Iran J Nucl Med. 2026;34(2):154-160 [Serial No. 67]

Homepage: https://irjnm.tums.ac.ir/

ORIGINAL RESEARCH ARTICLE

Dynamic renal scintigraphy in pediatric upper urinary tract malformations in Ouagadougou (Burkina Faso): A cross-sectional study of 51 cases

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ARTICLE INFO

Article History:
Received: 14 February 2026
Revised: 03 June 2026
Accepted: 12 June 2026
Published Online: 28 June 2026

Keyword:
Renal scintigraphy
Kidney
Pyeloureteral junction syndrome
DTPA
Malformative uropathies

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ABSTRACT

Introduction: Malformative uropathies are particularly common in children. They primarily concern the excretory tract and are readily obstructive. Imaging plays a vital role in their characterization and management. This study aimed to evaluate the contribution of renal scintigraphy (SR) in the management of malformative uropathies of upper excretory tract.

Methods: This is a retrospective study that included renal scintigraphy examination records carried out from January 31, 2020 to January 31, 2023 in children aged 0 to 15 years in the nuclear medicine department of the Yalgado Ouedraogo University Hospital in Ouagadougou.

Results: The average age of children was 4.7 years with extremes of 5 days and 14 years. The M/F sex ratio was 3.63. Pyeloureteral junction syndrome represented 78.43% of cases (n=40). The malformations investigated were mainly bilateral (n=25). Morphological analysis of RS revealed hypotrophy-type abnormalities (n_{right} = 5; n_{left} =3), right hypertrophy (n = 4), pelvic kidney (n_{right} = 1; n_{left} =2), megaureter (n_{right} = 2; n_{left} =1), absence of the left kidney (n= 2). Renal units (51 x 2) were classified into 4 groups according to the values of Relative Renal Function (RRF). Group 1 with RFR 10% had a number of 21 renal units (n_{right} = 11; n_{left} = 10). Group 2 was characterized by 10 ≤ RRF < 43%: its number was 24 renal units (n = 12 on each side). Group 3 was characterized by 43 ≤ RRF < 57%: it totaled 14 renal units n_{right} = 8 ; n_{left} = 6. Group 4 was characterized by an RRF > 57%: it totaled 43 renal units (20 on the right and 23 on the left). 58 renal units (30 on the right and 28 on the left) had delayed uptake. Drainage was mainly impaired (67.85%) with 3 left non-funtioning kidneys and 2 right non-funtioning kidneys. The hyperdiuresis test carried out according to the F+20 protocol revealed 30 mechanical obstuctions (14 on the right and 16 on the left), 39 functional obstacles (18 on the right and 21 on the left) and 7 equivocal obstacles (5 on the right and 2 on left).

Conclusion: Renal scintigraphy with induced hyperdiuresis test is a sensitive examination in the characterization of the malformative pathology of upper excretory tract. It makes it possible to establish the etiological diagnosis, essential information for the therapeutic decision.

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How to cite this article: Ki TR, Djigo S, Drame B, Zoungrana M, Hien S, Ouedraogo G, Adambounou K. Dynamic renal scintigraphy in pediatric upper urinary tract malformations in Ouagadougou (Burkina Faso): A cross-sectional study of 51 cases. Iran J Nucl Med. 2026;34(2):154-160.

https://doi.org/10.22034/irjnm.2026.130505.1757

INTRODUCTION

Urological malformations represent a major cause of chronic kidney disease in children. They primarily affect the upper excretory tract and are frequently obstructive [1]. Furthermore, pyeloureteral junction syndrome (PUJS) is the most common congenital anomaly in children and the leading cause the urinary tract dilation [2]. Medical imaging plays an important role in the management of malformative uropathies in general and in those of upper excretory tract in particular. If morphological imaging techniques are essential in the diagnosis of these pathologies, functional imaging techniques such as scintigraphic imaging are essential not only in the exploration of functional repercussions but also in their therapeutic monitoring. To this end, this non-invasive and low-radiation modality allows both to be specified the consequences of the malformation and to be determined its functional impact [3]. Despite the numerous challenges related to the regular operation of a nuclear medicine service in Africa, this possibility of functional exploration has existed in Burkina Faso since 2014. The aim of this study was to evaluate its contribution to the management of malformative uropathy of the upper excretory tract in children.

METHODS

We conducted out a cross-sectional study, with retrospective collection. This study included records of renal scintigraphy (RS) examinations carried out from January 31, 2020 to January 31, 2023 (a 3-years period) in children aged 0 to 15 years in the nuclear medicine department of the Yalgado Ouedraogo (YO) University Hospital in Ouagadougou.

We included:
- Children who underwent RS with hyperdiuresis test;
- Children referred for congenital malformation of the upper urinary tract.

The following parameters were analyzed:
- General characteristics: age, sex, origin
- Examinations and their diagnostic contributions: Indications, administered dose, isotopic nephrogram parameters, scintigraphic diagnosis following interpretation.

The equipments

The following equipment was used:
- A wide-field MEDISO NUCLINE ™ SPIRIT DH-V dual-head camera gamma, equipped with a low-energy, high-resolution parallel collimator;
- A computer for recording and adjusting acquisitions;
- A computer for storing, processing and analyzing data.

Radiopharmaceutical

The radionuclide used: Technetium-99m decays by isomeric transition with emission of gamma radiation of 140.5 keV.

Labelling agent: Diethylenetriaminepentaacetic acid (DTPA) is commercially available as a lyophilisate in sterile, ready-to-use vials.

The radiotracer obtained after labelling: [^{99m}Tc]Tc-DTPA: The activity injected based on a maximum activity of 300 MBq for an adult is calculated based on the child's weight, with a minimum activity of 20 MBq. Administration was performed intravenously**.** The injection is done according to the F + 20 scheme, Lasix ® (1mg/Kg without exceeding 20 mg) is injected 20 min after the radiopharmaceutical.

Study protocol

Patient preparation consisted of sufficient prior hydration and voiding immediately before the examination. The children were positioned in the supine position. Total immobilization of patients was respected throughout the scintigraphic examination, if necessary, physical restraint was applied. The gamma camera field included all of the upper urinary tract.

We proceeded with a dynamic acquisition of sequential images in posterior projection in two phases. The first is the angioscintigraphic phase, lasting 60 seconds (at a rate of 6 images of one second each), recorded with a 64 x 64 matrix, during which the first vascular passage of the radioactive bolus was recorded. The second is the nephroscintigraphic phase 44 minutes (comprising 132 images of 20 seconds each) with a matrix of 128 x 128. Furosemide was injected into our patients according to the F + 20 protocol, that is to say 20 minutes after injection of the radiotracer. The interpretation took into account the qualitative parameters of the nephrograms and semi-quantitative isotopic renograms (according to the area under the curve method) obtained after digitized processing of the recorded dynamic sequential images.

Data monitoring and analysis

The data were entered and analyzed by the "IBM SPSS Statistics 25" software. Ethically, the confidentiality and anonymity of those surveyed were respected.

RESULTS

Sociodemographic data

A total of 51 patients aged 5 days to 14 years were included in the study. The mean age was 4.7 years with extremes ranging from 5 days to 14 years. Two patients were under one month of age (5 and 24 days old). Children aged 1 to 5 years were the most represented age group (35.29%). Forty patients were male, representing a sex ratio (M/F) of 3.63.

Figure 1 shows the distribution of patients by age groups. The children referred for RS examination came from YO University Hospital in Ouagadougou (n=36) and Souro Sanou University Hospital in Bobo-Dioulasso (n=13). Two children were referred directly from the Regional Hospital Centers (RHC) of Fada and Kaya.

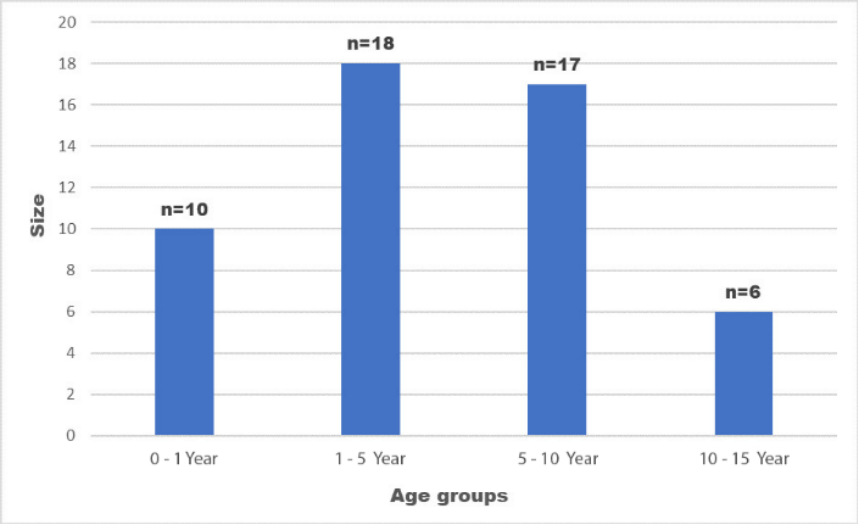

Figure 1. Distribution of patients according to age groups

Clinical data

Diagnostic circumstances: All 51 patients were referred after abdominal ultrasound performed antenatal screening as part of a prenatal assessment (n= 28), painful lumbar symptoms in the child (n=19) and in the context of recurrent urinary tract infections (n=14).

Indications: The main indication for RS was congenital stenosis of the pyeloureteral junction (78.43%) followed by congenital anomalies of the ureter (15.68%) and finally calyceal malformations (5.88%).

Location of malformations: The malformations investigated were predominantly bilateral (n=25). The unilateral malformations involved either the left upper excretory tract (n=9) or the right upper urinary tract (n=17).

Scintigraphic data

The scintigraphic characterization was performed on 102 renal units (51 patients: 51 left units + 51 right units)

Analysis of sequential images: Morphological analysis of RS revealed a predominance of normal findings estimated at 39 normal appearances on the right and 43 on the left. The anomalies identified are recorded in Table 1. We identified 3 cases of pelvic renal ectopia, including one on the right and two on the left.

Differential renal function: Renal units (51 x 2) were classified into 4 groups according to their Relative Renal Function (RRF) values:

- Group 1, with RRF < 10% comprised 21 renal units ($n_{right} = 11$; $n_{left} = 10$).
- Group 2, with 10 % ≤ RRF < 43% comprised 24 renal units (n = 12 on each side).
- Group 3, with 43 % ≤ RRF < 57% comprised 14 renal units ($n_{right} = 8$; $n_{left} = 6$).
- Group 4, with RRF > 57%, comprised 43 renal units (20 on the right and 23 on the left).

Table 2 summarizes the values of differential renal function values for all 102 renal units.

Overall, RRF was severely impaired (< 10%) in 21 renal units (11 on the right and 10 on the left). Additionally, 5 non-functioning kidneys (3 on the right and 2 on the left) were recorded.

Analysis of the isotopic nephrogram: The nephrogram analysis encompassed the assessment of uptake, drainage and the induced hyperdiuresis test. These results are summarized in Table 3. Figure 2 shows sequential images highlighting right pyelocaliceal stasis.

Table 1. Morphological characterization of SRs

Morphological abnormalities	Right Kidney		Left Kidney	
	Size	Percentage %	Size	Percentage %
Renal hypotrophy	5	9.80	3	5.88
Renal hypertrophy	4	7.84	2	3.92
Mega ureter	2	3.92	1	1.96
Pelvic ectopic kidney	1	1.96	2	3.92
Normal appearances	39	76.47	43	84.31
Total	51	100%	51	100%

Table 2. Separate renal function value (RRF)

Separate renal function	Right Kidney		Left Kidney	
	Size	Percentage %	Size	Percentage%
Group 1: RRF < 10%	11	21.57	10	19.60
Group 2: RRF: 10 to 43%	12	23.53	12	23.53
Group 3: RRF: 43 to 57%	8	15.69	6	11.76
Group 4: RRF > 57%	20	39.21	23	45.09
TOTAL UNITS RENALES	51	100	51	100

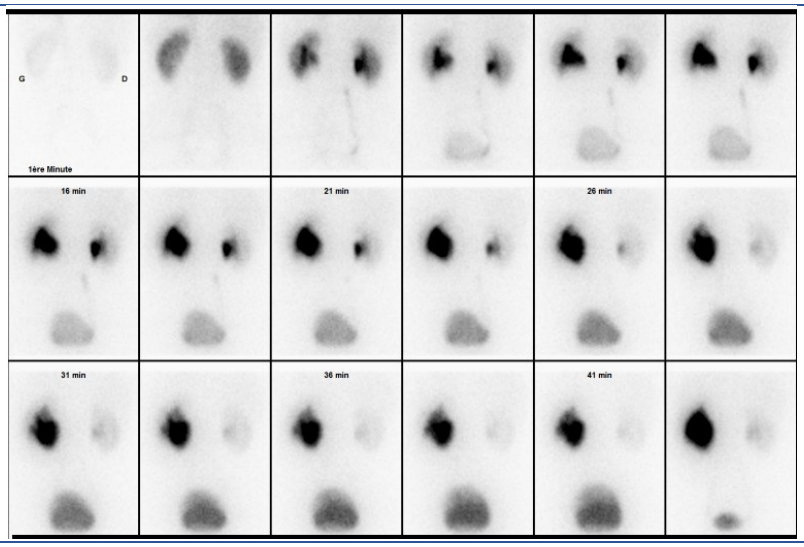

Figure 2. Example of sequential images: Left/right kidney regular contours, fixing the tracer homogeneously on the sum image of parenchymal time. Radiotracer stasis in straight pyelocalic cavities. Persistence of residual activity in the right pyelocalic cavities on the post-mictorial image

Table 3. Analysis of the isotopic nephrogram

		Right Kidney		Left Kidney	
		Size	Percentage %	Size	Percentage %
Capture	Absence	09	17.64	11	21.57
	Normal	12	23.53	12	23.53
	Delayed	30	58.82	28	54.90
	Total capture	51	100	51	100
Drainage	Absent (mute kidney)	03	5.88	02	3.92
	Normal	11	21.57	10	19.60
	Altered	37	72.55	39	76.47
	Total drainage	51	100	51	100
Induced hyperdiuresis test	Normal	14	27.45	12	23.53
	Organic obstacle	14	27.45	16	31.37
	Functional obstacle	18	35.29	21	41.17
	Equivocal Obstacle	5	9.80	2	3.92
	Total hyperdiuresis test	51	100	51	100

DISCUSSION

Socio-demographic characteristics

The main age of our study population was 4.7 years. In general, the mean age of diagnosis congenital malformative uropathies have been significantly influenced by the widespread use of obstetric ultrasound. Malformative uropathies of the upper urinary tract that escape antenatal diagnosis are identified at a varying mean age depending on the series. The reported mean age at diagnosis is 11 months in France [4]; 27.8 months in Algeria [5] and 12.08 months [6] in Benin. In reality the mean age recorded in our study does not reflect the actual age at diagnosis of uropathy in the children concerned.

We also noted 3.92% of patients (n=2) were under one month of age. While there is no contraindication of RS in newborns. However, the literature data is consistent on the fact that RS is only relieable after the age of one month. Indeed, in newborns, the upper urinary tract is characterized by its high compliance, whereby even minor flow disturbances can lead to particularly significant dilation [4]. Large neonatal dilations can subsequently have a spectacular spontaneous resolution, particularly in ureterohydronephrosis. Dilation of upper urinary tract plays a protective role by limiting the rise in pressure, which likely explains the significant potential for functional recovery in the newborn [2]. Furthermore, performing the hyperdiuresis test in newborns carries a risk of false-positive results. The low concentration power of urine (600 to 700 mOsmoles/L) causes significant urine flow. A furosemide test performed under conditions of near-maximal diuresis may therefore yield false-positive findings for obstruction. The validity of scintigraphic techniques perfectly demonstrated in children cannot therefore be extrapolated to the newborn period [7].

The clear male predominance observed in our series is consistent with the literature [1, 2, 4].

The majority of children referred from pediatric and pediatric surgery departments Ouagadougou and Bobo Dioulasso, the two main cities of Burkina Faso. The common practice of obstetric ultrasound in these two largest cities of Burkina Faso Ouagadougou does not fully explain this disparity. The low number of patients from rural areas is attribuable to the absence of pediatric surgery services outside major urban centers. Patients from remote areas are referred to urban hospitals, which are responsible for their ongoing care.

Clinical characteristics

Circumstances diagnostic: In our series, antenatal diagnosis was established in 54.90% of cases (n=28). Antenatal diagnosis can be considered a reflection of the level of healthcare development in a given country, the more developed the healthcare system, the higher the rate of antenatal diagnosis. This proportion is insufficiently investigated in sub-Saherian Africa. However, Bouah-Kamon reported a rate of 24% in Ivory Coast [1], compared to 7% in Tunisia [8] and 60-70% in France [4].

Fetal kidney development begins in the 5th week of gestation, but the fetal kidneys can only be clearly visualized on ultrasound at the 12th to 13th week of gestation, with a distinct renal architecture around the 20th week of gestation. The fetal bladder can be visualized at the 10-14th week of gestation, and its emptying at the 15th week of gestation. Its capacity varies from approximately 10 ml to 30 weeks of gestation and 50 ml eventually. Amniotic fluid volume becomes primarily dependent on urine production around 16 weeks of gestation, ranging from 380 ml to 20 weeks of gestation to 800 ml around 28-40 weeks of gestation [8]. In the United States, ultrasound screening for renal and urinary tract abnormalities of the kidneys and urinary tree is done halfway through the 2nd trimester, between the 18th and 20th weeks of pregnancy. However, urinary tract abnormalities have also been described in the third trimester, following a normal morphological ultrasound in the second trimester [4].

Upper urinary tract dilations diagnosed antenatally raise the question of postnatal investigations and management. The risk of significant uropathy is higher when the dilation is significant (greater than 15mm in the 3rd trimester of pregnancy) and as it worsens during pregnancy [9-11]. Recurrent urinary tract infections revealed uropathy in 27.45% (n=14) of cases in our series. An Algerian series from 2014 identified urinary tract infection as the revealing circumstance in 34% of children [12]. E. coli being the germ in question in 71% of cases. A study on the relationship between urinary infection in children and urinary tract malformations conducted in Cotonou in 2013 found that urinary infection was the first revealing situation in a proportion of 28% [6]. Furthermore, lower back pain and dysuria cumulatively represented 66.9% of the circumstances leading to the discovery of congenital uropathies in Mali in 2008 (37% and 25.9% respectively) [13].

Indications

According to Veyrac et al. [14] malformative uropathies of the upper urinary tract are classified as calyceal malformations, pyeloureteral junction stenosis (PUJS) and ureteral malformations. In our series, PUJS was by far the most common indication

(n=40); followed by ureteral malformations (n = 8) and calyceal malformations (n=3). Our results are higher than those reported by Adambounou in 2017 in Dakar [15], where PUJS represented a proportion of 38.3% of his series. This difference is attribuable to the fact that his study was extended to all pediatric uroprophropathies. Ours is specifically interested in congenital uropathies of upper urinary tract. Overall, the literature confirms the clear predominance of PUJS in malformative uropathies in general and in those of upper urinary tract in particular [1, 2, 4].

Location of Involvement: The left kidney was more frequently affected in our series as in the literature [4, 14]. The preeminent damage to the left remains unexplained to date. The proportion of bilateral involvement was 62.5% in our series. In pediatric urology, severe uropathy is defined by bilateral involvement or involvement of a single kidney and pyelic dilation > 20 mm, or with significant cortical thinning in antenatal ultrasound. These severe uropathies present a greater risk of impact on renal function [14].

Scintigraphic data

From a dosimetric standpoint, the radiation exposure induced by dynamic RS is relatively low in infants, the effective dose varies between 11 and 22 mSv/MBq [16], which is often comparable to that of a simple chest X-ray and remarkably negligible when compared to intravenous pyelography [17].

The radiopharmaceutical used: For dynamic RS, two radiopharmaceuticals available. One is excreted mainly by tubular secretion: ^{99m}Tc-Mercaptoacetyltriglycine ([^{99m}Tc]Tc-MAG3) and the other by glomerular filtration: diethylenetriaminepentaacetate, [^{99m}Tc]Tc-DTPA. [^{99m}Tc]Tc-MAG3 has a higher renal extraction fraction than [^{99m}Tc]Tc-DTPA [8, 15, 18]. In young children, preference should therefore be given to [^{99m}Tc]Tc-MAG3, a radiopharmaceutical which provides good quality images and makes it possible to assess differential renal function from as early as the end of the first week of life [18]. The higher cost of MAG 3 compared to DTPA is the main factor hindering its use in our setting.

Morphological and topographical anomalies: RS, although functional imaging, can visualize morphological and topographical anomalies. This is illustrated by the 3 cases of renal ectopia diagnosed in our series. Ghfir demonstrated the contribution of RS to the therapeutic strategy in obstructive forms of renal ectopia [19].

Functional anomalies: Relative renal function (RRF) was significantly impaired (< 10%) in 21 renal units (11 right and 10 left). Dynamic RS remains the gold standard for determining separate renal function in children [15, 16]. The hyperdiuresis test carried out at the 20th minute (protocol F+20) made it possible to classify renal units as organic obstruction (27.45% on the right and 23.53% on the left), functional obstruction (35.29% on the right and 31.37% on the left) and in equivocal obstruction (9.80% on the right and 3.92%) on the left. In a series including all pediatric nephrouropathies, Adambounou found in 2017 [15] /: impaired renal drainage (elimination) for 37.9% of right kidneys and 58.6% of left kidneys. Furthermore, we recorded 05 mute kidneys (03 right and 02 left).

Renal silence is the feared terminal course of neglected obstructive malformative uropathies. SR has high diagnostic performance in detecting mute kidneys with a positive predictive value better than intravenous pyelography [19]. Ghfir reported in a study carried out in Morocco that in 20 cases of renal silence labeled with intravenous pyelogram, RS had allowed a better assessment of the functional parenchymal potential which varied from 11% to 31%, thus calling into question the precision of the intravenous pyelography in the assessment of renal function at an advanced stage of the uropathy in question [19]. RS is therefore a diagnostic tool making it possible to overcome the limits of intravenous pyelography with regard to the precise evaluation of the functional value of pathological kidneys.

Limitations of the study

Data collection was hampered by the absence of a computerized archiving system for patient files. Some files were incomplete and lacked essential information, particularly regarding clinical data.

CONCLUSION

Imaging plays a fundamental role in the management of malformative uropathies in children. While renal ultrasound is the cornerstone, dynamic RS remains the examination of choice for determining the relative renal function of each renal unit. This isotopic imaging modality has been available in Ouagadougou, Burkina Faso since 2014. It is inexpensive, simple to produce and minimal radiation. Our study highlights the fundamental role of pediatric RS in pediatric surgery. RS with an induced hyperdiuresis test is a sensitive examination in the characterization of the malformative pathologies of upper urinary tract. It makes it possible to establish an etiological diagnosis, which is essential information for therapeutic decision-making. Despite advances in urinary tract assessement on MRI, isotopic investigations which require neither contrast

material nor sedation of the child occupy an indisputable place in the management of upper urinary tract dilations. The predominantly urban origin of patients reminds us that considerable efforts must be undertaken to strengthen the availability of nuclear medicine services in Africa and Burkina Faso. More extensive studies could clarify the contribution of dynamic RS in the progressive monitoring of malformative uropathies of the urinary tract in children.

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