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Evaluation of Renal Function in Infants and Children with ^{99m}Tc-DTPA Renography

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ABSTRACT

^{99m}Tc-DTPA renographies performed in thirty-two children younger than 5 years were retrospectively studied to investigate its feasibility for the assessment of pediatric renal function. Patients were categorized into two groups ; control group of 17 patients with normal renal function, and obstructive group of 15 patients with hydronephrosis. This study included glomerular filtration rate (GFR), renographical imagings, and renogram pattern. The following results were obtained.

(1) Normal ranges of total GFR from this study were as follows ; 50 to 60 ml/min in infants younger than three months, 60 to 80 ml/min in infants aged 3-12 months, and more than 80 ml/min in infants older than one year. The obstructive group could not be distinguished from the control group by the values of split GFR.
(2) All patients of the control group showed the standard pattern on renograms. Fifteen of 19 (78.9%) kidneys with hydronephrosis showed the obstructive pattern.
(3) Seventeen of 19 (89.5%) kidneys with hydronephrosis showed marked radioisotope retention in the pelvicocalyceal system.
(4) Diuretic renography was useful to identify the anatomical obstruction of the urinary tract.

In conclusion, evaluation of renal function with ^{99m}Tc-DTPA renography is useful in infants and children.

KEY WORDS

^{99m}Tc-DTPA, Glomerular filtration rate (GFR), Hydronephrosis, Diuretic renography, Infants

INTRODUCTION

Radioisotope renography can provide the clinician with an overall estimate of renal function including glomerular filtration rate (GFR)[1)-4)]. Anomalies of the urinary tract are frequently detected by ultrasonography in children, and it is important to assess the function of anomalous kidney for therapeutic decisions. However, it is questionable whether we could appropriately evaluate pediatric renal function using radioisotope studies because we use the formulae to estimate GFR derived from the results of adults and kidney depth estimated from patient's height and weight. In addition, it was also necessary to know normal ranges of GFR in children when radioisotope studies were used.

In this study, we investigated the feasibi-

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Table 1　Clinical data and image interpretation in the obstructive group.

NO	Age	Sex	C.D.	Site	GFR L	GFR R	GFR T	Renogram pattern L	Renogram pattern R	Image K.S.	Image Site	Image R.R.	Image P.D.	Image U.V.
1	5D	M	HYD	L	22	21	43	OB	DY	Normal	L	+	-	-
2	1M	M	HYD, UPste	B	36	28	64	OB	OB	Normal	B(L>R)	+	-	-
3	1M	F	HYD	L	23	21	44	OB	DY	Normal	L	+	-	-
4	2M	M	HYD, VUR	B	19	8	27	DY	HF	Normal	B(L<R)	+	-	-
5	3M	M	HYD, UPste	R	38	35	72	DY	OB	Normal	R	+	-	-
6	5M	M	HYD	L	18	19	37	OB	DY	Normal	L	+	-	-
7	5M	M	HYD	L	38	30	68	OB	OB	Normal	L	+	-	-
8	6M	M	HYD, UPste	L	11	85	96	OB	DY	L-swelling		-	-	-
9	8M	M	HYD, UPste	R	44	49	93	DY	OB	Normal	R	+	+	-
10	10M	M	HYD, VUR	R	14	33	47	HF	DY	Normal	R	+	-	+
11	1Y2M	M	HYD	L	23	34	57	OB	DY	Normal	L	+	-	-
12	1Y3M	M	HYD	R	31	58	89	HF	OB	L-HYP	R	+	+	-
13	1Y6M	F	HYD, UPste	B	0	63	63	HF	OB	L-NON	R	+	+	-
14	3Y8M	F	HYD, VUR	R	4	68	72	HF	OB	L-HYP	R	+	-	-
15	4Y4M	M	HYD, UPste	B	55	49	103	OB	OB	Normal	B(L=R)	+	+	-

C.D.=Clinical diagnosis, HYD=Hydronephrosis, UPste=Ureteropelvic junction stenosis, VUR=Vesicoureteral reflux
GFR=Glomelular filtration rate, L=Left, R=Right, T=Total, B=Bilateral, K.S.=Kidney size, R.R.=Radionuclide retention
P.D.=Pelvic dilatation, U.V.=Ureteral visualization, HYP=Hypoplasia, NON=Non-visualization

lity of renography for the assessment of pediatric renal function.

MATERIALS AND METHOD

Patients

Thirty-two children (22 boys and 10 girls) undergone renographies were studied. Their ages ranged from five days to five years. Patients were classified into two groups.

Fifteen patients were found to have hydronephrosis (left in six, right in five, and bilateral in four), which were diagnosed antenatally in five patients and postnatally in 10 patients by ultrasonography and intravenous pyelography (IVP) (Table 1). These patients were classified as obstructive group.

Of the remainder, six patients were diagnosed to have urinary tract infection, four proteinuria, two hematuria, and two hypertension. The other three children underwent renographies for the examination of renal function before chemotherapy for malignant tumors.

We categorized these 17 patients in the control group because it is not permitted to use healthy children as normal volunteers of radioisotope study. Their renal functions were regarded as normal, since they did not show renal abnormalies with ultrasonography, IVP and blood chemistry.

Renography and GFR determination

All patients were well hydrated and sedated if required. Immediately after intravenous injection of 15 MBq to 70 MBq (according to body weight) of ^{99m}Tc-diethylenetriamine pentaacetic acid (DTPA), data aquisition was performed on supine position for 20 minutes (1 sec per frame for 80 sec and 20 sec per frame for 1120 sec) by a scintillation camera (GCA-901A, Toshiba)[5]. Using 64×64 matrix on a computer processing system (GMS-550, Toshiba), dynamic images of 16 frames with 5 sec per frame and then serial images of 15 frames with 80 sec per frame were acquired. For the diuretic renography, 0.5mg/kg of furosemide was intravenously administered from 15 minutes after the injection of ^{99m}Tc-DTPA. The regions of interest (ROIs) were placed on both kidneys with a background ROI under each kidney, and the time-activity curve (renogram) of each kidney was generated. Tmax (time from injection to time of maximum count rate) and T1/2 (time from maximum activity above the kidney to time of half maximum count rate) were obtained. For the analysis, renograms were categorized into four types (Fig. 1) : type ST (standard pattern), Tmax is less than five minutes and renal excretion is prompt ; type DY (delayed pattern), slow renal excretion regardless of Tmax ; type OB (obstructive

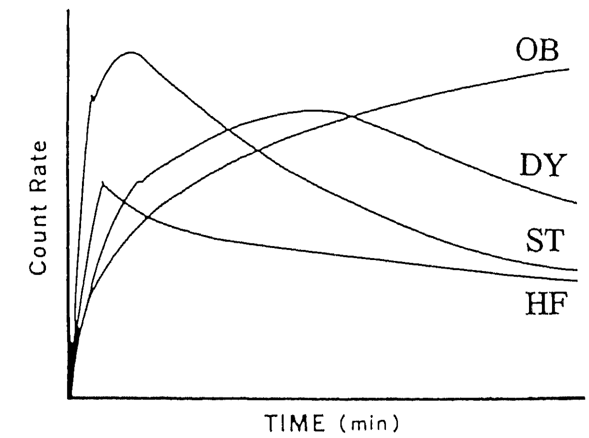


Fig. 1 Renogram pattern
ST, standard pattern ; DY,delayed pattern ; OB, obstructive pattern ; HF, hypofunctioning pattern

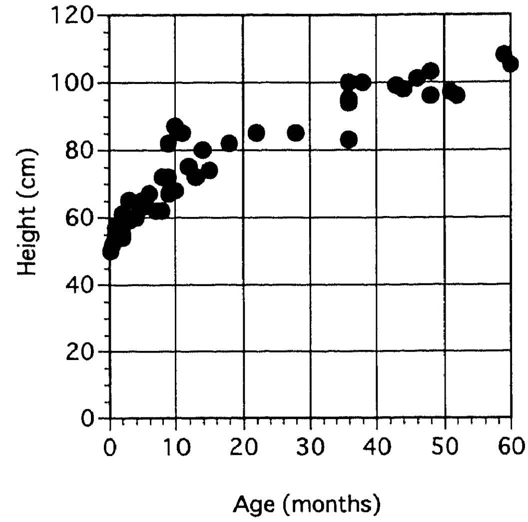


Fig. 2 Correlation between age (months) and height (cm)

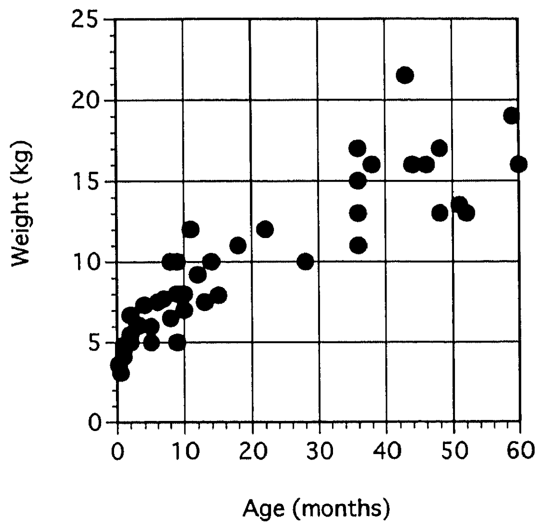


Fig. 3 Correlation between age (months) and weight (kg)

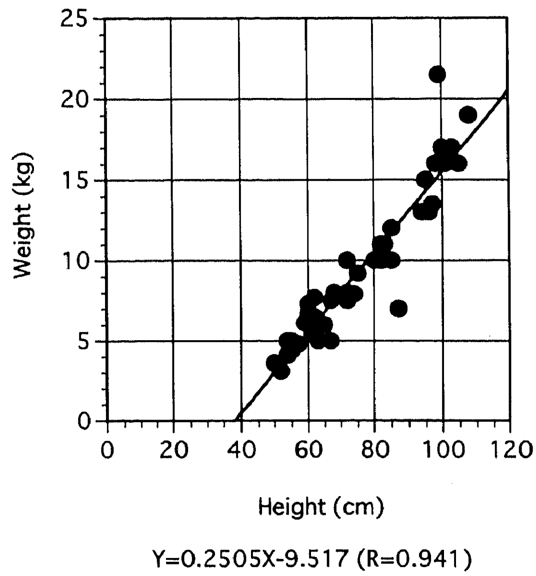


Fig. 4 Correlation between height (cm) and weight (kg)

pattern), Tmax occurs at the end of the preset time ; and type HF (hypofunctioning pattern), renal washout parallels the cardiac blood pool on background. Total GFR was calculated using the counts in the ROI from 2 to 3 minutes after the injection[5]. Kidney depth was estimated from patient's weight and height by the formulae ; left kidney depth (cm)=13.2(W/H)+0.7, right kidney depth (cm)=13.3(W/H)+0.7, where W and H are weight(kg) and height (cm), respectively. The value of split GFR was obtained by dividing total GFR with uptake ratio during 2-3 minutes. Images were interpreted on kidney size, degree of radioisotope retention, pelvicocalyceal dilatation, visualization of ureter, and so on.

RESULTS

1 Patients' height, and weight

As shown in Fig. 2, the deviation of height with the increase of age was small. On the other hand, the deviation of weight with the increase of age was not so small (Fig. 3). However, patients' weight was well correlated with height

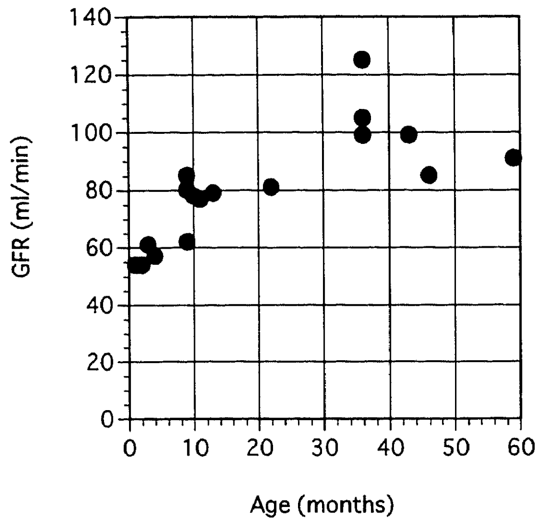


Fig. 5 Relationship between age (months) and total GFR (ml/min) in the control group

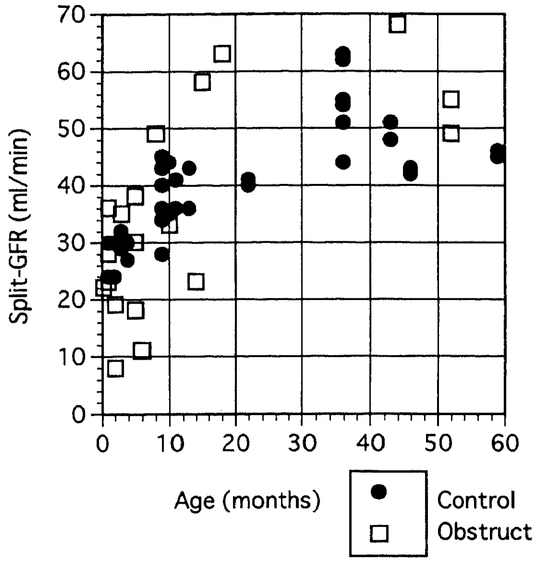


Fig. 6 Relationship between age (months) and split-GFR (ml/min) in the obstructive group and the control group

(Fig. 4).

2 Total, and split GFR

Total GFR in the control group was 50 to 60ml/min in infants younger than three months, 60 to 80ml/min in infants aged 3-12 months, and more than 80ml/min in infants older than one year. During the first one year of life, the levels increased from 54 ml/min to 80 ml/min (Fig. 5).

The values of split GFR in obstructive group were overlapped with those in control group (Fig. 6). Therefore, the value could not distinguish the two group.

3 Renogram pattern

In the control group, all 34 kidneys showed the standard pattern on the renograms. On the other hand, in the obstructive group 15 of 19 (78.9%) kidneys with hydronephrosis showed obstructive pattern, two delayed pattern, and two severe hypofunctioning pattern.

4 Image interpretation in the obstructive group (Table 1)

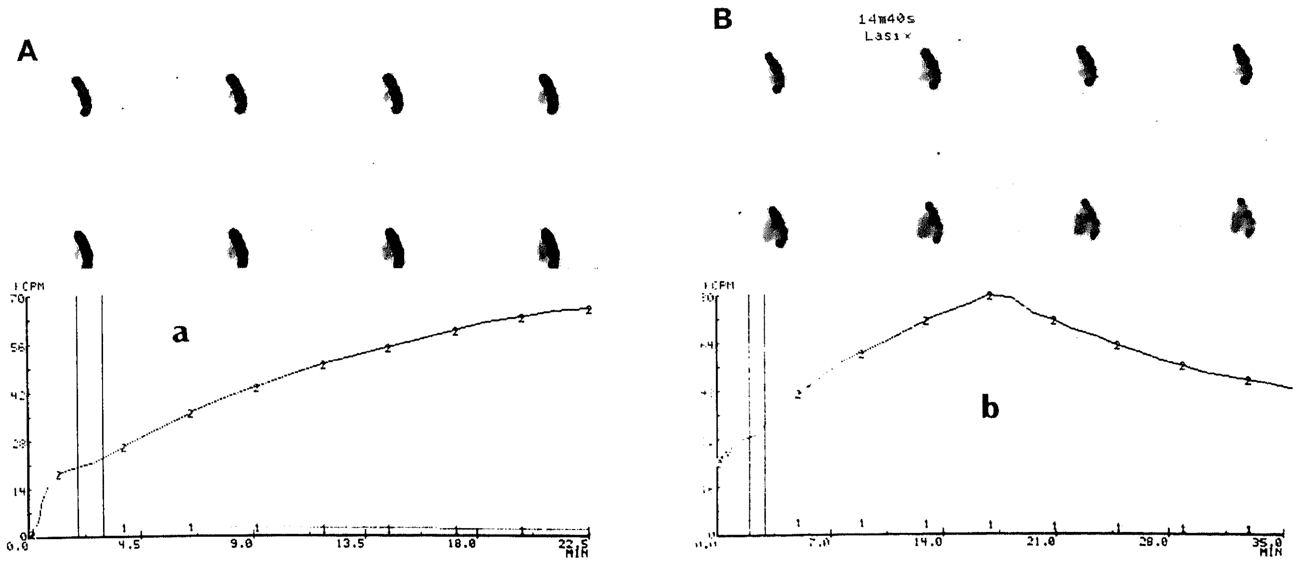
Seventeen of 19 (89.5%) kidneys with hydronephrosis showed marked radioisotope retention in the renal pelvis. One of the remaining two kidneys was not visualized and another one swelled with low tracer uptake. Pelvic dilatation was shown in six kidneys, and one kidney was associated with the ureteral visualization.

5 Case report

Case 13 A one-and-a-half-year-old girl admitted because of recurrent vomiting. Ultrasonography showed the bilateral hydronephrosis with markedly dilated calyces. Blood and urinary chemistry showed nothing abnormal. IVP delineated the right pelvis at 10 minutes and the ureter at 30 minutes. Renography showed the right hydronephrosis due to the ureteropelvic junction stenosis and the renogram showed the obstructive pattern (Fig. 7A, a). Left kidney was not visualized and oligouria of the left kidney was not resolved with percutaneous nephrostomy. Since it was suggested that left parenchymal dysfunction was irreversible and there was no indication for the left pyeloplasty, the nephrostomy was removed to avoid the infection. Diuretic renography performed two weeks later showed that right kidney responded to the diuretics and, thus, diagnosed to be a functional obstruction (Fig. 7B, b). Consequently patient was followed-up without surgical treatment.

DISCUSSION

We investigated normal ranges of GFR in



^{99m}Tc-DTPA renography.
(A) Serial images show the right hydronephrosis due to the ureteropelvic junction stenosis. Left kidney is not visualized.
(a) Renogram shows obstructive pattern of the right kidney.

^{99m}Tc-DTPA diuretic renography with 4mg of furosemide.
(B) Serial images show increased excretion of radioisotope from the right renal parenchyma
(b) Renogram shows the decrease of count rate following the injection of diuretics.

Fig. 7 Case 13 A one-and-a half-year-old girl

infants and children. Consequently, the value of total GFR was more than 80ml/min in infants older than one year, while it was 50 to 60 ml/min in infants younger than three months. Our results agreed with the description that GFR and tubular functions show their sharpest increase in early infancy[3].

In radioisotope studies, it is important to determine each kidney depth to evaluate renal function appropriately. The depth is usually estimated from the formulae using patient's height and weight which have been derived from the adults and not from the infants. In this study, the depth was estimated in the same manner. Therefore, the feasibility to adapt the formulae to this estimation should be studied. It is suggested, however, that the depth and its laterality are not great to effect the estimation of split GFR, since the body size is small in infants and children. For example, if height is 60cm and weight is 5.5kg, left and right kidney depths are estimated to be 1.91cm, and 1.92cm, respectively. Additionally if height is 100cm and weight is 15.5kg, they are 2.75cm, and 2.76cm, respectively. Therefore, the adaptation of the formulae was thought to be reasonable in clinical use.

As shown in Fig. 6, the obstructive group in this study could not be distinguished from the control group by the split GFR. This study included two cases (case 13, and 14) with unilateral hydronephrosis and contralateral near non-functioning kidney. In these cases, the affected kidneys with hydronephrosis showed high split GFR values as well as those in the control group, and it was supposed that those had compensatory function. It should be emphasized that split renal function is more useful than total renal function in the clinical estimation.

In children, most obstructive lesions are congenital, and may therefore be present during fetal life[6]. Obstruction occurs commonly at the ureteropelvic and ureterovesical junction. Some children show pooling of the urine in a dilated pelvicocalyceal system without anatomic obstruction. These cases include idiopathic megaureters, extrarenal pelvis, neurogenic bladder, reflux, and persistent dilatation of the urinary tract after the surgery[4]. In this study, 15 of 19 (78.9%) kidneys with hydronephrosis showed the obstructive pattern and renogram pattern as well as imaging was useful in detecting the obstruction.

Diuretic renography was firstly described by O'Reilly et al[7]. They tried to distinguish anatomical obstruction from functional stasis in the urinary tract by the renogram following diuretic injection. They categorized renogram pattern in patients with suspected urinary tract obstruction into the following four groups[8] ; I, both the standard and diuretic renograms were normal ; II, both renograms had an obstructive pattern ; IIIa, the initial renogram was obstructive but rapid radioisotope elimination occurred after diuretic ; IIIb, standard renography showed an obstructive pattern and diuretic produced only a slight improvement in excretion. With obstruction, the radioisotope retains in the collecting system and the excretion time is prolonged. The retention in the renal pelvis after the diuretic injection indicates anatomical urinary obstruction[9]. In the present study three children (case 3, 5, and 13) underwent the diuretic renography. Case 3 and 5 did not show significant change on renogram by diuretic injection indicating anatomical obstruction and then the pyeloplasty was successfully performed. Case 13 showed O'Reilly's IIIb pattern meaning functional obstruction. Thus, it was confirmed that diuretic renography was useful in the differentiation between obstructed and non-obstructed dilated systems. Surgical indication should be carefully determined because some patients shows the improvement of renal function without surgical treatment.

In conclusion, it is feasible to assess the renal function of children with GFR derived from ^{99m}Tc-DTPA study. ^{99m}Tc-DTPA renography and diuretic renography are useful in detecting hydronephrosis and in distinguishing the obstructive uropathy from the non-obstructive uropathy.

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^{99m}Tc-DTPA腎スキャンによる小児の腎機能評価

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要　　旨

５才以下の小児32症例に施行された ^{99m}Tc-DTPA 腎スキャンを見直した。対象をコントロール群17人と尿路閉塞群15人の２群に分け，糸球体濾過量（GFR），腎スキャンにおける画像所見，および時間放射能曲線（レノグラム）について比較し，以下の結果を得た。

(1)　コントロール群における核医学的に算出した全腎 GFR 値は，生後３か月以下が50-60ml/min，３か月－１才が60-80ml/min，１才以上が80ml/min 以上であった。分腎 GFR の値によってコントロール群と閉塞群とは鑑別できなかった。

(2)　レノグラムは，コントロール群の全例が標準型を示し，閉塞群では水腎症を認めた19腎中15腎（78.9%）が閉塞型を示した。

(3)　水腎症の19例中17例（89.5%）で腎盂部に放射能の貯留を認めた。

(4)　尿路閉塞の評価には利尿スキャンが有用であった。