (83.3)	4 (16.7)	24
Age 6 to < 10 y	4 (80.0)	1 (20.0)	5
All ages	42 (76.4)	13 (23.6)	55
Normal (no scarring)			
Age 0 to < 2 y	85 (20.0)	341 (80.0)	426
Age 2 to < 6 y	22 (24.2)	69 (75.8)	91
Age 6 to < 10 y	2 (18.2)	9 (81.8)	11
All ages	109 (20.6)	419 (79.4)	528
Total			
Age 0 to < 2 y	103 (22.8)	349 (77.2)	452
Age 2 to < 6 y	42 (36.5)	73 (63.5)	115
Age 6 to < 10 y	6 (37.5)	10 (62.5)	16
All ages	151 (25.9)	432 (74.1)	583

The imaging results are summarized in Tables 3–5. Table 3 compares the ultrasound findings (either positive or negative, as defined earlier) with the DMSA scintigraphy findings (presence or absence of renal scarring). Table 4 compares the MCU findings (either positive or negative, as defined earlier) with the DMSA scintigraphy findings. All cases were then divided into two groups: Group N refers to children with normal ultrasound and normal MCU findings, whereas group A refers to children with abnormal findings on either ultrasound or MCU. These results were then compared against DMSA scintigraphy findings in Table 5.

Group N and group A had 432 and 151 cases, respectively. Of the 432 children belonging to group N, only 13 (3.0%) were found to have renal scarring on DMSA scintigraphy. The overall ability of a negative ultrasound and negative MCU to exclude renal scarring—that is, the NPV—was 97.0% (range of NPVs in age subgroups = 90.0–97.7%). The NPV of ultrasound alone and the NPV of MCU alone were 92.8% and 96.9%, respectively (Table 6).

Of the 55 children with renal scarring as determined by DMSA scintigraphy, 16 (29.1%) had abnormal ultrasound findings (Table 3) and 41 (74.5%) had abnormal MCU results (Table 4). The sensitivity of ultrasound alone in predicting renal scarring was only 29.1%, whereas the sensitivity of MCU alone was 74.5% (Table 6). Of the remaining 528 children with no renal scarring, ultrasound was normal in 505 (95.6%) (Table 3) and MCU was normal in 434 (82.2%) (Table 4). The specificity of ultrasound alone for predicting renal scarring was 95.6%, whereas that for MCU alone was 82.2%. Ultrasound alone had a PPV of 41.0% for renal scarring (16 renal scars in 39 abnormal ultrasound), whereas the PPV of MCU alone was 30.4% (41 scars in 135 abnormal MCU) (Table 6).

If ultrasound and MCU results were reviewed together as a single criterion, the combined sensitivity for renal scarring increased to 76.4% and the specificity decreased to 79.4%. The PPV was 27.8% only (Table 6).

The accuracy of ultrasound alone in predicting renal scarring was 89.4% and that of MCU alone was 81.5%. The accuracy of the combined techniques was 79.1% (Table 6).

The relationship between DMSA scintigraphy results and ultrasound or MCU findings was confirmed by a statistically significant chi-square test ($p < 0.05$) (Tables 7–9).

TABLE 6: Sensitivity, Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), and Accuracy of Ultrasound Only, Micturating Cystourethrography (MCU) Only, and Combined Ultrasound and MCU in Predicting Renal Scarring

Performance Measure	Ultrasound Only	MCU Only	Combined Ultrasound and MCU
Sensitivity (%)			
Age 0 to < 2 y	26.9	69.2	69.2
Age 2 to < 6 y	33.3	79.2	83.3
Age 6 to < 10 y	20.0	80.0	80.0
All ages	29.1	74.5	76.4
Specificity (%)			
Age 0 to < 2 y	96.5	82.9	80.1
Age 2 to < 6 y	92.3	79.1	75.8
Age 6 to < 10 y	90.9	81.8	81.8
All ages	95.6	82.2	79.4
PPV (%)			
Age 0 to < 2 y	3 1.8	19.8	17.5
Age 2 to < 6 y	53.3	50.0	47.6
Age 6 to < 10 y	50.0	66.7	66.7
All ages	41.0	30.4	27.8
NPV (%)			
Age 0 to < 2 y	95.6	97.8	97.7
Age 2 to < 6 y	84.0	93.5	94.5
Age 6 to < 10 y	71.4	90.0	90.0
All ages	92.8	96.9	97.0
Accuracy (%)			
Age 0 to < 2 y	92.5	82.1	79.4
Age 2 to < 6 y	80.0	79.1	77.4
Age 6 to < 10 y	68.8	81.3	81.3
All ages	89.4	8 1.5	79.1

Discussion

Ultrasound, MCU, and DMSA scintigraphy are the three main imaging options for the investigation of UTI in children in many countries, including Hong Kong. Rickwood et al. [8] compared ultrasound and excretory urography findings in 200 children with UTI and concluded that ultrasound alone was sufficient for children younger than 2 years in predicting renal scarring. However, this conclusion has been questioned by some authors [12] because of the relatively small sample size in that study. Christian et al. [13] compared ultrasound and DMSA scintigraphy findings together with the clinical features of 990 children and reported that the risk of missing a scar is low using ultrasound alone in school-age children with solitary lower UTI. No studies to date, however, have compared DMSA scintigraphy–proven scarring with a single criterion that combines ultrasound and MCU findings, to our knowledge.

In our cohort, almost 600 children were included. All their clinical progress notes and renal imaging reports were reviewed in detail. The performances of ultrasound alone, MCU alone, and the techniques combined were systematically evaluated and compared with the performance of DMSA scintigraphy, thereby providing a comprehensive review on the relationship among these three major imaging techniques commonly used for the investigation of UTI in children.

For the detection of renal scarring by DMSA scintigraphy, we regarded focal photon deficiency as scarring-positive lesions. We note that studies have shown that focal photon deficiency can also represent prescarring conditions [14]. In our study, the prevalence of renal scarring was 9.4% (55/583) in all age groups and 5.8% (26/452) in the group of patients younger than 2 years (Table 5). The latter figure is in line with the commonly quoted 4% prevalence of renal parenchyma defects in the literature [4, 5].

The potential risk of missing renal scarring using combined ultrasound and MCU was the main focus in our study. As illustrated in Table 6, if ultrasound alone was performed, the NPV was only 92.8%. In other words, the probability of missing renal scarring was as high as 7.2%. Within individual subgroups, as categorized by patient age, the respective NPV ranged from 71.4% in the age 6 to < 10 group (lowest) to 95.6% in the age 0 to < 2 group (highest). Similarly from Table 6, if MCU alone was performed, the NPV was 96.9%, ranging from 90% in the age 6 to < 10 group (lowest) to 97.8% in the age 0 to < 2 group (highest). The corresponding probability of missing renal scarring was 3.1%.

If ultrasound and MCU were considered together as a single criterion as illustrated in Table 5, the probability of missing renal scarring could be further reduced to 3.0%. The overall NPV was 97.0% in the combined age group, 97.7% in the age 0 to < 2 group, 94.5% in the age 2 to < 6 group, and 90.0% in the age 6 to < 10 group. The NPV was improved in the age 2 to < 6 group when compared with ultrasound alone or MCU alone, but it was not significantly changed in the other two age groups.

TABLE 7: Dimer Captosuccinic Acid (DMSA) Renal Scintigraphy Compared with Ultrasound Alone: 2 × 2 Table

	No. of Patients With		
DMSA Findings	Normal Ultrasound Findings	Abnormal Ultrasound Findings	Total No. of Patients
Normal (no scarring)	505	23	528
Abnormal (scarring)	39	16	55
Total	544	39	583

Note—Chi-square test: $p < 0.001$.

TABLE 8: Dimer Captosuccinic Acid (DMSA) Renal Scintigraphy Compared with Micturating Cystourethrography (MCU) Alone: 2 × 2 Table

DMSA Findings	No. of Patients With		Total No. of Patients
	Normal MCU Findings	Abnormal MCU Findings	
Normal (no scarring)	434	94	528
Abnormal (scarring)	14	41	55
Total	448	135	583

Note—Chi-square test: $p < 0.001$.

TABLE 9: Dimer Captosuccinic Acid (DMSA) Renal Scintigraphy Compared with Ultrasound and Micturating Cystourethrography (MCU): 2 × 2 Table

DMSA Findings	No. of Patients With		Total No. of Patients
	Normal Ultrasound and MCU Findings	Abnormal Ultrasound or MCU Findings	
Normal (no scarring)	419	109	528
Abnormal (scarring)	13	42	55
Total	432	151	583

Note—Chi-square test: $p < 0.001$.

Using the chi-square test, a *p* value of less than 0.05 confirmed a statistically significant correlation between findings of the combined techniques with that of DMSA scintigraphy. A normal ultrasound and normal MCU therefore would safely exclude renal scarring in most cases with a false-negative risk of 3.0%. This risk is further lowered to 2.3% if the child is younger than 2 years.

Some may point out that because UTI is a relatively common disease in children, in which most will have both normal ultrasound and normal MCU findings, missing renal scarring in 3% of them is still a significant number for concern. In our study, 13 of the 583 children had renal scarring on DMSA scintigraphy despite having normal findings on ultrasound and on MCU. If we were to apply our recommendation and had withheld DMSA scintigraphy in these cases, these 13 cases would represent 13 missed diagnoses of renal scarring. To address this issue, we reviewed the progress of these 13 selected patients. We found that three had defaulted follow-up. The remaining 10 children who were successfully followed up had repeated DMSA scintigraphy at a minimum interval of 6 months from the initial study. Of these, eight had resolution of renal scarring. At the time of writing (> 1 year from the initial episode of UTI), no major complications have been identified in the two remaining cases. We therefore believe that most of these "missed scars" were transient lesions or minor lesions that may not be associated with long-term complications.

Although almost 600 children were recruited into this study, only 16 (2.7%) were 6 to < 10 years old (Table 2). The small sample size of patients in that age group makes it difficult to draw a valid conclusion about this subgroup of patients. Moreover, because DMSA scintigraphy is generally reserved at our institution for children with complicated UTI in this age group, a disproportionately high prevalence of renal scarring was seen in this subgroup of patients—a limitation we recognize as a consequence of the retrospective nature of our study.

We also note a reversed sex predominance in the patients 0 to < 2 years old, with 2.3 times more males than females being referred for renal imaging (Tables 1 and 2). Although we accept that there may be an element of referral bias, it is also documented in the literature that up to the age of 1 year, the incidence of UTI may be higher in Chinese males [15, 16], an occurrence likely related to factors such as no circumcision [17].

We did not classify the UTI cases into upper UTI or lower UTI because the distinction between the two is not always easy in young children [4]. Clinical presentations are often vague, and there is usually no definite confirmatory test. In some of our records, the clinical features of UTI either were not clearly defined or were equivocal between upper or lower tract infections.

In summary, we found that the NPV of combined ultrasound and MCU was high in predicting the absence of renal scarring. The overall risk of missing renal scarring if only the combined techniques were used was 3.0%. For children younger than 2 years, this risk was further reduced to 2.3%. On the basis of these figures, we recommend that DMSA scintigraphy may be withheld in children younger than 2 years in the absence of major congenital urinary tract abnormalities that would otherwise render them at high risk for long-term renal damage if both ultrasound and MCU are reported to be normal. For those with either positive ultrasound or positive MCU findings, further evaluation with DMSA scintigraphy should be performed to determine whether scarring is present. Our findings, which are in line with other studies in the literature, confirmed that neither ultrasound alone nor MCU alone can replace DMSA scintigraphy in the prediction of renal scarring because of the low respective PPV of each. DMSA scintigraphy rightly remains the gold standard.

By performing fewer DMSA scintigraphy studies in this group of low-risk patients who comprise most referrals for renal scintigraphy and who as infants are most susceptible to the effects of ionizing radiation, the radiation burden may be minimized and the cost be reduced [18]. We understand that the balance between cost and risk is always a contentious subject. What is considered to be an acceptable low risk is still a matter of debate. We hope that our study has nevertheless yielded additional information for clinicians and health care economists in their future formulation of the renal imaging policies for children with UTI [19].

We conclude that DMSA scintigraphy may be withheld for children younger than 2 years in the absence of major congenital urinary tract abnormalities if both ultrasound and MCU findings are reported to be normal.

Acknowledgment

We thank Karen Liu (Research Officer, Hospital Authority, HKSAR) for her statistical advice.

References

1. Larcombe J. Urinary tract infection in children: clinical evidence. *BMJ* 1999; 319:1173–1175
2. [No authors listed]. Guidelines for the management of acute urinary tract infection in childhood. Report of a Working Group of the Research Unit, Royal College of Physicians. *J R Coll Physicians Lond* 1991; 25:36–42

3. Deshpande PV, Jones KV. An audit of RCP guidelines on DMSA scanning after urinary tract infection. *Arch Dis Child* 2001; 84:324–327
4. Coulthard MG, Lambert HJ, Keir MJ. DMSAs after UTI: scan more children, not less. *Arch Dis Child* 2001; 85:348
5. Jakobsson B, Esbjörmer E, Hansson S. Minimum incidence and diagnostic rate of first urinary tract infection. *Pediatrics* 1999; 104:222–226
6. Jacobson SH, Eklöf O, Eriksson CG, Lins LE, Tidgren B, Winberg J. Development of hypertension and uraemia after pyelonephritis in childhood: 27 year follow up. *BMJ* 1989; 299:703–706
7. Phillips D, Watson AR, Collier J. Distress and radiological investigations of the urinary tract in children. *Eur J Pediatr* 1996; 155:684–687
8. Rickwood AMK, Carty HM, McKendrick T, et al. Current imaging of childhood urinary infections: prospective study. *BMJ* 1992; 304:663–665
9. Keren R. Imaging and treatment strategies for children after first urinary tract infection. *Curr Opin Pediatr* 2007; 19:705–707
10. Riccabona M, Avni FE, Blickman JG, et al. Imaging recommendations in paediatric uroradiology: minutes of the ESPR workgroup session on urinary tract infection, fetal hydronephrosis, urinary tract ultrasonography and voiding cystourethrography. Barcelona, Spain, June 2007. *Pediatr Radiol* 2008; 38:138–145
11. [No authors listed]. Practice parameter: the diagnosis, treatment, and evaluation of the initial urinary tract infection in febrile infants and young children. American Academy of Pediatrics. Committee on Quality Improvement. Subcommittee on Urinary Tract Infection. *Pediatrics* 1999; 103:843–852 [Errata in *Pediatrics* 2000; 105:141, *Pediatrics* 1999; 103:1052, *Pediatrics* 1999; 104:118]
12. Smellie JM, Rigden SP, Prescod NP. Urinary tract infection: a comparison of four methods on investigation. *Arch Dis Child* 1995; 72:247–250
13. Christian MT, McColl JH, MacKenzie JR, Beattie TJ. Risk assessment of renal cortical scarring with urinary tract infection by clinical features and ultrasonography. *Arch Dis Child* 2000; 82:376–380
14. Majd M, Rushton HG. Renal cortical scintigraphy in the diagnosis of acute pyelonephritis. *Semin Nucl Med* 1992; 22:98–111
15. Hellstrom A, Hanson E, Hansson S, Hjalmas K, Jodal U. Association between urinary symptoms at 7 years old and previous urinary tract infection. *Arch Dis Child* 1991; 66:232–234
16. Chow CB, Yau FT, Leung NK. Symptomatic urinary tract infection in Hong Kong children. *J Hong Kong Med Assoc* 1988; 40:276–280
17. Wiswell TE, Roscelli JD. Corroborative evidence for the decreased incidence of urinary tract infections in circumcised male infants. *Pediatrics* 1986; 78:96–99
18. Stark H. Urinary tract infections in girls: the cost-effectiveness of currently recommended investigative routines. *Pediatr Nephrol* 1997; 11:174–177; discussion 180–181
19. Jones KV. Prognosis for vesicoureteric reflux. *Arch Dis Child* 1999; 81:287–289