Renal Axis Deviation in Urinary Tract Abnormalities of Children

The Role of Renal Scintigraphy

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Background: Urinary tract pathologies are common in children. Previous reports suggested a relationship between some renal pathologies and renal anatomic variations. This study evaluates the effect of different urinary tract abnormalities on scintigraphic renal long axis.

Methods: Children referred to our nuclear medicine department for Tc-99m dimercaptosuccinic acid and/or Tc-99m *N*,*N*-ethylenedicysteine renal scintigraphies were entered consecutively. Presence of single, ectopic, or fused kidneys, extrarenal pathologies altering renal long axis, and history of renal surgery or advanced renal disease were used as exclusion criteria. If indicated, patients were assessed for vesicoureteral reflux (VUR). Long renal axis of each kidney was drawn with a line passing through the kidney's upper and lower poles using posterior image. The angle between this axis and patient's longitudinal body axis was defined as "renal angle." After defining age-groups, "age-corrected renal angle" was calculated.

Results: A total of 311 cases (622 kidney units) entered the study (183 females, 128 males). Mean age was 41.8 months. Mean "renal angle" was 11.7, 11.9, 14.1, 17.6, 28.5, 16.7, and 19.2 degrees in normal, mild, moderate, and severe VUR, high-grade ureteropelvic junction (UPJ) obstruction, nonobstructive pelvic dilatation, and ureterovesical junction obstruction, respectively ($P = 0.000$). Applying receiver operating characteristic analysis and using ultrasonography as the gold standard, renal angle deviation of 13.75 degrees led to the sensitivity of 74.6% and specificity of 70.7% to detect pyelocalyceal system dilatation. Using a "renal angle" cutoff value of 18.7 degrees, 85% sensitivity and 85% specificity were achieved for the diagnosis of high-grade UPJ obstruction. Using "age-corrected renal angle," a cutoff value of 3.9 degrees was consistent with 60% sensitivity and 73% specificity for the diagnosis of severe VUR.

Conclusion: Considerable renal axis deviation is noted in patients with UPJ obstruction and severe VUR in children. Measurement of "renal angle" provides indirect but useful clues to the presence of urinary tract pathologies. Renal scintigraphy is a useful tool for drawing renal axis and measuring "renal angle," potentially making it useful for prediction of urinary tract system abnormalities.

Key Words: scintigraphy, renal axis, UPJ obstruction, vesicoureteral reflux

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Hydronephrosis can be detected in 1.4% of fetuses using ultrasonography, and as many as half of these cases persist postnatally.[1] Owing to lack of consensus regarding treatment of these infants, the postnatal approach to fetal renal pelvis enlargement remains controversial.[2] Also, as pelvic dilatation may occur without clinically significant obstruction, the inability to establish or rule out obstruction has caused controversy in the management of infants with asymptomatic hydronephrosis.[3] Pyelocalyceal (PC) dilatation and hydronephrosis are also common problems among children with urinary tract infection,[4] which make the problems not limited to infancy.

Ureteropelvic junction (UPJ) obstruction is the most common cause of hydronephrosis in children.[5] Because early diagnosis and management of hydronephrosis in UPJ obstruction are associated with fewer long-term complications,[6] prompt evaluation of this condition is necessary. Nuclear medicine modalities (eg, dynamic renal scintigraphy, radionuclide cystographies) are among the most frequently requested diagnostic procedures to investigate the presence of different abnormalities in the urinary tract. Although dimercaptosuccinic acid (DMSA) renal scintigraphy has well-defined roles in the evaluation of the renal parenchyma in different medical conditions,[7] in the presence of dynamic renal scintigraphy and available radiographic procedures, this imaging modality has no reported role for the evaluation of hydronephrosis and assessment of the presence of obstruction in the urinary drainage pathway.

Using static images of renal scintigraphy (either DMSA scan or initial cortical images of the dynamic renal scintigraphy) for predicting the presence of obstructive lesion in the urinary tract (eg, UPJ obstruction) seems to be a farfetched goal that can be of great help if it comes to reality.

Previous reports suggest that renal anatomic factors contribute in different renal pathologies.[8–10] For example, anatomic differences in the lower calyceal stone formers were described by Gozen et al.[8] Also, it has been stated that the position of the longitudinal axis of the renal pelvis is of special significance in the diagnosis of the renal masses.[10]

By performing many DMSA or dynamic renal scintigraphies in our busy pediatric nuclear medicine department, we encountered kidneys with significantly deviated renal long axis, which encouraged us to investigate whether there is any association between these observations and different underlying renal pathologies.

MATERIALS AND METHODS

Subjects

All consecutive newborns, infants, and children who were referred for DMSA renal cortical imaging or dynamic renal scintigraphy were entered into this study. Patients with single, low-lying, ectopic, fused, or pelvic kidneys; those with history of any surgical intervention for congenital or acquired urinary tract problems; patients with vertebral column deformities (kyphosis and/or scoliosis); and patients with severely compromised renal function (in a way that defining renal long axis was impossible) were excluded from the study. Patients with concomitant obstruction (UPJ or UVJ obstruction) and vesicoureteral reflux (VUR) were also excluded from the study. All patients underwent DMSA renal imaging (n = 161) and/or dynamic renal scintigraphy (n = 217), whereas 67 patients underwent both procedures. Based on the results of the aforementioned scintigraphies or the presence of clinical indications for the assessment of VUR, some patients underwent voiding cystoure-

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thrography or direct radionuclide cystography, whereas others with no such indications were considered negative for VUR after a 6-month period of symptom-free follow-up. All patients had undergone ultrasonographic evaluation within 1 week of DMSA renal imaging and/or dynamic renal scintigraphy. Severity of PC dilatation was graded as none, mild, moderate, and severe according to the system used by the Society for Fetal Urology.[11] All patients with dilated PC system on ultrasonographic analysis underwent further assessment with dynamic renal scintigraphy.

Radiopharmaceutical Administration and Image Acquisition

The activity for injection of Tc-99m-DMSA (AEOI, Tehran, Iran) was calculated using a body surface area scaling factor on the adult dose activity of 5 mCi (185 MBq).[12] Two and a half hours after injection, anterior, posterior, and posterior oblique images of both kidneys were acquired using a single-head gamma camera (model DSX, Summit Medical Vision, France) fitted with a low-energy, parallel-hole, high-resolution collimator. A zoom factor of 1.33 to 2 was used. Images were obtained with 500k counts for each view using a 256 × 256 matrix. Particular attention was paid to avoid patient's movement during image acquisition. Imaging was repeated when movement was suspected. For dynamic renal scintigraphy, Tc-99m *N,N*-ethylenedicysteine (EC) (AEOI, Tehran, Iran) was used. The activity for injection was calculated using a body surface area scaling factor on the adult dose of 8 mCi (296 MBq).[12] Imaging was performed in the posterior view for 35 minutes using a 128 × 128 matrix. Lasix was given 18 minutes after radiotracer injection.

Image Processing, Defining the Renal Long Axis, and Measuring the "Renal Angle"

For DMSA renal scintigraphy, posterior image was used to define renal long axis, whereas for dynamic renal scintigraphy, the initial cortical uptake images (minutes 2 to 5) were used. Renal long axis was defined by drawing a line passing through the upper and lower poles of each kidney, and the angle between this line and another line that was drawn parallel to the longitudinal axis of the patient's body was measured ("renal angle") (Fig. 1). The above-mentioned lines were drawn, and the "renal angle" was measured by 2 nuclear medicine physicians blinded to each others' measurements and the clinical diagnosis of the patient. The mean value of these 2 independent measurements was used as the final result for the "renal angle." Different age-groups were defined (Table 1). For each age-group, mean "renal angle" was calculated in normal kidneys. These calculated values were then subtracted from the measured "renal angle" for each abnormal kidney. The result was defined as "age-corrected renal angle."

Statistical Analysis

Data were expressed as mean values ± 1 standard deviation and maximum and minimum values. For calculation of the cutoff value at which "renal angle" and "age-corrected renal angle" optimally distinguished high-grade UPJ obstruction from other renal conditions, receiver operating characteristic (ROC) curves were drawn. Comparisons of 2 mean values were performed by using a paired *t* test and a nonpaired *t* test where appropriate. Statistical multigroup comparisons were performed with analysis of variance followed by Tukey multiple comparison tests with correction. All statistical analyses were performed using SPSS 11.5 for Windows software. Statistical significance was set as a P value of ≥0.05.

RESULTS

Three hundred eleven patients (622 kidneys units) entered into the study from January 2005 until October 2007, of which 183 cases were female (58.8%) and 128 were male (41.2%) with mean age of 41.8 ± 37.4 months (range: 0.5–156 months).

Of the total 622 kidney units, 323 (51.9%) were normal, 98 (15.8%) had low-grade VUR, 50 (8.0%) had moderate VUR, 88 (14.1%) had severe VUR, 40 (6.4%) had high-grade UPJ obstruction, 17 (2.7%) had nonobstructive dilatation of the renal pelvis, and 6 (1.0%) had ureterovesical junction obstruction.

In normal kidney units, the right "renal angle" was significantly smaller than the left side (11.1 ± 4.3 [range: 1.0–25.5] vs. 12.4 ± 4.5 [range: −2.5–27.0], P = 0.04). The mean "renal angle"

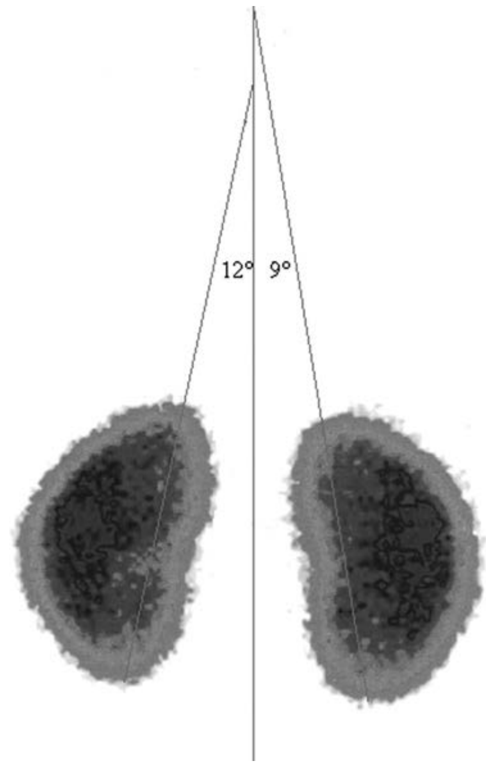

FIGURE 1. Renal long axis is defined by passing a line through the superior and inferior poles of each kidney. The angle between this line and the longitudinal body axis is defined as "renal angle." Right and left "renal angle" are 9 and 12 degrees, respectively, in this patient with no renal pathology.

TABLE 1. Mean "Renal Angle" in Different Age-Groups in Cases With Normal Kidneys

Patients' Age-Group (Age in Months)	No. Patients	Mean "Renal Angle" (P = 0.005)	SD
≤6 mo	40	13.1	4.0
6<age≤12 mo	56	11.2	4.2
12<age≤24 mo	47	10.9	4.0
24<age≤36 mo	26	10.4	5.4
36<age≤48 mo	34	10.7	3.4
48<age≤60 mo	28	12.1	4.1
60<age≤120 mo	87	12.9	4.6
120 mo<age	5	15.0	2.5

SD indicates standard deviation.

TABLE 2. Mean "Renal Angle" and Mean "Age-Corrected Renal Angle" in Different Renal Pathologies

	No. Kidney Units	Mean "Renal Angle" (P = 0.000)	SD	Mean "Age-Corrected Renal Angle" (P = 0.000)	SD
Renal diagnosis					
Normal	323	11.7	4.4	0.0	4.2
Mild VUR	98	11.9	5.5	0.7	5.2
Moderate VUR	50	14.1	6.3	2.3	6.0
Severe VUR	88	17.6	7.9	5.6	7.8
UPJ obstruction	40	28.5	9.9	16.0	9.9
Nonobstructive dilatation of the renal pelvis	17	16.7	5.0	5.1	5.0
UVJ obstruction	6	19.2	8.1	5.5	7.8

SD indicates standard deviation; VUR, vesicoureteral reflux; UPJ, ureteropelvic junction; UVJ, ureterovesical junction.

TABLE 3. Mean "Renal Angle" and Mean "Age-Corrected Renal Angle" in Different Severities of PC Dilatation of the Kidneys

	No. Kidney Units	Mean "Renal Angle" (P = 0.000)	SD	Mean "Age-Corrected Renal Angle" (P = 0.000)	SD
Severity of PC system dilatation					
No dilatation	383	11.4	4.5	−0.1	4.3
Mild dilatation	54	12.1	4.4	0.4	4.4
Moderate dilatation	56	17.5	6.5	5.3	6.4
Severe dilatation	129	21.1	9.7	9.0	9.7

SD indicates standard deviation; PC, pyelocalyceal.

in normal kidneys was 11.3 degrees in girls and 12.4 degrees in boys (P = 0.052).

Table 1 shows the mean "renal angle" in different age-groups in normal kidney units (P = 0.005). Although the P value was <0.05 for the mean "renal angle" in different age-groups in normal cases, post hoc analysis showed no significant difference between any of the 2 different age-groups. Table 2 shows mean "renal angle" and mean "age-corrected renal angle" in different renal pathologies (P = 0.000).

No dilatation of the PC system was noted in 383 kidneys (61.6%), whereas mild, moderate, and severe dilatation was seen in 54 (8.7%), 56 (9.0%), and 129 (20.7%) of the kidneys, respectively. Table 3 shows the mean "renal angle" and mean "age-corrected renal angle" in different severities of renal PC dilatation.

ROC curve was drawn for diagnosing PC dilatation based on the "renal angle," using the ultrasonographic findings as the gold standard. The area under the curve was equivalent to 0.80 (Fig. 2A). Using the cutoff point of 13.75 degrees, the sensitivity and specificity of the "renal angle" to diagnose the presence of ultrasonographically- detected moderate-to-severe degrees of PC dilatation were calculated to be 74.6% and 70.7%, respectively.

Considering that the highest values for mean "renal angle" were obtained for kidneys with the diagnosis of high-grade UPJ obstruction (Fig. 3), ROC curves were drawn for diagnosing this renal pathology using the "renal angle" as well as "age-corrected renal angle" (Fig. 2B, C).

ROC curve analysis (Fig. 2B) shows that using a "renal angle" cutoff value of 18.7 degrees, 85% sensitivity and 85% specificity can be achieved for the diagnosis of high-grade UPJ obstruction. To reach even higher specificity, a cutoff value of 20.7 degrees can be adopted, which results in 90% specificity and a decrease in the sensitivity to 72.5%. ROC curve of "age-corrected renal angle" (Fig. 2C) reveals that a 6.0-degree deviation of the "age-corrected renal angle" has 80% sensitivity and 82% specificity for the diagnosis of high-grade UPJ obstruction. Again, to achieve a higher specificity, an 8.9-degree deviation in the "age-corrected renal angle" can be used, which increases the specificity to 90% and decreases the sensitivity to 72.5%.

Considerable alteration in renal long axis is also noted in patients with severe VUR. ROC curves were also drawn for diagnosing severe VUR using the "renal angle" as well as "age-corrected renal angle" (Fig. 2D, E). For the diagnosis of severe VUR, ROC curve analysis (Fig. 2D) showed that using a "renal angle" cutoff value of 14.7 degrees would lead to 60% sensitivity and 70% specificity. Using "age-corrected renal angle," a cutoff value of 3.9 degrees is consistent with 60% sensitivity and 73% specificity for the diagnosis of severe VUR (Fig. 2E).

DISCUSSION

The arbitrary definition of the normal renal long axis describes it as either paralleling the psoas muscle or intersecting the vertebral body of T10.[13,14] Although few reports have been directed to normal values of the renal long axis and its changes in different conditions in the radiologic renal evaluation,[14] there are no such studies using scintigraphic procedures.

Best et al[14] have evaluated renal long axis in 2 different age-groups of the adult population and have reported a more vertical long axis as age increases. Also Chiari and Braganza reported that up to the age of 11 years, in both boys and girls, the renal angle increases without side difference.[9] These authors emphasized that the lateral contour of psoas muscle changes in similar fashion.[9]

To the best of our knowledge, there is no report assessing the above findings by nuclear medicine procedures. As shown in Table 1, in our normal pediatric population, mean "renal angle" has decreased from 13.1 degrees in newborns to 10.4 degrees in children in their third year of life. Subsequently, the mean "renal angle" gradually increases and finally reaches to 15.0 degrees in those who are older than 10 years, an increasing pattern similar to that observed by Chiari and Braganza.[9] This latter value is approximating the renal angle (17 degrees) measured by Best and his colleagues[14] in the normal adult population evaluated during intravenous urography. It can be stated that in the pediatric population, the "renal angle" decreases initially, whereas after 3 years of age, it starts to reach to the adult value gradually.

Similar to the findings of Best et al,[14] the results of the current study show that mean "renal angle" and its variation (standard deviation and range) are higher in the left kidney as compared with the right one. A possible explanation for such finding is increased renal mobility associated with a longer renal vein on the left and the stabilizing influence of the liver on the right kidney.

On the other hand, there are only few reports concerning alteration of "renal angle" in pathologic conditions. One of these rare reports is Fernbach et al,[15] in which they have confirmed abnormal renal long axis in children with spina bifida and gibbus deformity. In fact, their study has focused on the effects of extrarenal pathologies on renal long axis changes, without assessing the effects of intrinsic renal pathologies on renal long axis and "renal angle."

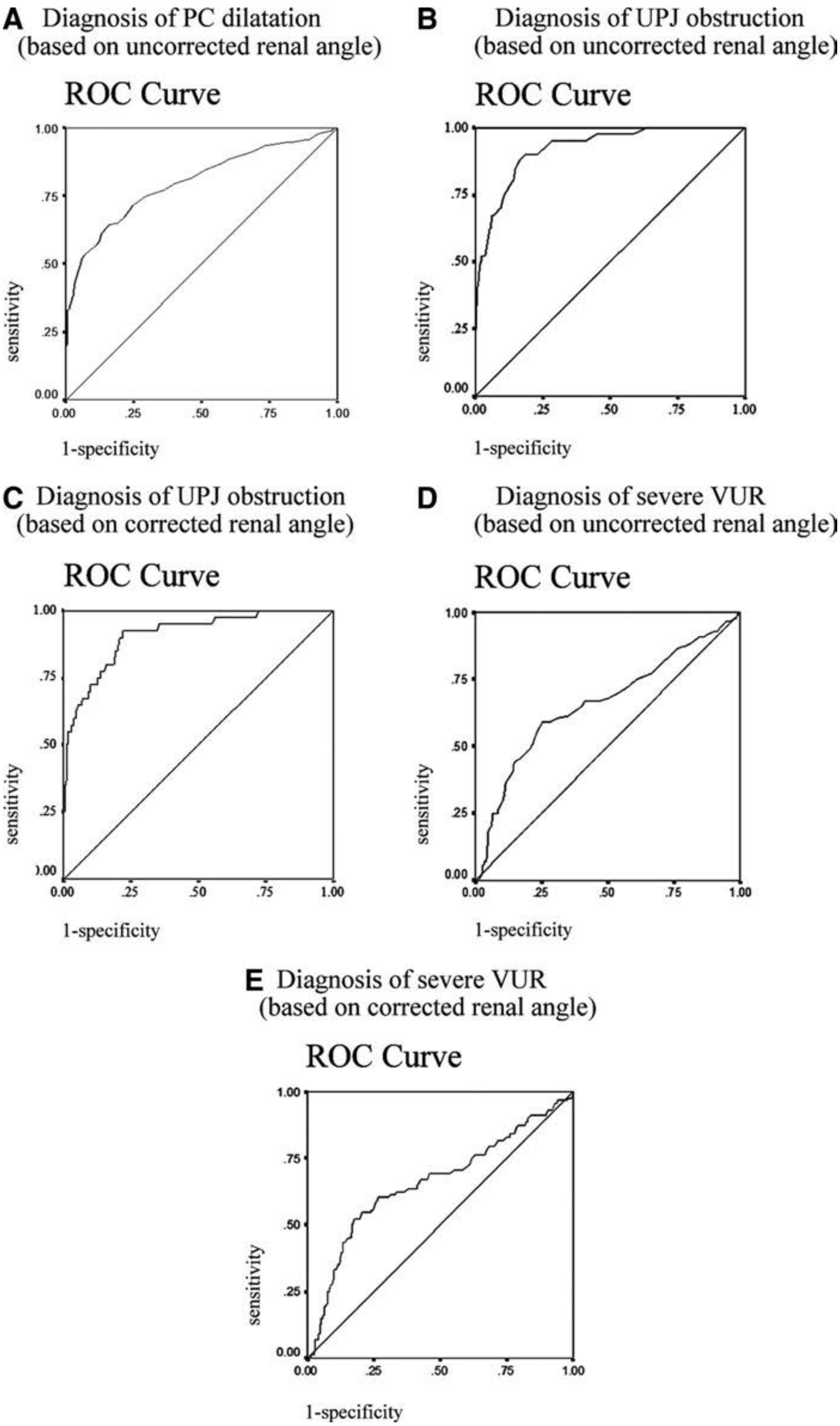

FIGURE 2. A, ROC curve for diagnosing PC dilatation based on the "renal angle;" **B,** ROC curve obtained for detecting UPJ obstruction using "renal angle" (area under the curve = 0.922); **C,** ROC curve obtained for detecting UPJ obstruction using "age-corrected renal angle" (area under the curve = 0.910); **D,** ROC curve obtained for detecting severe VUR using "renal angle" (area under the curve = 0.660); and **E,** ROC curve obtained for detecting severe VUR using "age-corrected renal angle" (area under the curve = 0.660).

The only studies that have evaluated renal long axis in a renal anomaly are those which evaluated the renal long axis in patients with a horseshoe kidney[16–18]; all in consensus report considerable vertical alignment of these kidneys, when compared with normal ones.

To the best of our knowledge, this is the first study that evaluates alterations in the renal long axis and "renal angle" in different urinary tract pathologies using scintigraphic procedures. Based on the results of our study, renal scintigraphy (even static images) can provide important but indirect clues for the diagnosis of

UPJ obstruction. Our study showed that mean "renal angle" was significantly higher in patients with UPJ obstruction (28.5 degrees), when compared with mean "renal angle" in normal kidneys (11.7 degrees) ($P < 0.001$).

The change in renal axis after PC dilatation (due to VUR, high-grade UPJ, and/or UVJ obstruction) is possibly caused by the simple mechanical effect of the dilated system in changing the position of the kidneys relative to the adjacent structures. As can be expected, the severity of change in the renal axis is proportional to the severity of the dilatation of the PC system, grade of the VUR, and the severity of the UPJ or UVJ obstruction. This change is more pronounced in the left side possibly because of the stabilizing effect of the shorter right renal vein and liver on the right kidney.[14]

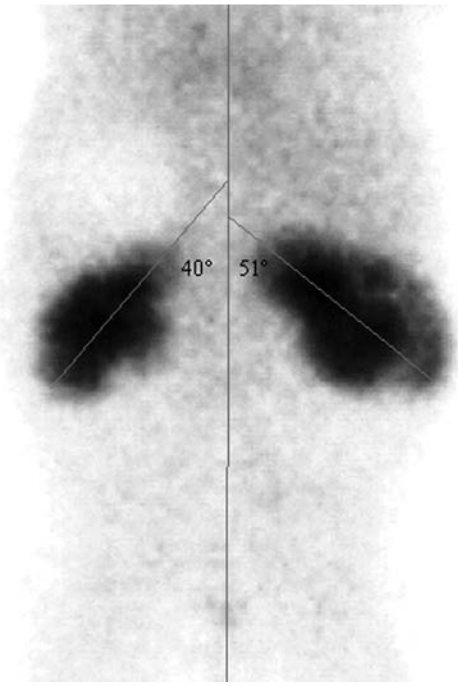

FIGURE 3. Considerable renal axis deviation ("renal angle" = 51 and 40 degrees in the right and left side, respectively) is visible in a patient with bilateral high-grade obstruction at UPJ level.

Based on our study results, using static renal scintigraphy, it can be possible to predict the presence of UPJ obstruction in pediatric population with sensitivity and specificity of at least 72.5% and 82%, respectively, using the "renal angle" or "age-corrected renal angle." It is also important to assess the effects of these renal pathologies on "renal angle" in the adult population, while also evaluating the effect of other causes of urinary tract obstruction (eg, obstruction caused by tumors or renal stones) on the "renal angle," which can be the subject of further studies. Findings of the current study also signify the importance of assessing alterations of renal long axis and "renal angle" in renal pathologies using other imaging modalities (eg, ultrasonography).

Another important issue to be addressed in the future studies is assessing the effect of UPJ obstruction treatment on the "renal angle." In one of our studied patients who showed normal right kidney and high-grade UPJ obstruction on the left side on dynamic renal scintigraphy at age 24 days, follow-up dynamic renal study at age 7 months showed spontaneous resolution of obstruction in the left side. The "renal angle" in the left abnormal kidney was 57 and 27 degrees in the first and follow-up scans, respectively (Fig. 4A, B), whereas in the right normal kidney, this angle changed from 28 degrees in the baseline study to 15 degrees in the follow-up imaging. The spontaneous resolution of the neonatal hydronephrosis has been reported in previous studies.[19,20] However, predicting the natural course of hydronephrosis is difficult, and current techniques cannot reliably diagnose obstruction without an observation period.[19] The alteration in the "renal angle" in this patient during the follow-up and at the same time the improvement of obstruction in this period may show the potential value of "renal angle" as an index in the follow-up of patients with antenatal and postnatal hydronephrosis.

Although it is not as impressing as that of UPJ obstruction, considerable renal long axis deviation was also noted in kidneys with severe VUR (17.6 degrees vs. 11.7 degrees in normal kidneys). It can be postulated that static renal scintigraphy can again be a useful tool to give a gross estimate of the presence of severe VUR, which of course needs to be verified by VCUG or DRNC.

The results of the current study can be useful in predicting the presence of other renal pathologies with reasonably good sensitivi-

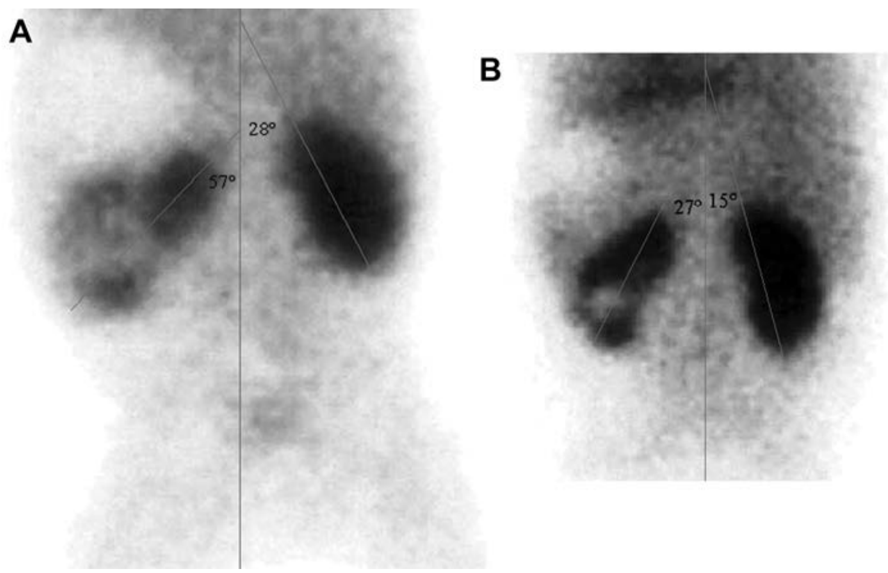

FIGURE 4. A, Initial cortical uptake image (minute 3) of an EC renal scintigraphy in a newborn (24 days) showing considerable renal axis deviation ("renal angle"= 57 degrees) in the left side, which showed minimal radiotracer drainage (high-grade UPJ obstruction). "Renal angle" in the normal right kidney is 28 degrees. **B,** Follow-up image of the same patient at 7 months of age, showing spontaneous resolution of obstruction in the left kidney as well as considerable reduction in the measured "renal angle" (27 degrees). The right "renal angle" in this study is 15 degrees.

ties and specificities in patients who have already undergone DMSA renal scintigraphy or other nuclear medicine procedures for UTI, acute pyelonephritis, or other renal problems.

As the ultimate goal of any diagnostic imaging procedure is the patient's well-being, all additional information obtained from DMSA images that inherently could lead to alteration of patient management should be reported and interpreted. In fact, as there is the opportunity to reveal other pathologic conditions, the interpretation of DMSA scintigraphy should not be limited to detection of cortical scar. Apart from probable increase in the specificity of the test, such findings from DMSA study can have a considerable impact on redirecting the attending physician's attention to other renal problems (eg, UPJ obstruction, VUR, UVJ obstruction), which predispose to or simply coexist with the child primary renal problem (eg, UTI, acute pyelonephritis).

CONCLUSIONS

Renal axis and "renal angle" can give indirect but useful information regarding the presence of urinary tract abnormalities, especially high-grade UPJ obstruction, at least in children. This angle can be easily calculated with images obtained by renal scintigraphy (DMSA scan, initial cortical uptake images of dynamic renal scan), adding another potentially useful application to these nuclear medicine procedures.

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