Hydronephrosis

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Maria Felicia Villani, Milena Pizzoferro, Simona Nappo, and Maria Carmen Garganese

4.1 Introduction

Hydronephrosis, which is the dilatation of the renal pelvis, is the most common urological anomaly. In the vast majority of cases, hydronephrosis is nowadays detected prenatally and is therefore asymptomatic. A limited number of cases are still diagnosed during childhood or adolescence after symptoms (urinary tract infection, hematuria, and pain), and their management is straightforward surgical in order to relieve symptoms and obstruction.

Congenital hydronephrosis is detected from 1 to 5 % of all pregnancies. These patients offer a unique dilemma, since over 50–75 % of them will undergo resolution either prenatally or postnatally. The goals of treatment are therefore the early identification of patients at risk of significant uropathy and prevention of renal damage, avoiding at the same time overmedicalization of children not at risk.

How should patients with hydronephrosis be evaluated prenatally and postnatally and who should be candidate to surgery have been the objects of intense debate over the past 20 years.

4.1.1 Prenatal Diagnosis

Prenatal hydronephrosis is one of the most common findings on prenatal ultrasound, with an incidence of 1–5 % of pregnancies. The most common clinically significant etiology of hydronephrosis is ureteropelvic junction obstruction (UPJO), which has an incidence of 1/1000–1/1250.

There is no clear consensus defining the entity of prenatal dilatation and which should be considered clinically significant, and therefore requires postnatal investigation.

The first and most common system of classification of hydronephrosis is by measuring the anteroposterior diameter (APD) of the renal pelvis. In the original work by Corteville, an APD >4 mm at 33 weeks and >7 mm at 40 weeks of gestational age were considered threshold for postnatal evaluation. Other studies have proposed clinically significant hydronephrosis as being >10 mm in the second trimester and >15 mm in the third trimester: such cutoff values are associated with a >50 % likelihood of UPJO in the postnatal age. However, one should keep in mind that dilatation also depends on gestational age, bladder fullness, and maternal hydration status.

A second classification system of hydronephrosis was proposed by the Society of Fetal Urology (SFU) in 1993, based not only on the pyelic diameter but also on the global appearance of the renal collecting system. The SFU system goes from grade 1, with normal parenchymal thickness and/or renal pelvis splitting, to grade 4 hydronephrosis, in which distension of pelvis and calyces goes together with parenchymal thinning. The SFU grading correlates with the potential for postnatal resolution of the hydronephrosis, with >50 % grade 1 and only 3 % grade 4 hydronephrosis resolving spontaneously. However, similarly, hydronephrosis with APD <15 mm seldom requires surgery, while almost 100 % of those with APD >40 mm will definitely need surgery.

When facing a hydronephrosis, in addition to defining the grade of pyelocalyceal dilatation, the ultrasonography must also assess other issues: presence and morphology of contralateral kidney, visualization of dilated ureter, visualization of the distended bladder and bladder cycling, and in the fetus, amount of amniotic fluid, fetal growth, and other organ system abnormalities. These additional findings will guide prenatal counseling and postnatal differential diagnosis (Table 4.1).

M.F. Villani • M. Pizzoferro
Nuclear Medicine Unit, Imaging Department, "Bambino Gesù" Children Hospital, Rome, Italy

S. Nappo (✉)
Unit of Urology, "Bambino Gesù" Children Hospital, Rome, Italy
e-mail: simona.gerocarni@opbg.net

M.C. Garganese
Department of Diagnostic Imaging-Nuclear Medicine, IRCCS Bambino Gesù Paediatric Hospital, Rome, Italy

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Other postnatal obstructive uropathies than PUJO can be associated with prenatal or neonatal hydronephrosis, such as posterior urethral valves (PUV) or ureterovescical junction obstruction (UVJO), and are more often associated with higher grades of hydronephrosis. Vesicoureteric reflux (VUR) is present in 5–15 % of prenatal hydronephrosis and, differently from the aforementioned obstructive uropathies, does not appear to be related to the severity of the dilatation, which is obvious if one thinks to the intermittent nature of VUR. As a consequence, postnatal imaging could be warranted even in the setting of mild prenatal hydronephrosis.

Table 4.1 Differential diagnosis of antenatal/postnatal hydronephrosis

Etiology	Incidence (%)	US findings	Diagnostic exams
Transient hydronephrosis	50–70	Isolated hydronephrosis (mild)	US
UPJO	10–30	Isolated hydronephrosis (DAP >15 mm)	MAG3
VUR	10–40	Intermittent hydronephrosis, ureteric dilatation, small kidney	VCUG/DMSA
UVJU	5–10	Ureteric dilatation	VCUG/MAG3
MCDK	1–5	Random renal cyst, little or no hyperechoic parenchima	DMSA
PUV	2–5	Thickened bladder wall, hydronephrosis, hyperechoic kidney, ureteric dilatation, oligoidramnios (fetal), key-hole sign (fetal)	VCUG/MAG3

4.1.2 Postnatal Management

There is general consensus that moderate to severe prenatal hydronephrosis should undergo routine postnatal imaging: in such cases, the risk of postnatal pathological finding ranges from 45 to 80 % of cases (the more severe hydronephrosis is, the higher is the risk). In infants with mild hydronephrosis, the role of postnatal imaging is less clear; however, up to 10 % of these cases may have significant uropathies. Therefore, even in infants with mild or disappeared hydronephrosis, at least a single postnatal imaging seems of benefit.

Renal ultrasonography (US) is the principal imaging technique used in both postnatal and in prenatal life, due to the easy availability, low cost, and absence of radiation exposure; however, it is operator-dependent.

Postnatal ultrasonography should be performed at 3–7 days of life, in order to avoid underestimation or incorrect assessment due to physiological disidratation occurring in the very first days of life.

Differential diagnosis of postnatal hydronephrosis based on US findings is shown in Table 4.1.

When dilatation of calyces and pelvis is isolated and not associated with any other abnormal finding, up to 50–70 % of these cases will be transient, and will gradually disappear spontaneously without any clinical sequelae or renal impairment. The remaining 30 % of prenatal hydronephrosis will require further postnatal investigation other than ultrasonography.

4.1.3 Diagnostic Investigations

Since the vast majority of hydronephrosis will gradually disappear, periodic urinary tract ultrasonography (every 2–3 months in the first year of life) is mandatory in order to assess the evolution of the urinary dilatation.

In cases of hydronephrosis associated with ureteric dilatation, and in patients presenting with symptomatic UTI, international guidelines recommend the execution of VCUG in order to rule out the presence of VUR, as in the chapter on VUR. Otherwise, in asymptomatic isolated hydronephrosis, routine VCUG may not be needed: in this instance, infact VUR prevalence is low (15 %), with VUR being of low grade in most cases and clinically not significant.

In the absence of VUR, and when periodic ultrasonography shows persistence or worsening of hydronephrosis, the presence of UPJO has to be suspected. Dynamic renal scan is the imaging investigation of choice.

The most popular dynamic scan in cases of suspected obstruction uses Tc-mercaptoacetyltriglycine (MAG3) as radiotracer. Briefly, MAG3 is primarily excreted by secretion from the proximal tubule. As a result, it can allow evaluation of both split renal function and urine progression to the bladder.

Renal immaturity prompts us to perform nuclear medicine exams before the infant is 1 month old, for the risk otherwise to underestimate split renal function. For the same reason, the child must be adequately fed and well hydrated. IV fluids are however considered unnecessary to the vast majority of cases. Sedation is not required, and the placement of a bladder catheter should be reserved to much selected cases.

4.1.4 Particular Cases

4.1.4.1 Symptomatic Hydronephrosis

Symptomatic hydronephrosis is a totally different entity from congenital asymptomatic hydronephrosis. It generally occurs in a school-age child or adolescent, which presents with intermittent abdominal pain, sometimes together with vomiting. Urinary tract infection may or may not be present. Perinatal US may be negative, or a previous hydronephrosis may have solved spontaneously. Children as young as 3 years may present with colicky pain due to hydronephrosis. In the vast majority of symptomatic cases, aberrant vessels may be found going to the lower pole of the kidney and causing intermittent compression of the UPJ. In situation of hyperdiuresis, the UPJ is compressed and the pelvis gets distended; this in turn determines reduction of diuresis and reduction of the hydronephrosis. The pain is therefore intermittent, as is the US finding of hydronephrosis, Nonetheless, this mechanism can lead to significant loss of kidney function. Grade of hydronephrosis can be extremely variable at US. MAG3 scan can be nonobstructive. The treatment is straightforward surgical.

4.1.4.2 Hydronephrosis in Renal Anomalies

Three peculiar cases are possible: hydronephrosis in duplex system, hydronephrosis in ectopic kidney, and in horseshoe kidney. In most cases of renal anomalies, an anatomical defect of UPJ is present and spontaneous resolution of obstruction is less plausible.

Hydronephrosis in horseshoe kidney occurs more commonly than in normal kidneys. Vascular anomalies with aberrant vessels may be present as well as the anomalies of the UPJ with very high insertion of the ureter on the pelvis. The surgical approach must be decided, keeping in mind the abnormal position of the renal pelvis (anterior and medial to the kidney), and a laparoscopic transperitoneal approach should be considered nowadays the surgical approach of choice. Section of the hystums is no longer an option.

Hydronephrosis in the ectopic kidney can be associated with reduced function due to renal hypoplasia. At US, the

pelvis is generally malrotated. Evaluation of UPJO and indication to surgery may not be so evident.

Hydronephrosis in the duplex kidney is the less common. It generally occurs in the lower pole. Compression by aberrant vessels to the lower pole can be a possible cause. Hypoplasia of UPJ in case of incomplete duplex system (two pelvis draining in a single ureter) is also a possible occurrence.

4.2 The Surgical Treatment

Surgical correction of UPJO consists of excision of the obstructed tract at the UPJ and a pyeloureteral anastomosis, as described by Anderson–Hynes technique. Surgery can be performed in an open fashion, through a lumbar lateral, anterior or posterior incision. In the last decade, minimally invasive approaches have become popular, which means by small open-fashioned incisions in infants and young children, laparoscopy-assisted procedures in infants and young children, laparoscopic trans-or retroperitoneal in grown-up children, or robotics-assisted procedures. These procedures have gained wide acceptance due to the reduced pain, quicker recovery, and similar results as in traditional open surgery.

In children and adolescents with aberrant vessels, cephalad mobilization of the vessel (so-called "vascular hitch"), according to Hellstrom technique, can be as effective as the dismembered Anderson–Hynes pyeloplasty in selected patients.

4.3 The Follow-Up

Periodical US is recommended after surgery. Significant reduction of the hydronephrosis is expected, but it may take months or years to take place. Persistent dilatation of the renal pelvis is a possible occurrence even in the absence of obstruction, especially when very large hypotonic pelvis and calyces were observed before surgery. MAG3 scan should be repeated at 6–12 months follow-up, or earlier if dilatation persists. In this latter case, definition of persistent obstruction from large hypotonic pelvis with dilated calyces can be particularly challenging for the nuclear medicine specialist.

4.4 Dynamic Renal Scintigraphy

Dynamic renal scintigraphy allows to assessing renal function and drainage, evaluating both renal excretion and differential renal function (DRF).

Most common indications in pediatric population include determination of DRF and drainage in hydronephrosis and megaureter, in diagnostic phase, after surgical repair (when performed), and during follow-up.

4.4.1 Study Technique and Interpretation

The patient, adequately hydrated, receives ^{99m}Tc-MAG3 (mercaptoacetyltriglycine) as a bolus injection contextually with the starting of 30-min dynamic acquisition The administered activity of radiotracer is adjusted to the patient's weight, according to EANM dosage card and to the national regulations.

Region-of-interest (ROI) around the heart, the kidneys, and the area around the kidneys ("background") are drawn on a summed image of dynamic frames using a dedicated software; thus, time/activity curves are obtained, of expression of perfusion (flow T/A) and of renal function and drainage (renograms), respectively. In renograms, the ascending part represents the parenchymal phase (single kidney function) and the descending part reflects renal transit and emptying; with the same method, differential renal function (DRF or split function) is also determined.

If renal drainage is impaired at the end of the dynamic study, an additional image after 5 min standing upright is acquired ("gravity-assisted drainage," GAD1). In case of still poor drainage (cutoff = 30 %), a 1 mg/kg dose of furosemide is given intravenously and an additional 20-min dynamic acquisition follows. If pyelic drainage is still incomplete (half-time >20 min, drainage <30 %), a second "gravity-assisted drainage" test (GAD-2) is also performed. The drainage is classified as impaired on the basis of all the previous mentioned three tests.

4.4.2 Teaching Cases

4.4.2.1 Case 4.1 Normal Ultrasonographic and Scintigraphic Pattern After Left Pyeloplasty

A 5-year-old boy came to Emergency for recurrent left lumbar pain. On ultrasonography, grade 3 left hydronephrosis was detected. No urinary tract dilatation was referred at prenatal ultrasound. Dynamic renal scintigraphy showed symmetrical split function with obstructive urinary drainage at diuretic test. Pyeloplasty for correction of UPJO was performed with complete ultrasonographic resolution of the left hydronephrosis. MAG3 scan was repeated at 1-year follow-up after pyeloplasty (Fig. 4.1).

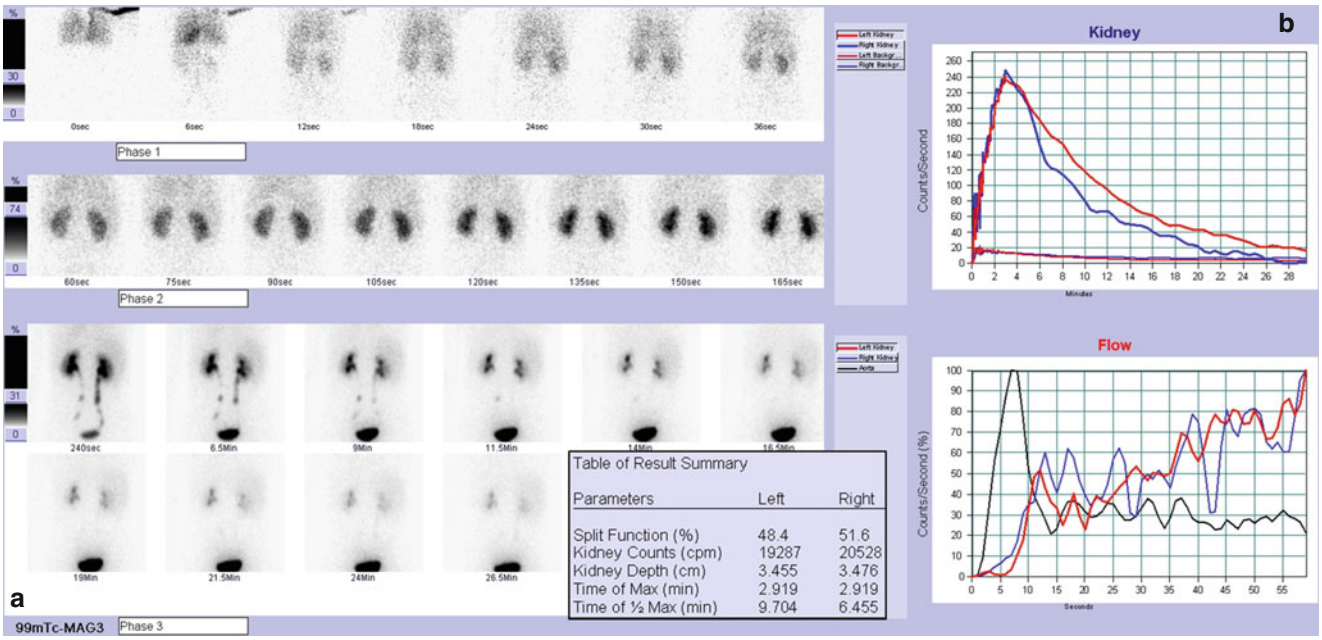

Fig. 4.1 MAG3 dynamic renal scan (after pyeloplasty): dynamic images (**a**) show good and homogeneous radiotracer uptake and normal drainage in both kidneys; renograms (**b**) confirm normal function and drainage of both kidneys (left DRF: 48 %; right DRF: 52 %); flow T/A curves (**b**) show synchronous and symmetrical perfusion

4.4.2.2 Case 4.2 Persistent nonobstructive Left Hydronephrosis with Normal Split Function

A boy of 3 years was followed for prenatal diagnosis of bilateral hydronephrosis, stable during pregnancy and confirmed at birth with an anteroposterior diameter (APD) of 15 mm. After birth, progressive decrease of right pyelic dilatation and persistent left hydronephrosis was found. One episode of acute pyelonephritis occurred at 3 months with subsequent cystography (VCUG) negative for vesicoureteric reflux. No further episodes of urinary tract infections (UTI). At the age of 3 years, he presented persistent left hydronephrosis with anteroposterior (AP) pyelic diameter of 24 mm and good parenchymal thickness, asymptomatic. MAG3 scan showed normal left split renal function and adequate urinary drainage after GAD-1 test. No surgical indication. Ultrasonographic follow-up was recommended (Fig. 4.2).

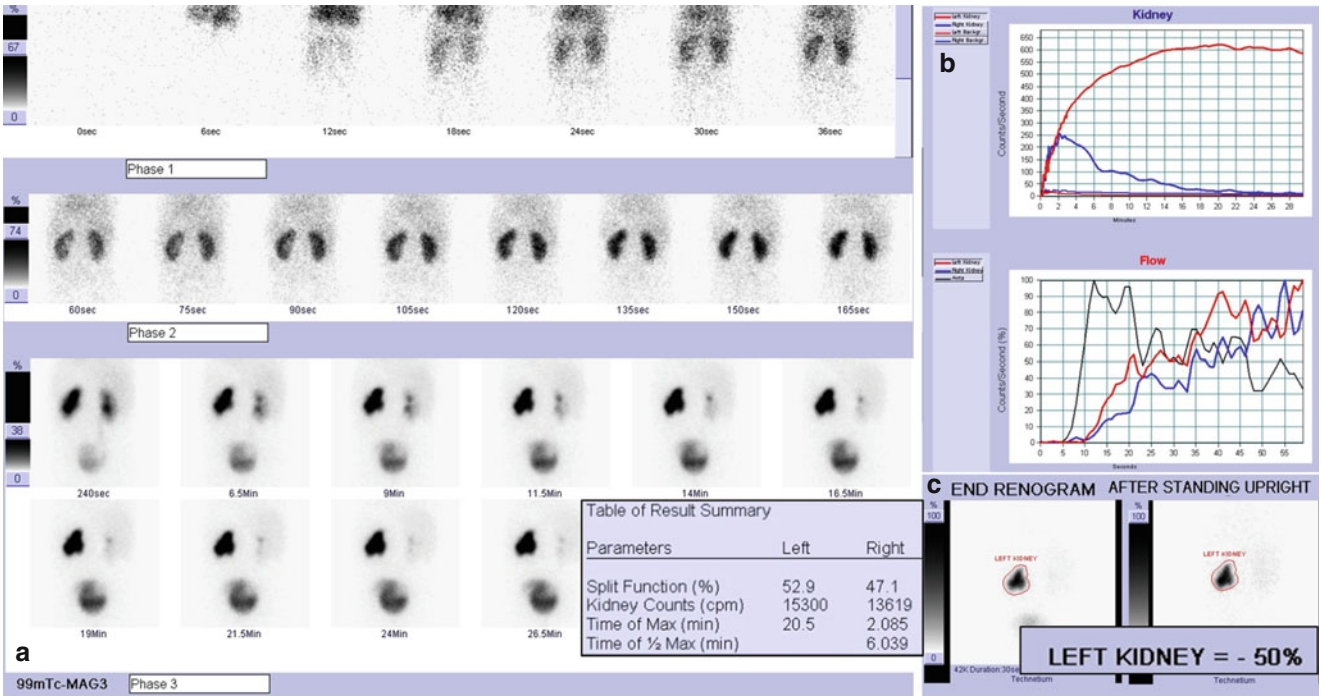

Fig. 4.2 MAG3 dynamic renal scan: dynamic images (**a**) show good radiotracer uptake and nonhomogeneous intraparenchymal distribution in left kidney; an area devoid of tracer corresponding to dilated renal pelvis is evident and drainage is poor; right kidney presents good and homogeneous radiotracer uptake and normal drainage; renograms (**b**) confirm normal function but poor drainage of left kidney ("plateau pattern") and normal function and drainage of right kidney (left DRF: 53 %; right DRF: 47 %); flow T/A curves show synchronous and symmetrical perfusion. Gravity-assisted drainage-1 test shows significant emptying of left kidney, excluding a significant obstacle in the upper pyelic junction (**c**)

4.4.2.3 Case 4.3 Prenatal Diagnosis of Right Hydronephrosis with Worsening of Dilatation at Follow-Up

A girl of 4 years was seen for prenatal diagnosis of right hydronephrosis, confirmed at birth and stable at follow-up. No UTI were referred. Toilet training was attained at the age of 2, with no lower urinary tract symptoms. At 4 years, ultrasonography showed increase of right hydronephrosis with AP diameter of 28 mm and calyceal dilatation. The girl was asymptomatic. Dynamic renal scintigraphy showed normal right split function and adequate urinary drainage after diuretic test. No surgical indication. Ultrasonographic follow-up was recommended (Fig. 4.3).

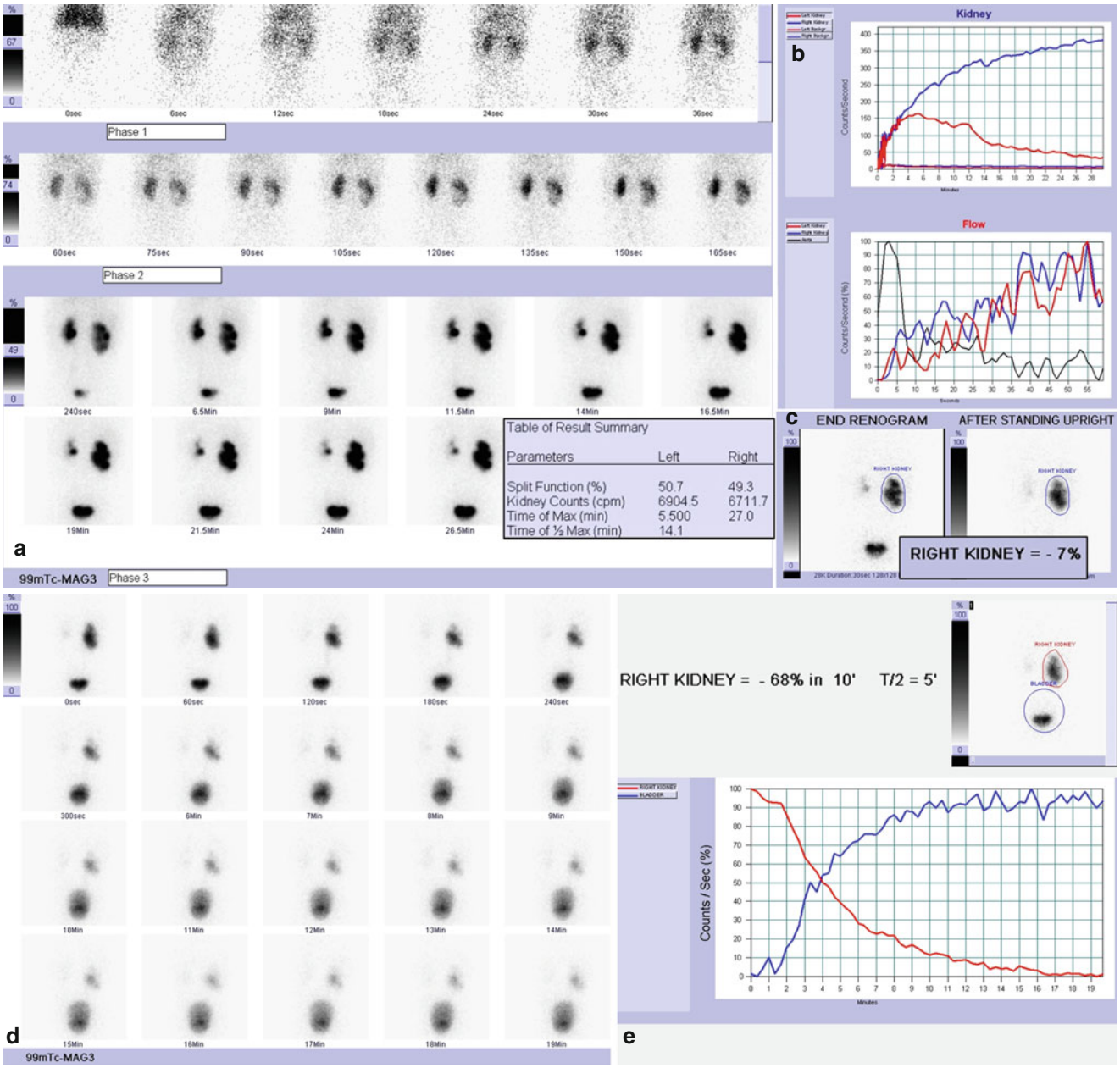

Fig. 4.3 MAG3 dynamic renal scan: dynamic images (**a**) show good and homogeneous radiotracer uptake and normal drainage in left kidney; right kidney shows good radiotracer uptake and nonhomogeneous intraparenchymal distribution. A large area devoid of tracer corresponding to right dilated renal pelvis and collecting system is evident, and urinary drainage is poor. Renograms (**b**) confirm normal function and drainage of left kidney and normal function but poor drainage of right kidney ("rising curve") (left DRF: 51 %; right DRF: 49 %); flow T/A curves (**b**) show synchronous and symmetrical perfusion. Gravity-assisted drainage-1 test shows no significant improvement in right kidney drainage (**c**). Diuretic dynamic images (**d**) and diuretic renogram (**e**) show prompt and significant renal washout after administration of furosemide, ruling out a significative obstructive pattern

4.4.2.4 Case 4.4 Persistent Left Calyceal Dilatation at 10 Years Follow-Up After Pyeloplasty with Preserved Split Renal Function

A case of a boy with Noonan syndrome is presented. Left pyeloplasty was performed at 1 year of age for UPJO. During follow-up, at 13 years of age, the boy was asymptomatic, and ultrasonography and MAG3 renal scan were performed; ultrasonography showed persistent calyceal dilatation, stable over time, without significant pyelic dilatation (AP diameter 9 mm). Dynamic renal scintigraphy showed normal split renal function and slow but significant urinary drainage after diuretic test. Delayed transit time at diuretic test may be found in calyceal dilatation, but significant washout at diuretic test and preserved split renal function support the thesis of absence of significant obstruction. Since left kidney split function was preserved at 12 years follow-up, ultrasonographic surveillance every 3–5 years is suggested (Fig. 4.4).

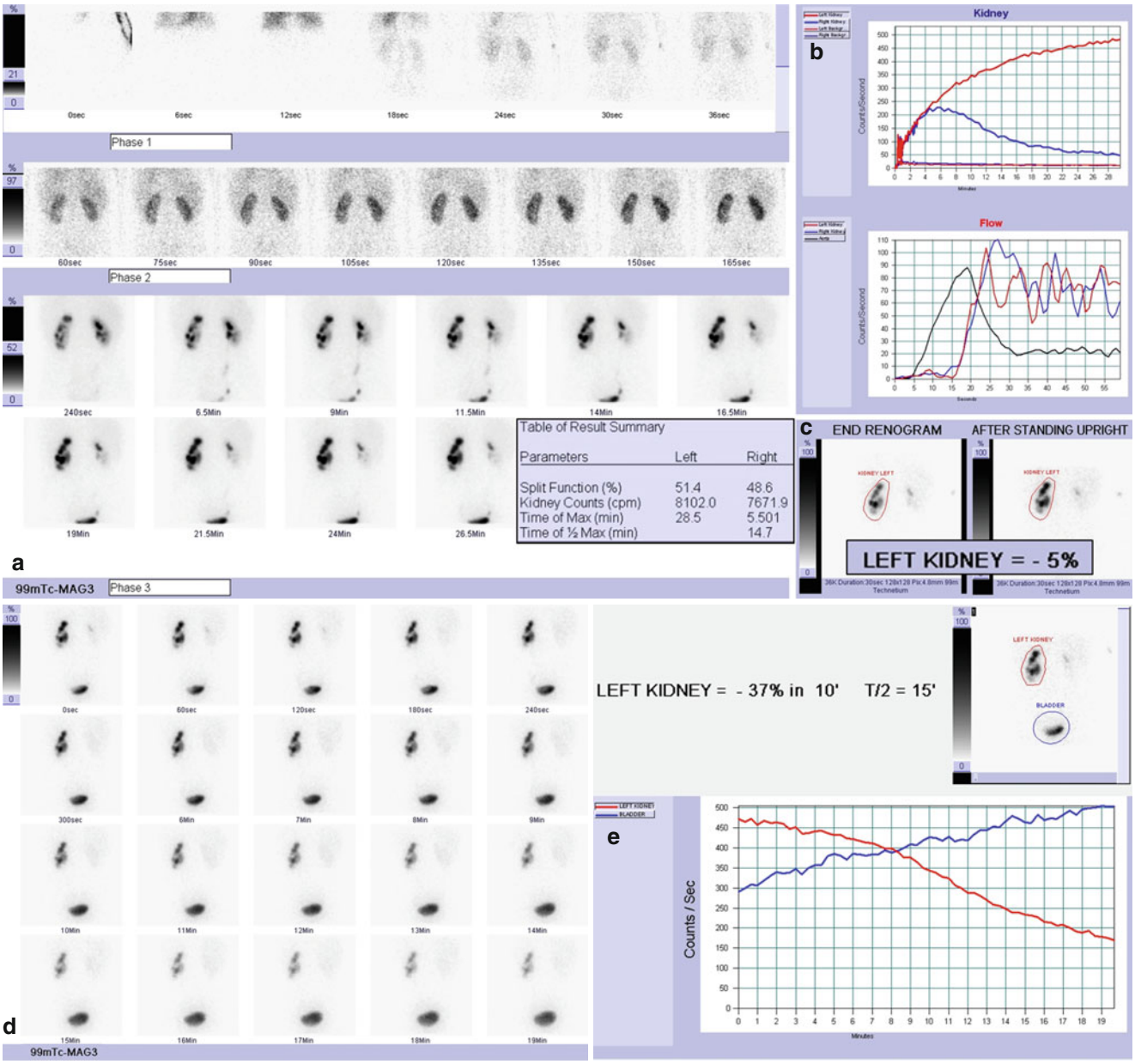

Fig. 4.4 MAG3 dynamic renal scan: dynamic images (**a**) show good radiotracer uptake and nonhomogeneous intraparenchymal distribution in left kidney; an area devoid of tracer corresponding to dilated renal pelvis and collecting system is evident, and drainage is poor; right kidney presents good and homogeneous radiotracer uptake and normal drainage. Renograms (**b**) confirm normal function but poor drainage of left kidney ("rising curve") and normal function and drainage of right kidney (left DRF: 51%; right DRF: 49%); flow T/A curves (**b**) show synchronous and symmetrical perfusion. Gravity-assisted drainage-1 test shows no significant improvement in left kidney drainage (**c**). Diuretic dynamic images (**d**) and diuretic renogram (**e**) show slow response to furosemide in left kidney, but significant washout

4.4.2.5 Case 4.5 Persistent Left Hydronephrosis with Delayed Urinary Drainage After Pyeloplasty

After prenatal finding of bilateral grade 3 hydronephrosis, with postnatal progressive worsening of dilatation on the left side, a girl of 3 years of age underwent left pyeloplasty for UPJO. At follow-up, persistent grade 3–4 hydronephrosis was found. MAG3 scan was performed 6 months after pyeloplasty and showed preserved split function and urinary drainage after GAD-2 test; based on the scintigraphic scan, the ultrasonographic finding of persistent high-grade hydronephrosis was interpreted as hypotonic dilated pelvis in the absence of significant obstruction. Repeated surgery was not indicated. Strict ultrasonographic surveillance was scheduled (Fig. 4.5).

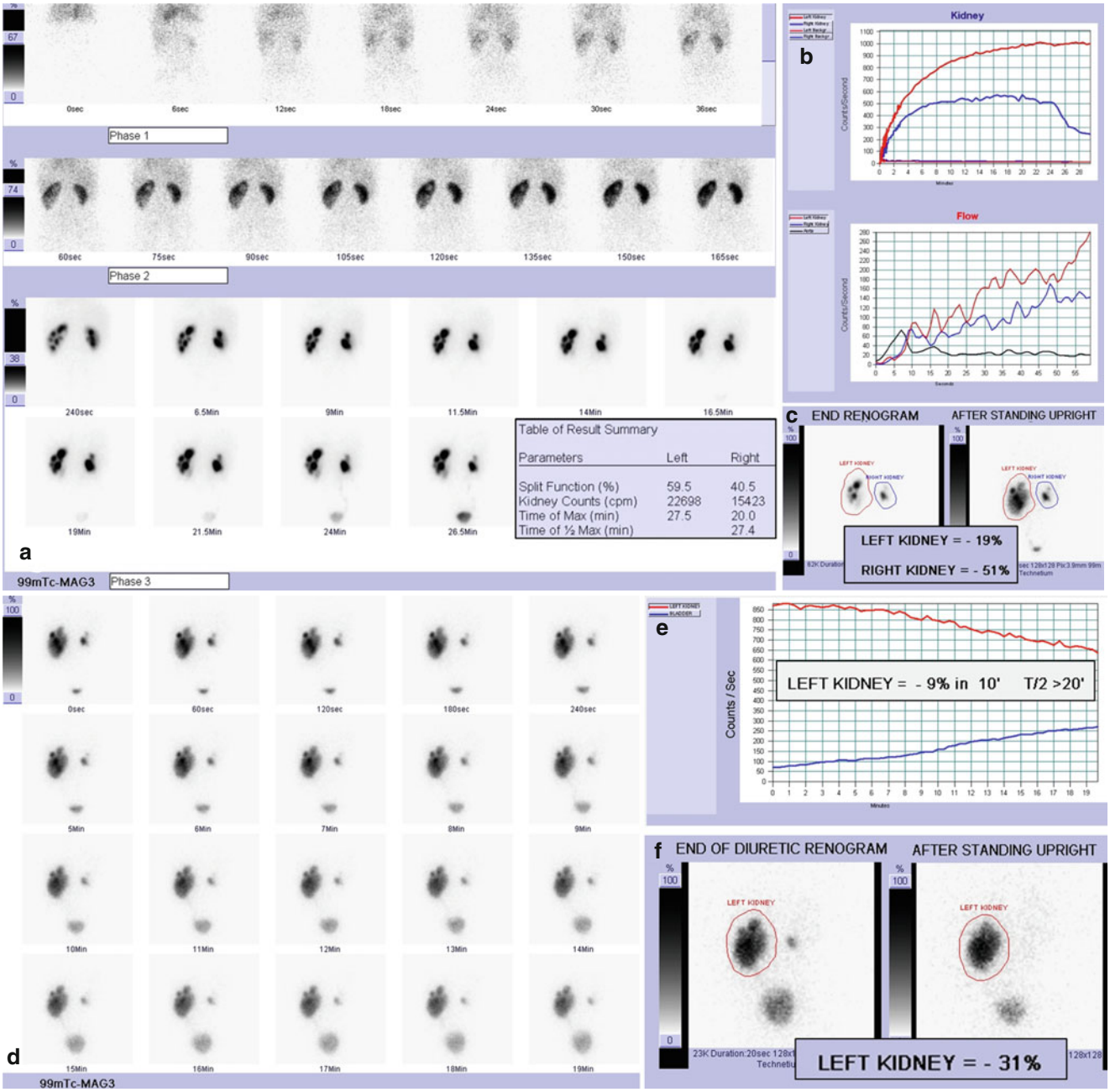

Fig. 4.5 MAG3 dynamic renal scan: dynamic images (**a**) show good radiotracer uptake and nonhomogeneous intraparenchymal distribution in left kidney; an area devoid of tracer corresponding to dilated renal pelvis and collecting system is evident, and drainage is poor; right kidney presents good and homogeneous radiotracer uptake and mildly poor drainage; renograms (**b**) show normal function and impaired drainage of left kidney ("rising curve") and normal function of right kidney with partial radiotracer washout during the last minutes of the study (left DRF: 59.5 %; right DRF: 40.5 %); flow T/A curves (**b**) show synchronous but mildly asymmetrical perfusion (reduced in right kidney, due to reduced size of the kidney). Gravity-assisted drainage-1 test shows further improvement in right kidney drainage, but no significant improvement in left kidney drainage (**c**). Diuretic dynamic images (**d**) and diuretic renogram (**e**) show slow response to furosemide and no significant improvement in drainage in left kidney. Gravity-assisted drainage-2 test (**f**) shows significant washout in left kidney

4.4.2.6 Case 4.6 Prenatal Hydronephrosis: Normal Split Function

A boy of 7 months of age was seen after prenatal diagnosis of left hydronephrosis. Postnatally, progressive increase of left hydronephrosis was found, with most recent ultrasonography showing grade 4 hydronephrosis and AP diameter of 32 mm with calyceal dilatation. No UTI occurred. MAG3 scan showed symmetrical split function with insufficient urinary drainage after all scintigraphic tests. Pyeloplasty was scheduled. At surgery confirmation of intrinsic UPJO was found. Postoperative follow-up was uneventful with minimal residual dilatation at ultrasonography at 6 months follow-up (Fig. 4.6).

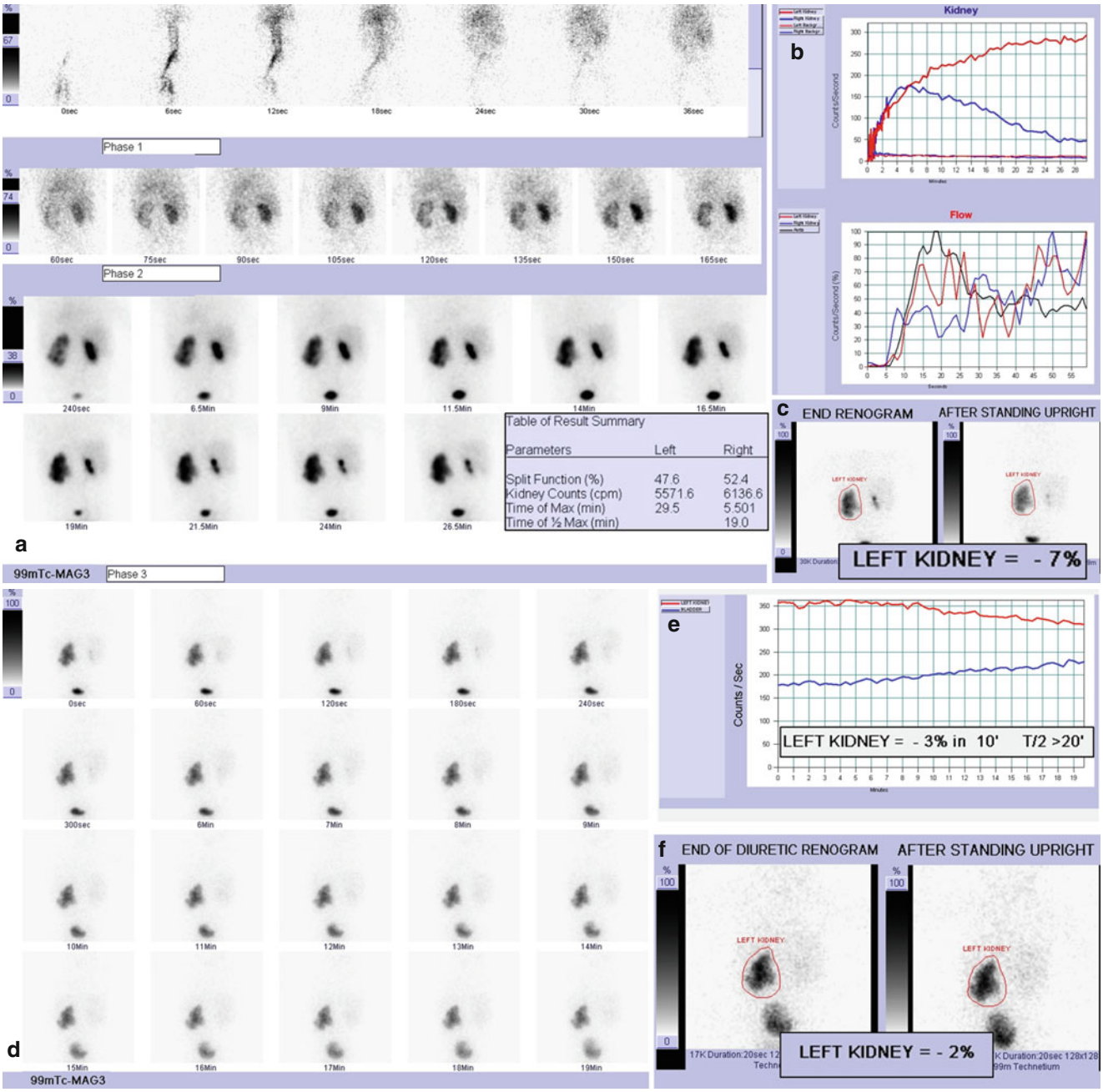

Fig. 4.6 MAG3 dynamic renal scan: left kidney is larger than the other one, with good radiotracer uptake and nonhomogeneous intraparenchymal distribution; a large area devoid of tracer corresponding to dilated renal pelvis and collecting system is evident, and drainage is poor; right kidney presents good and homogeneous radiotracer uptake and normal drainage (dynamic images, **a**); renograms (**b**) confirm normal function but poor drainage of left kidney ("rising curve") and normal function and drainage of right kidney (left DRF: 48 %; right DRF: 52 %); flow T/A curves (**b**) show synchronous and symmetrical perfusion. Gravity-assisted drainage-1 test shows no significant improvement in left kidney drainage (**c**). Diuretic dynamic images (**d**) and diuretic renogram (**e**) show very slow response to furosemide and no significant improvement in drainage in left kidney. Finally, left kidney drainage remains still poor even after gravity-assisted drainage-2 test (**f**)

4.4.2.7 Case 4.7 Late Diagnosis of Right Hydronephrosis: Reduced Split Function

An 8-year-old girl came to Emergency for acute lumbar pain and vomiting. Ultrasonography showed right grade 4 hydronephrosis. In the history, prenatal detection of bilateral hydronephrosis was reported, which was improved at 1 year of age. The patient was then lost at follow-up. Considering the diagnosis of hydronephrosis, a MAG3 scan was performed in order to assess split function and urinary drainage, and showed severe hypofunction and poor drainage of right kidney. Based on the results of MAG3 scan, laparoscopic pyeloplasty was performed confirming UPJ obstruction without aberrant vessels. At 1 year follow-up, ultrasonographic reduction of dilatation was found, together with mild increase of split function at MAG3 scan (left split function 27 %) and improvement of urinary drainage (Fig. 4.7).

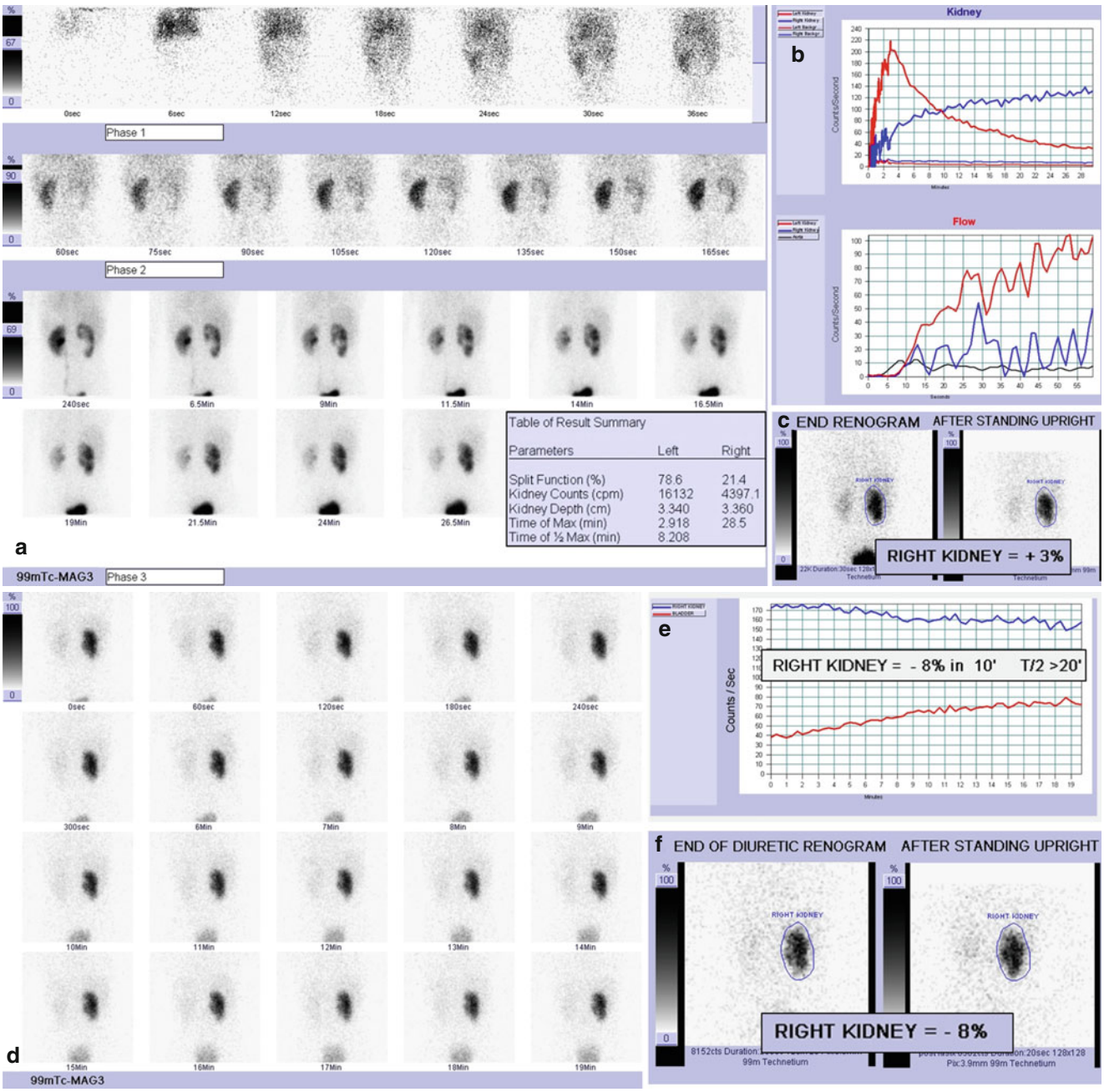

Fig. 4.7 MAG3 dynamic renal scan: dynamic images (**a**) show good and homogeneous radiotracer uptake and normal drainage in left kidney; right kidney shows globally reduced radiotracer uptake and nonhomogeneous intraparenchymal distribution with a large area devoid of tracer corresponding to dilated renal pelvis and collecting system, and drainage is poor; renograms confirm normal function and drainage of left kidney and severe hypofunction and poor drainage of right kidney ("rising curve") (left DRF: 79 %; right DRF: 20 %); flow T/A curves (**b**) show synchronous but asymmetrical perfusion (reduced in right kidney). Gravity-assisted drainage-1 test shows no significant improvement in right kidney drainage (**c**). Diuretic dynamic images (**d**) and diuretic renogram (**e**) show very slow response to furosemide and no significant improvement in drainage in right kidney. Right kidney drainage remains still poor even after gravity-assisted drainage-2 test (**f**)

4.4.2.8 Case 4.8 Bilateral Prenatal Hydronephrosis with Nonobstructive Pattern

A male newborn was seen with prenatal diagnosis of bilateral grade 4 hydronephrosis, normal amniotic fluid, and normal intrauterine growth. Postnatal ultrasonography showed grade 2 right hydronephrosis with APD 9 mm and grade 4 left with APD 28 mm. Based on MAG3 scan showing mildly reduced left function with an adequate urinary drainage after diuretic test, a strict ultrasonographic follow-up was scheduled. At 6 months follow-up, right hydronephrosis (APD 5 mm) appeared significantly improved while left hydronephrosis was severely worsened with APD of 38 mm. Left pyeloplasty was scheduled (Fig. 4.8).

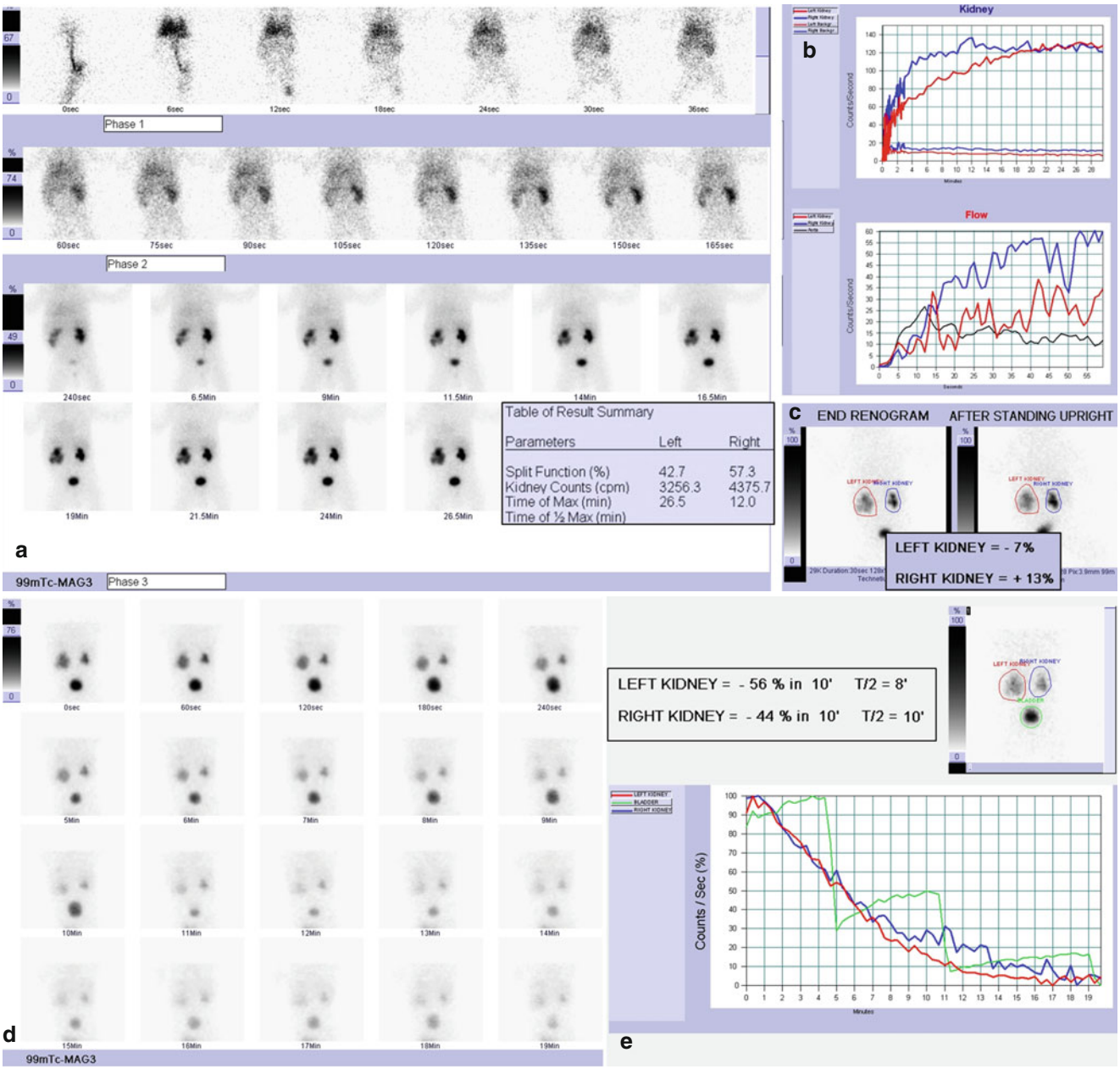

Fig. 4.8 MAG3 dynamic renal scan: left kidney is larger than the other one, with irregular shape; radiotracer uptake is globally reduced, and intraparenchymal distribution is nonhomogeneous, with a large area devoid of tracer corresponding to dilated renal pelvis and collecting system; drainage is poor; right kidney shows good and homogeneous radiotracer uptake and normal drainage (dynamic images, **a**); renograms confirm mild hypofunction and impaired drainage of left kidney ("plateau pattern") and normal function of right kidney with poor drainage ("rising curve") (left DRF: 43%; right DRF: 57%); flow T/A curves (**b**) show synchronous but asymmetrical perfusion (reduced in left kidney). Gravity-assisted drainage-1 test (**c**) shows no significant improvement in drainage in both kidneys, but diuretic dynamic images (**d**) and diuretic renogram (**e**) show prompt and significant renal washout after administration of furosemide in both kidneys

4.4.2.9 Case 4.9 Hydronephrosis in Lower Pole of Complete Duplex System

A 10-year-old boy was seen at Emergency for acute abdominal pain in the left upper quadrant. Previous history was uneventful, in particular prenatal ultrasonography was referred as normal and no UTI were reported. Ultrasonography showed bilateral duplex system with grade 2 hydronephrosis of the left lower system. MAG3 scan was asked in order to enquire split function of the lower and upper poles, together with the evaluation of urinary drainage (Fig. 4.9).

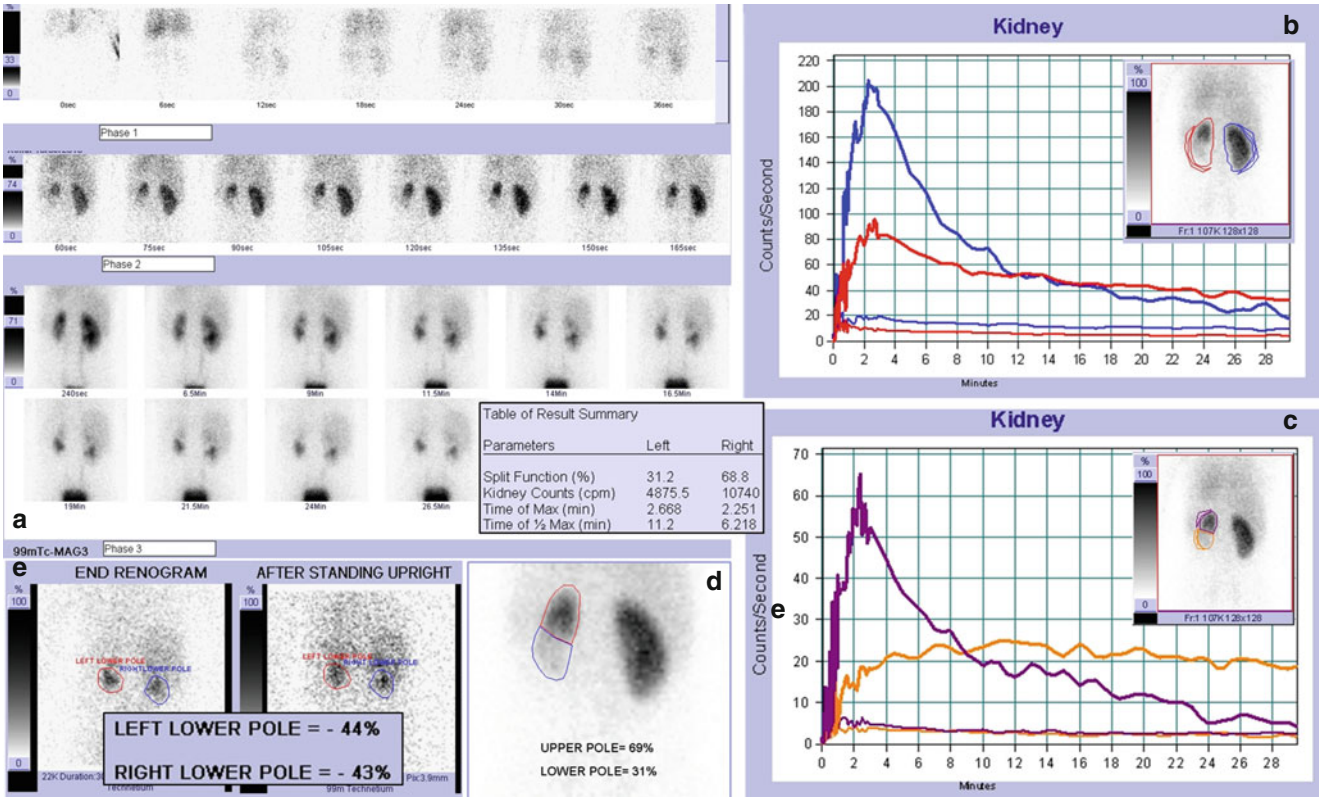

Fig. 4.9 MAG3 dynamic renal scan: dynamic images (**a**) show duplex system in left kidney, which is smaller than the other one, with irregular shape; radiotracer uptake is good and homogeneous, and drainage is normal in upper pole; lower pole shows reduced uptake and nonhomogeneous intraparenchymal distribution, with an area devoid of tracer corresponding to dilated system and poor drainage; right kidney also shows a duplex system, with good and homogeneous radiotracer uptake in both systems; drainage is normal in upper system and mildly poor in lower one; renograms (**b**) confirm mild hypofunction and preserved drainage of left kidney and normal function and drainage of right kidney (left DRF: 31 %; right DRF: 69 %). T/A curves of duplex systems of left kidney (**c**) show normal function and drainage of upper system and moderate hypofunction and poor drainage of lower system. DRF of duplex systems calculated on a composite image extracted from parenchymal phase (**d**) shows: upper system DRF: 69 %; lower system DRF: 31 %. Gravity-assisted drainage-1 test (**e**) shows significant improvement in drainage in lower systems of both kidneys

4.4.2.10 Case 4.10 Hydronephrosis in Ectopic Kidney

A boy was followed after prenatal diagnosis of right pelvic kidney. At birth, ultrasonography confirmed the renal ectopia, showing grade 2 hydronephrosis. VCUG did not show any VUR. At the age of 10 years, worsening of the right hydronephrosis was detected with grade 3 hydronephrosis and APD of 22 mm. MAG3 scan was asked in order to assess renal split function and urinary drainage (Fig. 4.10).

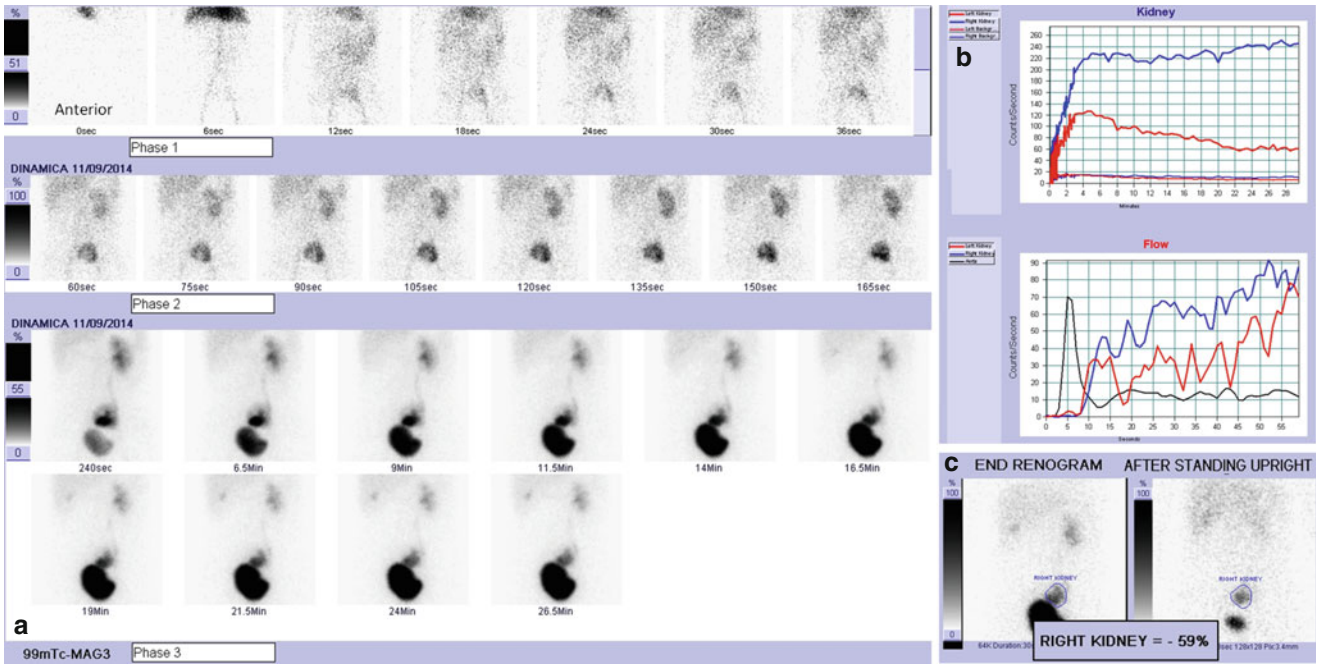

Fig. 4.10 MAG3 dynamic renal scan (anterior view): left kidney is located in its own proper site and shows good and homogeneous uptake of radiotracer and normal drainage; right kidney is ectopic pelvic, with round shape and good radiotracer uptake; intraparenchymal distribution is nonhomogeneous, with an area devoid of tracer corresponding to dilated renal pelvis, and drainage is poor (dynamic images, **a**); renograms (**b**) show normal function and drainage of left kidney and normal function but poor drainage of right kidney ("plateau pattern"); flow T/A curves (**b**) show synchronous and symmetrical perfusion. Gravity-assisted drainage-1 test shows significant emptying of right kidney (**c**)

4.4.2.11 Case 4.11 Hydronephrosis in Horseshoe Kidney: Nonobstructive Pattern with Preserved Renal Function

A 7-year-old boy was seen after recurrent abdominal pain. Ultrasonography was suspicious for horseshoe kidney with bilateral grade 2 hydronephrosis. MAG3 scan was asked in order to confirm renal fusion and assess urinary drainage (Fig. 4.11).

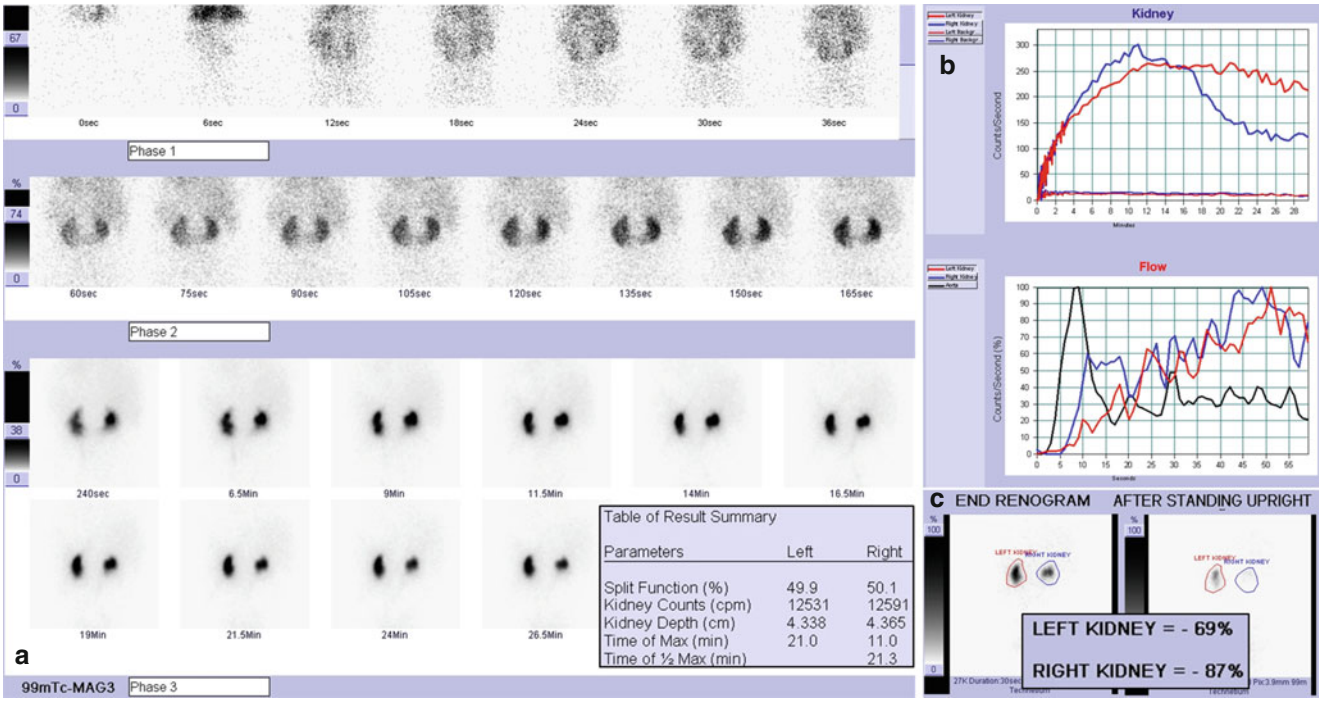

Fig. 4.11 MAG3 dynamic renal scan: dynamic images (**a**) show horseshoe kidney, with good radiotracer uptake and poor drainage in both kidneys; renograms (**b**) show normal function (left DRF: 50%; right DRF: 50%) and impaired drainage with delayed excretion phase in both kidneys, in particular, in the left one; flow T/A curves (**b**) show synchronous and symmetrical perfusion. Gravity-assisted drainage-1 test (**c**) shows significant improvement in drainage in both kidneys

4.4.2.12 Case 4.12 Hydronephrosis in Horseshoe Kidney: Obstructive Pattern with Renal Function Impairment

A 14-month-old girl was seen for prenatal diagnosis of left hydronephrosis. At postnatal follow-up, progressive worsening of the left hydronephrosis was observed (grade 4 hydronephrosis with pyelic APD of 33 mm). No UTI occurred. MAG3 scan was asked in order to confirm surgical indication (Fig. 4.12).

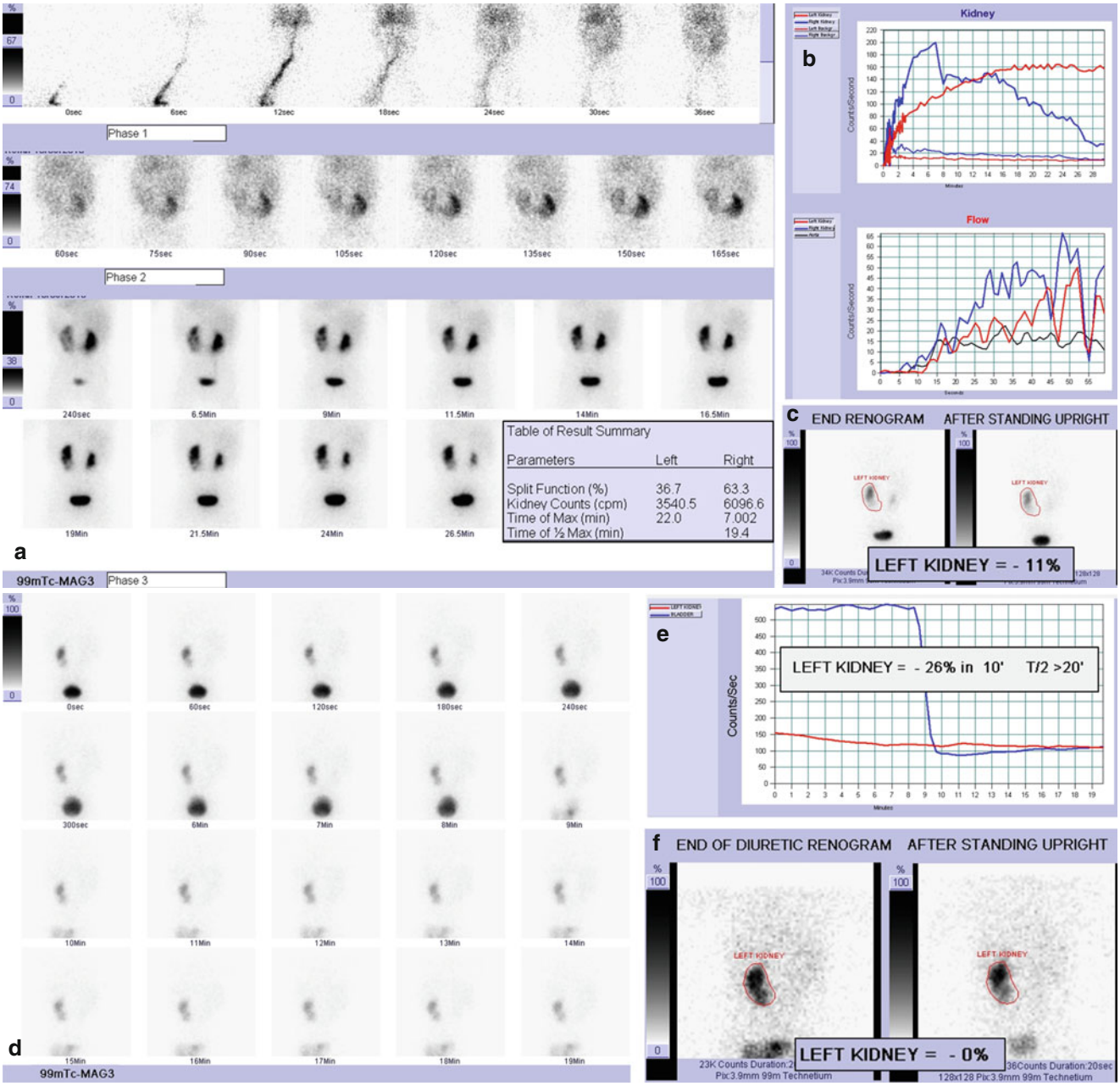

Fig. 4.12 MAG3 dynamic renal scan: dynamic images (**a**) show a horseshoe kidney; in left kidney, radiotracer uptake is reduced and intraparenchymal distribution is nonhomogeneous, with an area devoid of tracer corresponding to dilated renal pelvis and collecting system; drainage is poor; right kidney shows good and homogeneous radiotracer uptake and normal drainage; renograms (**b**) show moderate hypofunction and impaired drainage of left kidney ("plateau pattern") and normal function and drainage of right kidney (left DRF: 37 %; right DRF: 63 %); flow T/A curves (**b**) show synchronous but asymmetrical perfusion (mildly reduced in left kidney). Gravity-assisted drainage-1 test (**c**) shows no significant improvement in drainage in left kidney. Diuretic dynamic images (**d**) and diuretic renogram (**e**) show very slow response to furosemide and no significant improvement in drainage in left kidney. Drainage remains still poor even after gravity-assisted drainage-2 test (**f**)

4.4.2.13 Case 4.13 Poor Drainage in Very Dilated Renal Pelvis: A Potential Scintigraphic Pitfall

A girl was first seen at the age of 6 years for recurrent abdominal pain since 3 years of age. Ultrasonography showed grade 4 right hydronephrosis with pyelic APD of 60 mm. Pyeloplasty was performed. At follow-up, gradual decrease of ADP was first seen, with a minimum APD of 20 mm. Then progressive increase of right hydronephrosis occurred. MAG3 scan was asked in order to assess renal split function and urinary drainage and showed normal function of right kidney and poor drainage. Ascending pyelogram did not show any kinking or recurrent obstruction at the pyeloureteric junction. The girl remained asymptomatic. Split renal function was stable (Fig. 4.13).

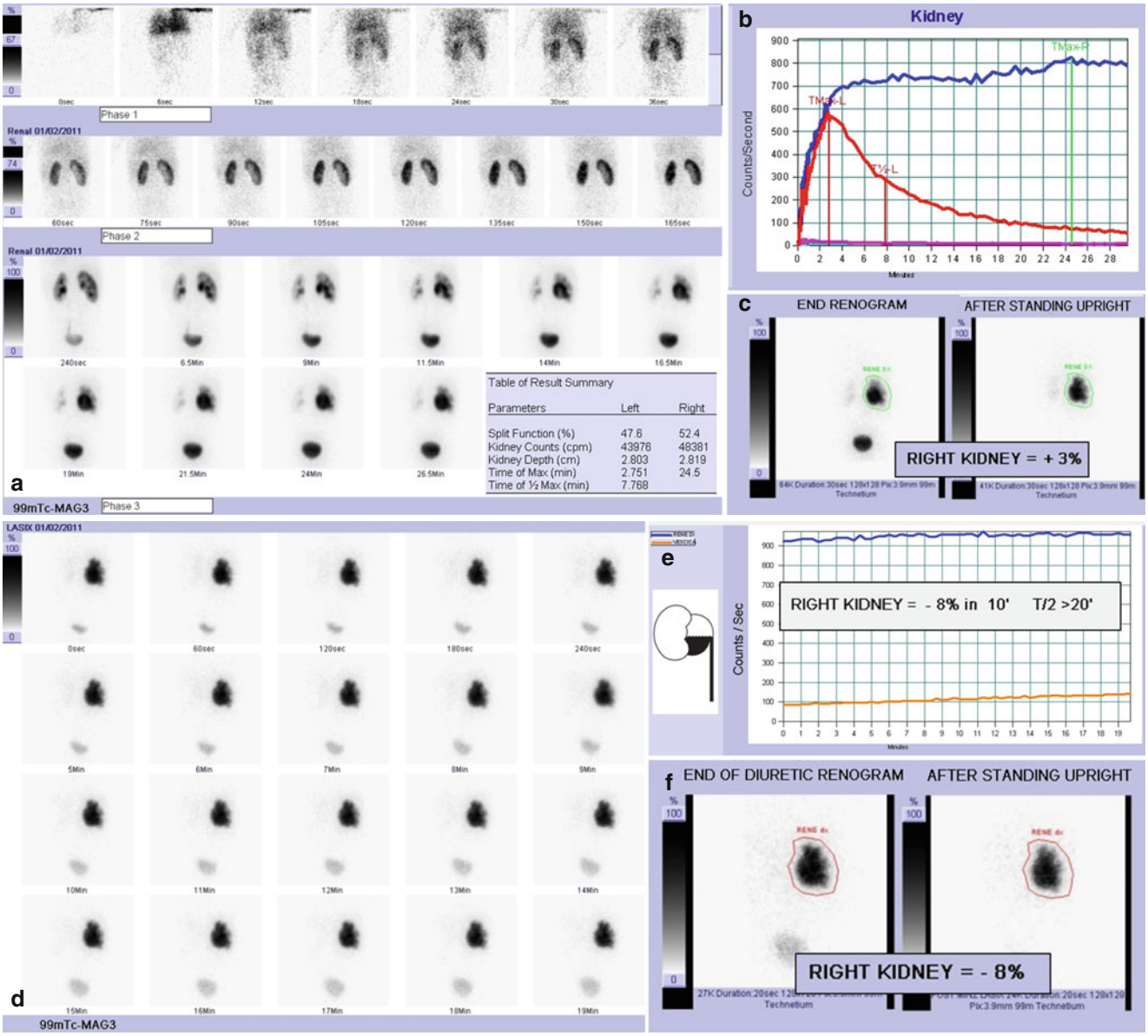

Fig. 4.13 MAG3 dynamic renal scan: dynamic images (**a**) show good and homogeneous radiotracer uptake and normal drainage in left kidney; right kidney is larger than the other one, with good radiotracer uptake and nonhomogeneous intraparenchymal distribution; a large area devoid of tracer corresponding to very dilated renal pelvis and collecting system is evident, and drainage is poor; renograms (**b**) confirm normal function and drainage of left kidney and normal function but poor drainage ("plateau pattern") of right kidney (left DRF: 48 %; right DRF: 52 %). Gravity-assisted drainage-1 test shows no improvement in right kidney drainage (**c**). Diuretic dynamic images (**d**) and diuretic renogram (**e**) show very slow response to furosemide and no significant improvement in drainage in right kidney. Right kidney drainage remains still poor even after gravity-assisted drainage-2 test (**f**). Persistence of a very dilated pelvis after pyeloplasty may represent a potential pitfall in interpretation of scintigraphic findings, because some renal scintigraphies could show a persistent poor drainage even in the absence of anatomical pyeloureteric junction obstruction. In our experience, this could be probably explained with the analogy of the "bathtub": it takes long time to empty a bathtub when the plug has been removed, because of the dimension of the bathtub related to the small drainage hole. In the same way, emptying of very dilated pelvis can be very slow, even in the absence of an anatomical obstacle. In this group of patients, when renal function remains stable over the time, periodical clinical evaluation and ultrasonographic monitoring are recommended

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