CHAPTER 9. URINARY TRACT IMAGING

9.1. Radiological researches of urinary tract

Radiological researches are indicated for each patient in whom kidneys, ureters, urinary bladder diseases are suspected.

Assignments are carried out by the attending physician, formulating the primary goal of research. In contact to a radiologist the order and volume of radiological researches is established.

Ultrasonic scanning of kidneys.

Due to harmlessness and high informativeness ultrasound in most cases is the first method with which research in urological clinic begins.

For kidneys ultrasound a patient does not need special preparation, however if products causing bloating are avoided, ultrasonic diagnostics becomes more exact.

Detection of kidneys at ultrasonic scanning is about 100 %. However in patients with adiposity of the III-IV stage (much adeps hypodermic fat absorbing a significant part of ultrasonic energy), hypoplasia, dislocation of a kidney they are hardly detected.

Ultrasonography is carried out both on the back and on the abdominal cavity.

In examination on the abdominal cavity the right kidney is detected through the liver. The left kidney in such body position is hardly detected because of the intestine. Kidneys examination are performed through the right and left side in the supine and standing position in different scans.

Ultrasonic scan in longitudinal direction shows that the normal kidney has the oval form and precise contours. The size of it on the average at the adult makes 7,5-12,5 cm, width of 4,5-6,5 cm, thickness 3,5-5 cm. Distinction in length of kidneys does not exceed 1,5-2 cm. The kidney in newborns proportionally is larger in volume and mass, than in adults. Proportions of kidney thickness, width and lengths in a newborn is 1:1,5:2; in an adult - 1:1,5:3. In a newborn the length of a kidney is 4-4,5 cm, width - 2,5-2,7 cm and thickness - 2-2,3 cm. The kidney is covered by connective tissue with a capsule appearing as a continuous light stripe 1-1,5 mm in width. Renal cortex and the medullary substance causes dark area (almost free from echoes – hypoechoec) with width of ≈15 mm (up to 25 mm). This peripheral zone represents parenchyma (fig. 9.1). Normal renal cortex has lower echogenicity, than the spleen or the liver. The central zone is defined as a congestion of echostructure with non-homogenous reflection, corresponding to renal pelvis, major and minor renal calices. Normally the front-back size of renal pelvis does not exceed 1,0 cm. In norm the ureters is almost not detected, except for the top third.

Due to low information ultrasonic scanning of ureters and vessels of kidneys except for rare cases has no great practical value.

Opportunities of ultrasonic scanning as method of initial visualization:

• allows to estimate position of kidneys, dislocation at breath, sizes,

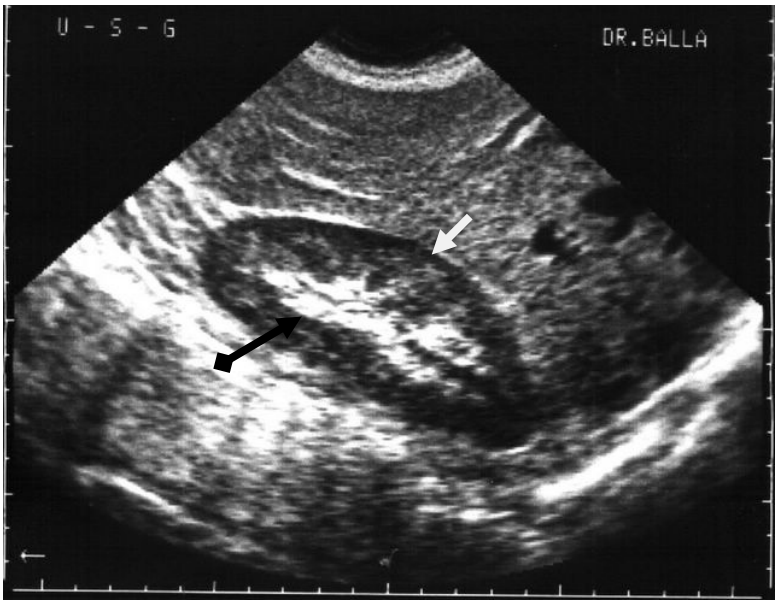

Fig. 9.1. Ultrasound of the kidney in longitudinal direction. Peripheral zone represents parenchyma (hypoechoec, arrow). The central zone is detected as a congestion echoes with non-uniform reflection (arrow with a rhombus). Norm

form, outlines, a differentiation of parenchyma on the renal cortex and renal medulla; renal sinus with renal pelvis and calix and perirenal tissues;

• focuses concerning character of a disease, necessity of the further visualization and a choice of its method;

• the majority of stones in kidney and urinary tract is visualized;

• the method is high-sensitive to obstruction of urinary tract;

• allows to reveal diffuse and focal changes in the parenchyma of kidneys.

Disadvantages of the method:

• does not give the information on function of kidneys;

• ureter is badly visualized.

Ultrasound of the urinary bladder.

This method is safe and informative enough. It is possible only if the urinary bladder is well filled with urine or disinfectant solution. The sizes depend on a degree of its filling (average capacity 250-300 ml). The filled bladder normally is free from echoes, has precise contours, is located in the small pelvis cavity behind symphysis pubica. More often it has an oval or pear-shaped form. In norm thickness of the bladder wall in case of its filling is 3-6 mm, and the mucous membrane is less than 2 mm.

The prostate is located directly behind the bladder and in norm has smooth contours. The tissue of the prostate is represented by alternation of hypoehoic sites

and fine dot and linear structures (fig. 9.2). Length of the prostate is 2,5-4 cm, front-back size comprises 1,8-2,5 cm, and transverse size is 2,7-4,2 cm.

In transurethral or rectal exam it is possible to receive images of the top, average part and the basis of the prostate.

Now ultrasonic scanning has taken the central place in research of urinogenital system since it has the big diagnostic value, is simple, cheap and harmless.

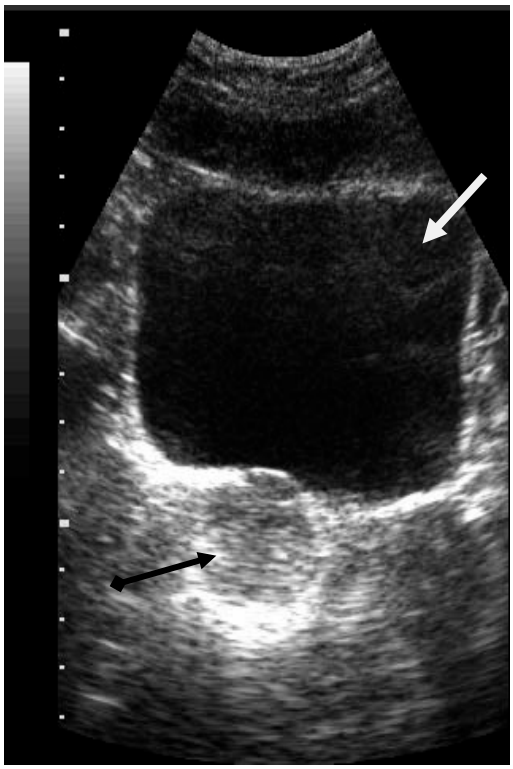

Fig. 9.2. Ultrasound scan of the urinary bladder. Transverse scan. Urinary bladder (arrow). Prostate (arrow with a rhombus). Norm

Usual ultrasound gives the information on morphology, but not on function. Ultrasound is an excellent auxiliary method at various intervention procedures, such as nephrostomy, biopsy and drainage.

X-ray researches.

First of all it includes a survey film. Preparation: to clear intestine in the evening and in the morning of the day of research. X-ray study should be performed on an empty stomach. Exception includes the patients with sharp renal colic. Survey examination should be performed on the 30×40 cm film. It should cover area of all the urinary tract, starting from X thoracal vertebra and finishing the symphysis pubica.

Interpretation of survey film includes a rating of quality of an image, definition of correctness of a projection, studying of a shadow picture of soft tissues, a bone skeleton, organs of GT, kidneys, the ureters, the bladder.

Kidneys are located as bean shaped shadows at the level of XII chest - II lumbar vertebraes from the left and I lumbar - III from the right. Upper poles are

located closer to a median line, than a lower one. Contours of kidneys shadows normally are smooth and look like arched lines, convex in the lateral side.

Size of kidneys at radiological research in adults: length is 11,5-13,7 cm, width is 5,1 - 6,7 cm. Normal ureters in a survey film are not visible. The empty bladder in a usual film is not detected. Survey radiography of kidneys and the bladder in a direct projection helps to reveal stones and gas. It is a general part of all usual radiological researches of the urinary tract which should precede researches with use of contrast agents.

Intravenous urography (IU). IU is impotant mode of kidneys research. Opportunities of its application concern to advantages of IU in children's practice, at narrowings of the urethra, at traumas of kidneys and renal bleedings.

In IU contrast substance is injected intravenously (on 1 kg of weight – 1 ml of the solution containing 300 mg of iodine per/ml).

Contraindications to research: the increased sensitivity to preparations of iodine and a poor patient’s condition.

Films are made during the first 60 second, that allows to see kidneys during nephrography phase, but more often in 5-7 min. and 20-25 min. In nephrography phase there is a distinct shadow of the whole renal parenchyma, containing contrast substance, which arrives in renal calyx and pelvis. In a healthy person the shadow of renal parenchyma is homogeneous. Later an image of pelves appears. Displacement of the renal pelvis lower than the III lumbar vertebra is the abnormal phenomenon. Kidneys are mobile during breathing; their excursion in a vertical direction can achieve 10 cm. In research in horizontal and vertical position of the patient displacement of a kidney in identical conditions of a respiratory pause should not be higher than 1,5 vertebraes. Renal pelvis usually settles down within the limits of a kidney, but can settle extrarenally. The shortest distance from a pelvis contour up to a lateral contour of a kidney shadow normally is 2-3 cm. The form of renal pelvis is various, but the basis is more often triangular, longitudinal to the body axis.

Upper and external borders of the pelvis are convex, bottom one is concave (fig. 9.3). Sizes of the pelvis are variable; its capacity in average is 6-7 cm^3. There are major and minor renal calices. Usually there are 3 major renal calices, they connect pelvis to major and minor renal calices. In each major renal calyx there is the basis - its junction with pelvis, the neck – a middle part of the major renal calix as the lengthened tubule and the apex from which one or several small calices depart. The number of minor renal calices is from 4 to 20. In each minor renal calix three parts are distinguished: neck – the narrowest part in the place where the minor calyx detaches from the major renal calyx, actually the calyx and the arch which surrounds cone shaped papilla. As minor renal calices settle down in different planes it is not

always possible to receive the image of each of them, therefore in many cases it is necessary use multiprojective research.

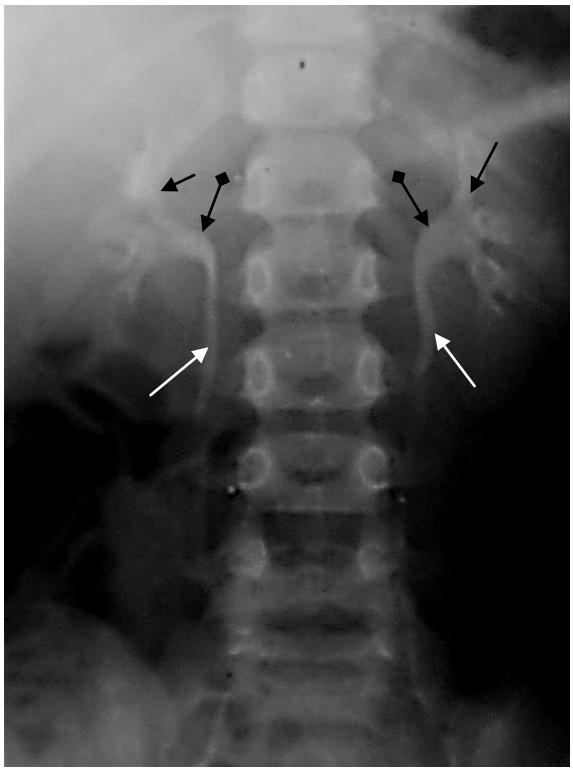

Fig. 9.3. Intravenous urography. Normal excretory phase of an intravenous urogram. This film was taken approximately 7 minutes following intravenous injection of iodinated contrast material. The kidneys are excreting contrast into non dilated calyces (arrows), renal pelvis (arrows with rhombus), ureters (white arrows). Norm

During reading of IU it is possible to observe various phases of emptying of the upper urinary tracts, since calices and pelvis and finishing terminal departments of ureter.

As emptying of calices occurs nonsimultaneously normal IU shows than one calix is filled with contrast substance while others do not contain it, as they are in a phase of contraction. Similar phases of a systole and diastole appear on a series films.

Normal ureter is represented as shank shaped shadows which correspond to filling by contrast substance of separate segments in a phase of a systole and diastole.

In the majority of people 3 segments is common, less often – 2. Ureters with contrast substance are visible as a band with width from 3 to 10 mm. IU allows to make radiological research of the bladder as well (descending cystogram).

Advantages of IU:

1) examination of all urinary tracts;
2) an opportunity to detect structure of renal pelvis and calices;
3) detection of stones, especially in the ureter;
4) exact diagnostics of obstruction.

Disadvantages of the method:

1) dependence on kidneys functional ability;

2) unsatisfactory opportunity to estimate structure of renal parenchyma on presence of cysts or solid formations;
3) all kidney contours are hardly detected; frequently it is impossible to detect formations starting from forward or back kidney parts;
4) impossibility to estimate perirenal space;
5) necessity to use contrast agents and radiation;
6) impossibility to investigate a level of glomerular filtration. However the latter can be estimated if blood of the patient will be taken 3-4 hours after the introduction of contrast substance and investigated on the contents of iodine.

Ability of urography to show detailed anatomy of renal pelvis and calices is important for diagnostics of papilla necrosis, tumours of renal pelvis and urinogenital tuberculosis. The method is exact in diagnostics of stones in urinary tract, but concedes CTon sensitivity.

In presence of acute obstruction IU is the important diagnostic method but the combination of a survey film, ultrasonic scanning and scintigraphy represents alternative. Congenital developmental anomalies, for example, adnation of kidneys, rotation, variants of renal pelvis and calicces structure, are very well visible with the help of IU. In traumas when the minimal damage of kidneys is supposed, the urography enables prompt and effective inspection.

Retrograde ureteropyelography. The retrograde ureteropyelography is a direct injection of contrast agent (75-100 mg of iodine / ml, 7-8 ml) in a lumen of the upper urinaty tract (fig. 9.4). The preparation can be injected through a catheter, fixed in the ureter in cystoscopy. Retrograde ureteropyelography is used when there is intolerance to a contrast agent injected in blood in a patient.

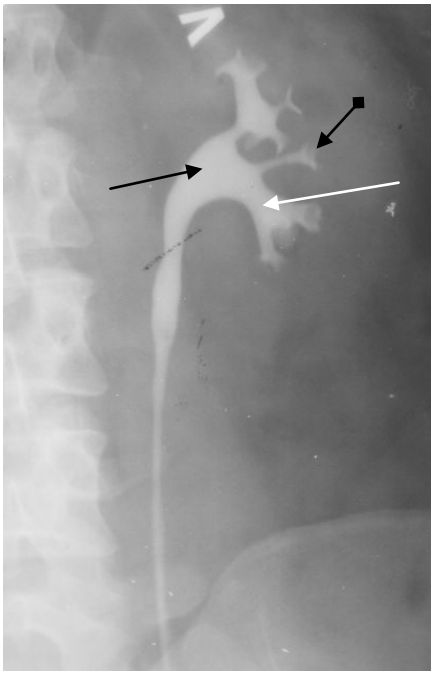

Fig. 9.4. Retrograde ureteropyelography :
- renal pelvis (black arrow);
- major renal calix (white arrows);
- minor renal calix (arrows with rhombus).

Norm.

The method is demonstrative for diagnostics of:

1) minor changes of the mucous;

2) diverticula and cavities;

3) various processes including obstruction, when intravenous urography is not infomative;

4) absence of the image of the upper urinary tract in intravenous urography (in obvious cases, for example, in a big tumour, it is more preferable than CT);

5) in patients with risk of intravenous injection of iodine content contrast agent, limiting application of IU;

The method is contraindicated in acute inflammatory processes in kidneys and urinary tracts and in macrohematuria.

Retrograde ureteropyelography almost is completely superseded by application CT and MRI.

Angiography: in this method a catheter is fixed in venous or arterial systems. The end of a catheter is placed under the fluoroscopy control in a vessel entering the examinated area or emerging from it (fig. 9.5). Renal angiography is used seldom nowadays for detection and differential diagnostics of volumetric formations because of wide use of ultrasonic and, especially, CT. Angiograhy can be used in case of elective operation on the abnormal kidney or in case of a kidney resection.

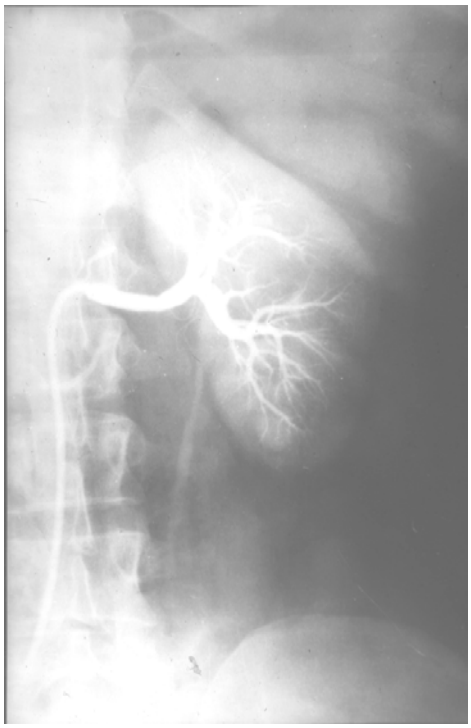

Fig. 9.5. The selective arteriogram of the left kidney. Norm.

Other indications for renal angiograhy include suspicion on renal arterie stenosis and aneurysm (fig. 9.6). Angiograhy is necessary before vascular operations, such as embolisation, stenting or balloon dilation of the renal arterie.

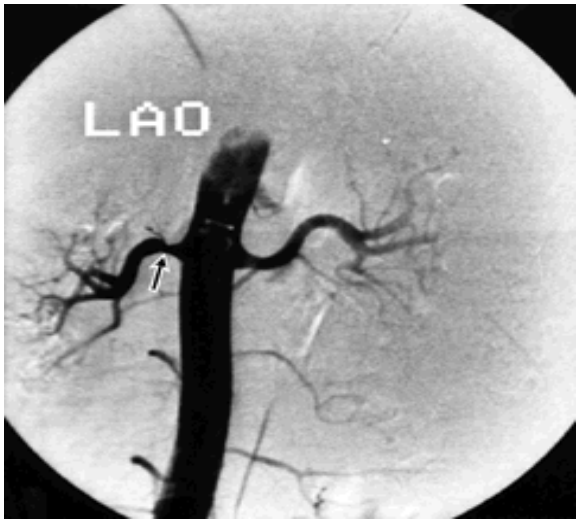

Fig. 9.6. Angiography:the stenosis of the renal arterie (arrow) [99].

On a series of films in the beginning the image of the aorta with its large branches, including renal arteries (an early arterial phase), then a shadow of small arteries (a late arterial phase), further the common increase of kidneys shadow intensity (nephrography a phase), a weak shadow of renal veins and, at last, the image of pelvis and calices is received since the contrast substance is discharged from blood with urine. Renal arteries depart from the aorta almost at a right angle at the level of the Ist lumbar vertebra or a disk between it and the IInd lumbar vertebra. Diameter of the renal arteries trunk makes 1/3-1/4 diameters of the aorta at this level. Length of the right artery is 5-7 cm, and left one is 3-6 cm. Contours are smooth, a shadow is homogeneous and intensive. Diameter of renal veins is 1-1,5 cm, diameter of the vena cava inferior at the level of the kidneys portal is not larger than 2,5 cm.

Cystography. Films for IU are usually made for research of the bladder 0,5 - 1 hour after introduction in blood of contrast agent (fig. 9.7).

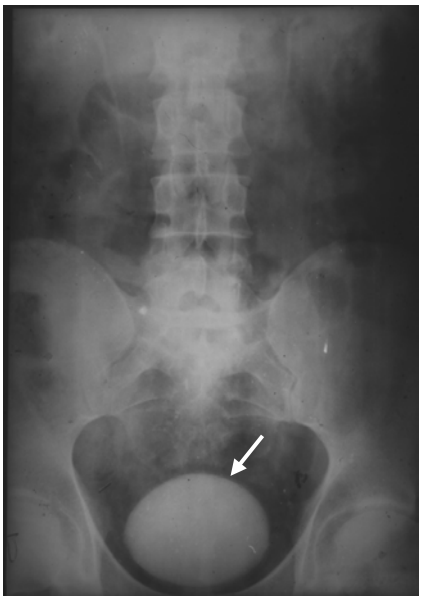

Fig. 9.7. Intravenous urography. Phase of filling urinary bladder (arrow). Norm

Considerably more precise image is achieved by means of ascending cystography, carried out with liquid or gaseous contrast substances (fig. 9.8).

Micturating cystourethrography, radiographic examination of the urinary bladder after filling with contrast medium and of the urethra during voiding.

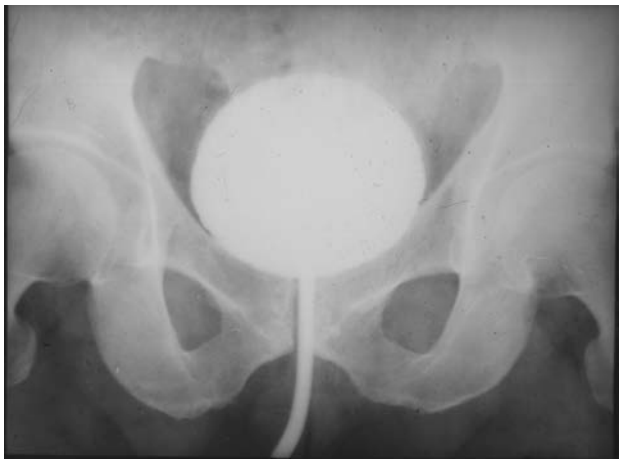

Fig. 9.8. Ascending cystography. Norm.

The normal bladder has oval, spherical or the pyramidal form. Its lower border is located at the level of symphysis pubica; upper border achieves the level of the IIIrd sacrum vertebra. In women in case of insignificant filling of the bladder by a contrast substance the normal bladder gets the saddle form dependent on uterus pressure. Contours equal are smooth.

More often cystography is performed for diagnosing of posttraumatic or postoperative extra bleeding, diverticulum, vesicoureteral reflux and tumors detection (fig. 9.9, 9.10).

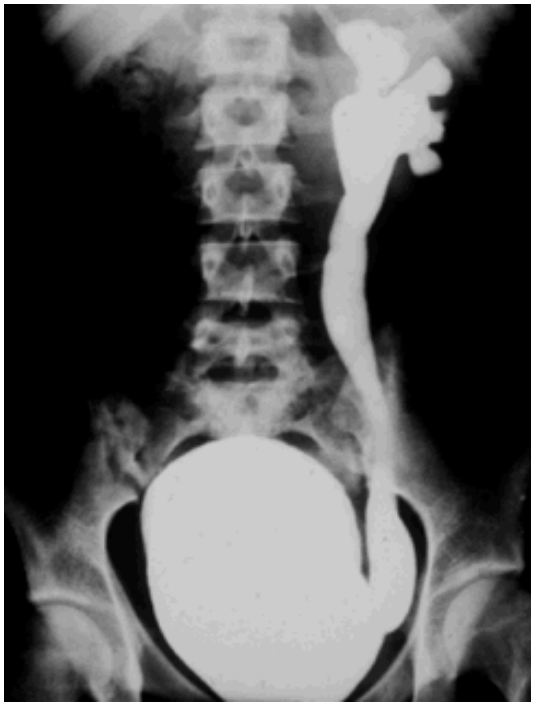

Fig. 9.9. Micturating cystourethrography. Note the right vesicoureteral reflux with dilated ureter, pelvis and calyces. Vesicoureteral reflux

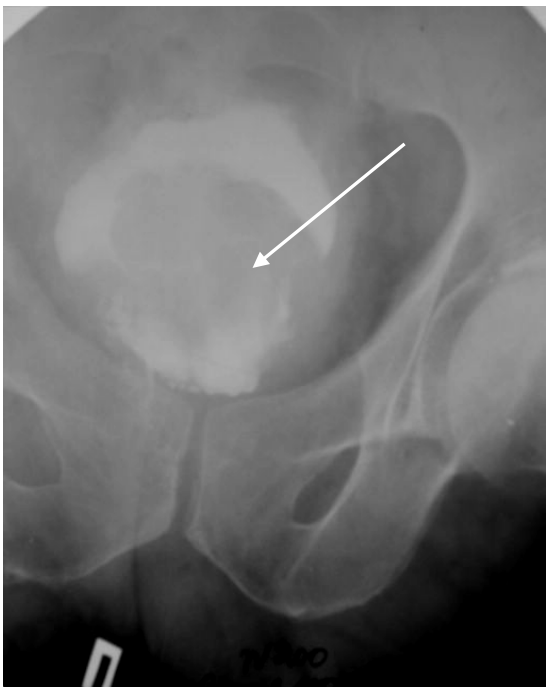

Fig. 9.10. Cystography. Extensive defect of filling connected with a wall of the bladder with rough contours is defined (arrow). Cancer of the bladder.

Urethrography. It can be ascending (at urination) or retrograde. The image during urination gives the information on the posterior urethra, while the anterior urethra is not well visible (fig. 9.11). Retrograde urethrography gives more information on the anterior urethra, than on the posterior one.

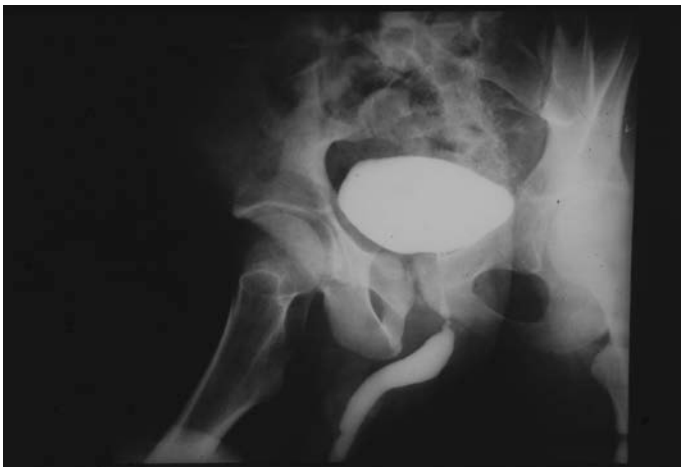

Fig. 9.11. Ascending urethrography. Norm

Computerized tomography (fig. 9.12). CT is an excellent method for revealing and diagnosing of volumetric formations of kidneys, and also for definition of a stage of malignant tumours in kidneys. The method is very informative in stones diagnosing. CT surpasses ultrasonic in revealing perirenal, periureter and pelvic the processes touching urinary tract.

CT is a method of choice for evaluation of consequences of kidneys trauma when severe organ damage is suspected. CT is the best method of visualization of adrenal glands and the method of choice in these diseases diagnosing. A new

method of renal pelvis and calices visualization is computerized tomographic urography (in presence of a spiral tomograph), carried out with intravenous contrast enhancement. Three-dimensional reconstruction on a spiral computer tomograph shows the image of kidneys vessels.

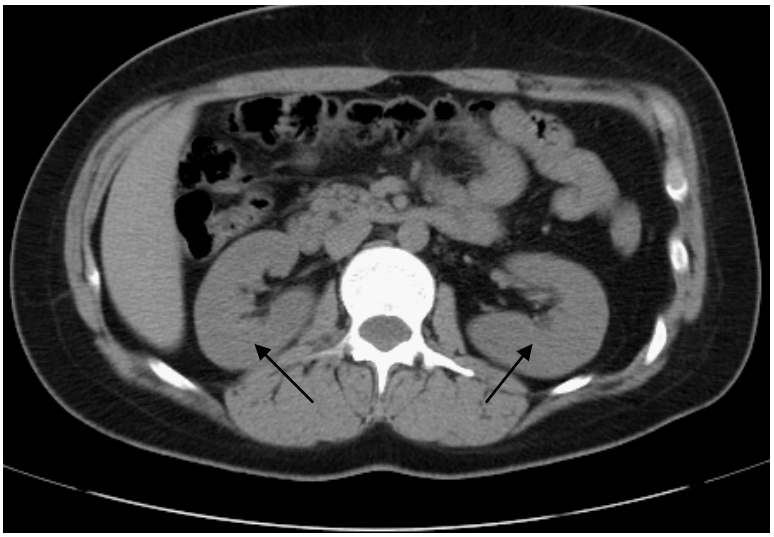

Fig. 9.12. Normal CT kidneys. Note the homogeneous renal density on the nonconrast images (arrows)

MRI.

Visualization of pelvics organs (the bladder, prostate, uterus and genitals) is one of important fields in MRI. The method gives the valuable information on a stage of a tumoral process; it detects volumetric formations more precisely, than CT. Now MRI of kidneys is carried out when the diagnosis is not clear after CT and ultrasonic scanning, when there is intolerance of contrast preparations, and in vascular lesions (fig. 9.13). MR-urography (MRU) is completely non-invasive method; it does not demand introduction of a contrast agent, does not depend on function of kidneys and it can be applied in patients with renal insufficiency.

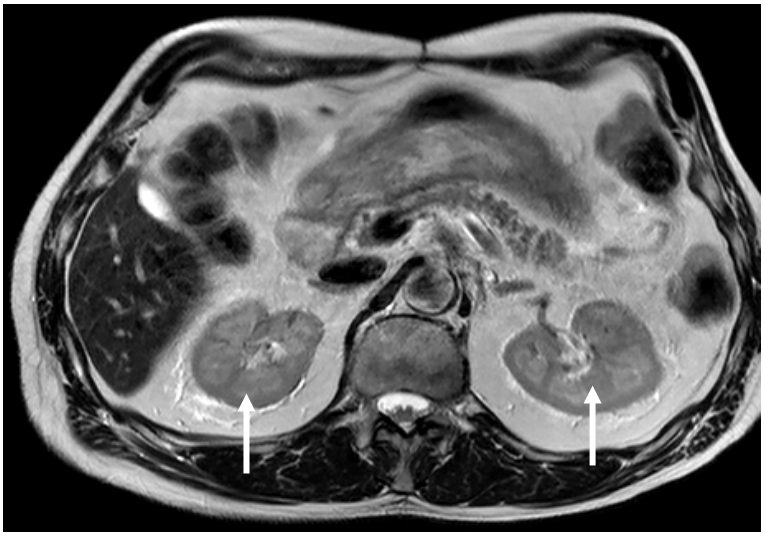

Fig. 9.13. MRI of the abdominal cavity at the level L2. Axial T2-WI normal kidneys view (arrows)

MRU enables to receive the image of urinary tract comparable on quality and results with IU and even from a retrograde ureteropyelography. Expansion of urinary tracts is visualized, the level and, in most cases, the reason of obstruction are distinguished. MRU with paramagnetic contrast enhancement displays both anatomy of urinary tract, and function of kidneys, it is comparable with dynamic nephroscintigraphy. Advantages of MRU allow consider it a method of future.

Radionuclide renal imaging.

A radionuclide study of the kidneys in the clinic has received general distribution and recognition.They enable to study a functional status of: 1) renal tubular cells; 2) glomerular filtration; 3) excretory phase; 4) a status of a vascular channel and parenchyma of kidneys, kidneys topography.

Following kinds of radionuclide kidneys researches are distinguished:

1) radiorenography (studying of renal tubular cells function and excretory phase with ^{131}I-orthoiodohippuric acid);

2) dynamic nephroscintigraphy (research of glomerular filtration with – ^{99m}Tc-DTPA (the pharmacological moiety is a pentavalent chelating agent);

3) renal static scintigrapy (research of the renal blood flow with ^{99m}Tc-DMSA. The pharmacological moiety ^{99m}Tc-DMSA is dimercaptosuccinic acid).

Radiorenography. The technique consists in graphic registration of changes of a radio-activity above each kidney and above heart area after intravenous introduction of ^{131}I-orthoiodohippuric acid. On character of elimination ^{131}I-orthoiodohippuric acid is mainly renal tubular cells (80 % secretion by renal tubular cells, 20 % is filtered by glomerulars). Radioiodine can be injected in the thyroid gland; therefore the blockade of the thyroid gland with potassium iodine is necessary.

Two curves reflect work of kidneys, and one above the heart – clearence (fig.9.14).

The first segment of a curve is a quality indicator of a kidney blood supply. Time of initial ^{131}I-orthoiodohippuric acid (a vascular segment) passage lasts in average 17-20 sec.

The second segment rises slower – 2,5-4 min., it is a secretory phase. This phase is regarded as a reflection of, at least, three factors: accumulation of ^{131}I-orthoiodohippuric acid by renal tubular cells, removing of a preparation in a gleam tubulars and clarifications of blood from a preparation. The point of the hinge rise of a curve reflects the period of time balance between process of accumulation and excretion of ^{131}I-orthoiodohippuric acid in a kidney, it is the end of the IInd segment.

The third segment reflects removing of a preparation from a kidney. $T_{1/2}$ 8-10 min. (up to 15 min.). In norm the difference in height of right and left kidneys curves amplitude does not exceed 10 %, as well as time parameters.

The third curve of radiorenography (above area of heart) is a curve of clearance of ^{131}I-orthoiodohippuric acid; its hows speed of blood clarification from radiopharmaceutical. The first 3-4 min. from the beginning of research it reflects the common distribution of ^{131}I-orthoiodohippuric acid, and in a later period it is a parameter of total activity of kidneys.

Effective renal flow of plasma is detected: radio-activity in blood on the 20th min; 40th min is measured and compared to the entered activity on the special formula. Normally, renal flow of plasma equals to 500-800 ml /min./1,73 of m^2. Selective decrease of the effective renal flow of plasma is observed in arterial hypertension, in heart and sharp vascular insufficiency.

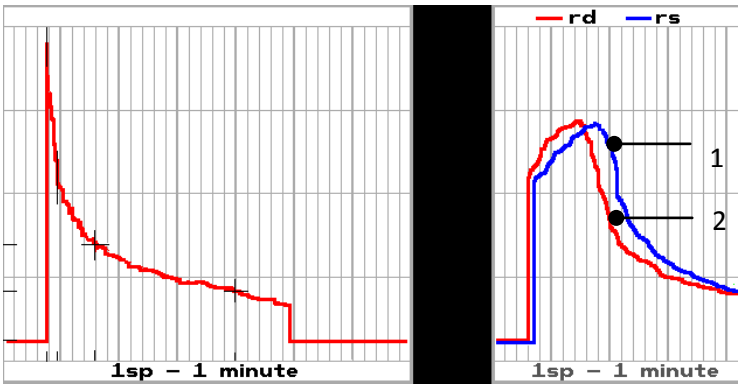

Fig. 9.14. Radiorenography with ^{131}I-orthoiodohippuric acid. At the left − a curve over the heart area, reflecting a blood road clearance, i.e. speed of clarification of blood from ^{131}I-orthoiodohippuric acid. On the right - the curves characterising work of kidneys and deducing ^{131}I-orthoiodohippuric acid (1- left kidney; 2- right kdney). Norm (explanatories in the text)

Dynamic nephroscintigraphy (research of glomerular filtration with – ^{99m}Tc-DTPA (the pharmacological moiety is a pentavalent chelating agent).

The image of distribution of given radiopharmaceutical in parenchyma of kidneys and graphic registration of a preparation transfer in kidneys is received (fig. 9.15).

The glomerular filtration agent used is ^{99m}Tc-DTPA, of which 10–15 % is extracted on the first pass. With the help of a special formula (computer) the volume of functioning parenchyma (area) in % is calculated. Norm is 100-90 %. The glomerular filtration is calculated according to a special formula as well. There are special tables depending on age. On the average $T_{1/2}$ of glomerular filtration equals to 100-140 ml / minutes. Blood half-life in norm is 18 minutes on the average.

Static renal scintigraphy. The renal tubular cell uptake marker in clinical use is ^{99m}Tc-DMSA. A dose of 2,5–3,0 MBq/kg (max. 80 MBq) is injected into the patient, the radionuclide is extracted by the renal tubular cells but not excreted into the tubuli, thus marking regions of poor renal parenchymal function (fig. 9.16, 9.17, 9.18). This

is a static imaging method and in a sense functions as a chemical microsphere (perfusion agent). It is mostly used for the detection and follow-up of pyelonephritis.

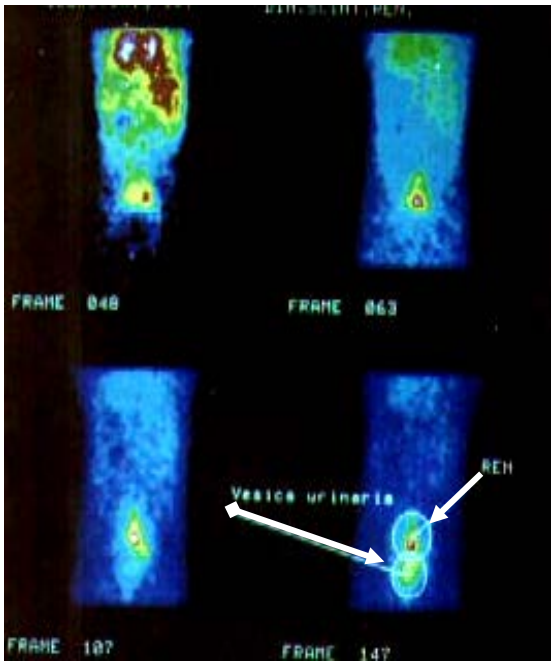

Fig. 9.15. Dynamic nephroscintigraphy. Dynamic scintigraphy of kidneys with – ^{99m}Tc-DTPA. On the received scintigrams the unique kidney (arrow), in a small pelvis above a bladder (arrow with rhombus). Sharp infringement of functional activity (glomerular filtration) and excretory functions of a unique kidney

The pharmacological moiety ^{99m}Tc-DMSA is dimercaptosuccinic acid. The received information with ^{99m}Tc-DMSA allows estimating a renal blood flow as a whole in each kidney and its separate parts. It has the great diagnostic value in revealing infringements of renal blood supplies in each kidney separately, that allows to estimate presence of renal arteries stenosis.

The following parameter is used: transit time is the time from occurrence of the maximal intensity count rate above the aorta till the maximal count rate on a kidney. In norm the transit time is 8-9 sec.

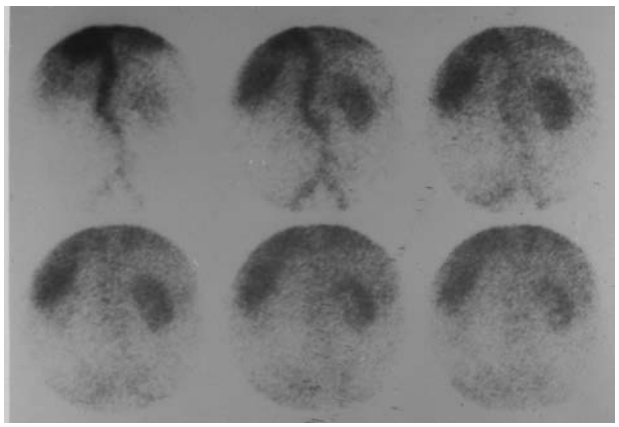

Fig. 9.16. Static renal scintigraphy with ^{99m}Tc-DMSA. Accumulation ^{99m}Tc-DMSA in the aorta and blood vessels of kidneys

So, radionuclide renal imaging, nuclear imaging methods can help to evaluate

bilateral renal function individually. In combination with pharmacological "stressors" such as furosemide (furosemide renography) and captopril (captopril renography),

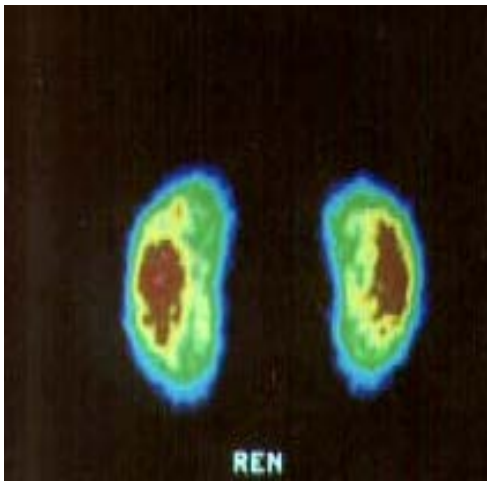

Fig. 9.17. Static renal scintigraphy of kidneys with ^{99}mTc- DMSA. Accumulation ^{99m}Tc-DMSA by both kidneys intensive enough and uniform. Both kidneys of the usual form, the sizes and a position. Norm

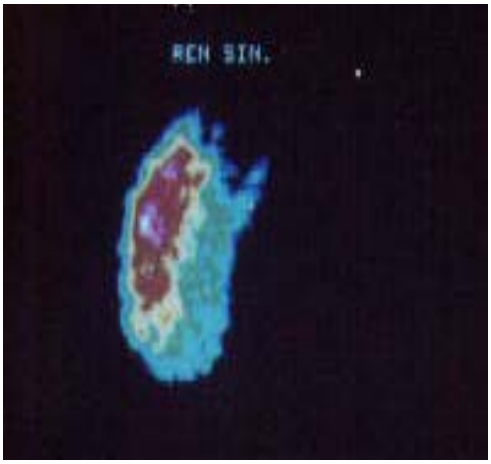

Fig. 9.18. Static renal scintigraphy with ^{99m}Tc-DMSA (dimercaptosuccinic acid). On a scintigram only the left kidney is defined. Accumulation of ^{99m}Tc-DMSA by a left kidney is intensive enough; its distribution is diffusively non-homogenous, in the top pole is detected a defect of radionuclide accumulation. Focal lesion of the top pole of a left kidney. The right kidney is not detected

these methods are used for a wide range of purposes to evaluate renal function in renal disease such as the follow-up of renal function in patients with renal congenital malformations and pyelonephritis. In the adult, the tests can be used to identify renal vascular hypertension, to assess renal function prior to nephrectomy and renal transplants.

If the initial study is normal or near normal, the patient is then administered the angiotensin converting inhibitor orally and the isotope study is repeated 1 hour later following reinjection of the radionuclides. If stenosis of renal artery occurs there is virtually no function in the kidney with stenosis of renal artery. The healthy kidney has normal curve.

9.2. Radiological symptoms of illnesses and damages of kidneys

Radiological diagnostics of congenital kidneys anomalies.

Kidneys aplasia. On survey films, as well as on IU, the shadow of one kidney is absent, and renal pelvis and ureters are not filled by contrast agent injected intravenously.

The basic ultrasonic sign which should guard concerning unilateral aplasia, is a definition of obviously increased kidney owing to it compensation hypertrophies. From the opposite side the kidney is not found out.

With the help of aortography only one renal artery can be detected. With the help of CT and MRI, executed both with contrast enhancement and without it, only one kidney and one vascular bunch can be detected.

Kidneys hypoplasia. Unilateral and bilateral hypoplasia is distinguished. In hypoplasia kidneys are of considerably smaller size, however their macrostructure remains normal. It is detected by intravenous contrast enhancement, thus there is no deformation of renal pelvis and calices and there is no infringement in urinary excretion. With the help of CT and MRI it is possible to perform precise measurements of kidneys, and in presence of contrast enhancement it is possible to make sure that their contrast enhancement is simultaneous. In ultrasonic scanning kidney with hypoplasia has smaller sizes, but ultrasonic structure is not damaged.

Duplex kidney. Duplex kidney is one of the most often developmental anomalies of the upper urinary tract (fig. 9.19).

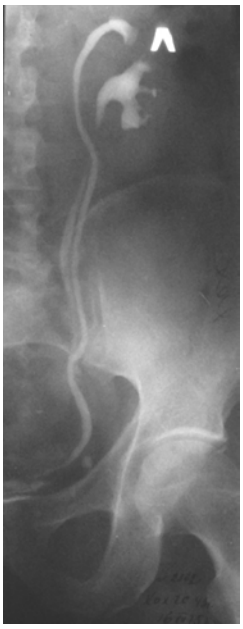

Fig. 9.19. Retrograde ureteropyelography. Note the double renal pelvis from the upper pole of the left kidney and duplicated ureter. Duplication of the upper collecting system

It can be uni- and bilateral. Doubling from the one side is observed more often, than from both sides. In anatomic-topographical understanding double kidney represents a single organ consisting of the upper and lower segments. A duplex kidney has two pelves, two ureters and a single fibrous capsule. With the help of contrast enhancement two isolated pelves and calices can be detected in one kidney.

CT is less informative, taking into account the limited opportunities of ureters imaging. Presence of two isolated pelves and calices in one kidney is detected on CT with the help of amplification and longitudinal reconstruction, and on MRI on frontal scans. Ultrasound scanning allows to identify two hyperechoic central complexes in the background of the enlarged kidney hypoechoic parenchyma structure.

Nephroptosis. Except the congenital reasons there are following reasons of this disease development: decrease of intra-abdominal pressure, reduction perirenal fat, increase in kidney weight, traumas of structures fixing a kidney. X-ray researh identifies it in various positions of a patient (laying on a back, vertically). IU has the greatest value nephroptosis detection. The increase in kidney mobility is detected in a change of body position on more than body of the lumbar vertebra hight, sharp pelvis-ureter angle and twisting of the ureter with expansion of pelvis-calices system (fig. 9.20).

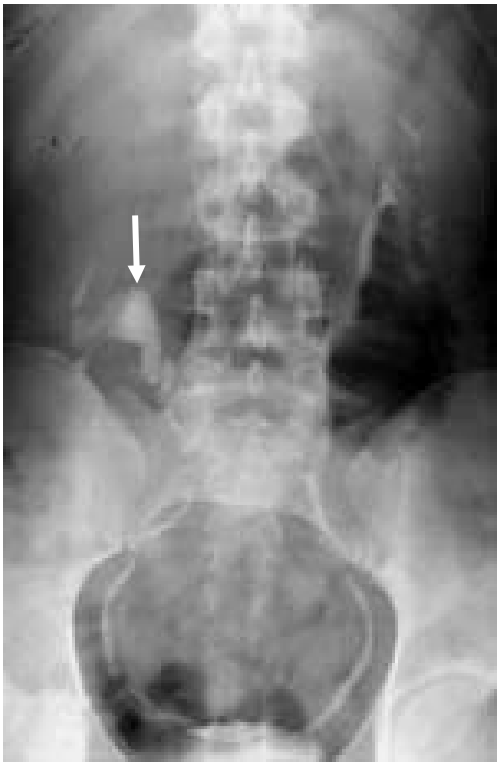

Fig. 9.20. Intravenous urography. A standing position. Right kidney pelvis at the level of IV lumbar vertebrae (arrow). Nephroptosis of a right kidney [18]

Radiologycal diagnostics of kidneys inflammatory diseases.

Acute pyelonephritis.The majority of kidneys acute inflammatory diseases are accompanied by their inlargement.

In addition to clinical methods ultrasonic scanning is indicated, it is an important initial technique since it helps to see stones, hydronephrosis, intrarenal or perirenal abscesses. Ultrasonic signs of acute pyelonephritis are: a kidney enlargement (but it can have normal sizes), echoes decrease, expansion of renal pelvis and calies (fig. 9.21).

Some changes of renal parenchyma, connected with inflammatory process, are better detected by CT, than by ultrasound, and consist of spotty areas, characteristic of insufficient blood supply, small dense sites, puffiness of perirenal fat. CT shows formation of microabscesses 0,5-1 cm. The density is close to liquid density (8-12 HU).

Static renal scintigraphy with ^{99m}Tc-DMSA also is informative, as it shows the located infectious centers before they become visible by ultrasonic scanning or CT. Research with ^{131}I-orthoiodohippuric acid shows decrease of renal tubules function.

IU during acute inflammatory process in a kidney, as a rule, does not give the qualitative information though in some cases a kidney enlargement, moderate expansion of renal pelvis calices and the ureter, decrease of kidney functionis detected.

Severe pyelonephritis in inadequate treatment or tolerance of flora to antibiotics can result in chronic inflammatory process or abscess of a kidney. IU detects ill- defined contour of a lumbar muscle on the side of lesion, diffuse increase in kidney or volumetric formation in its background, deformation of renal pelvis and calices.

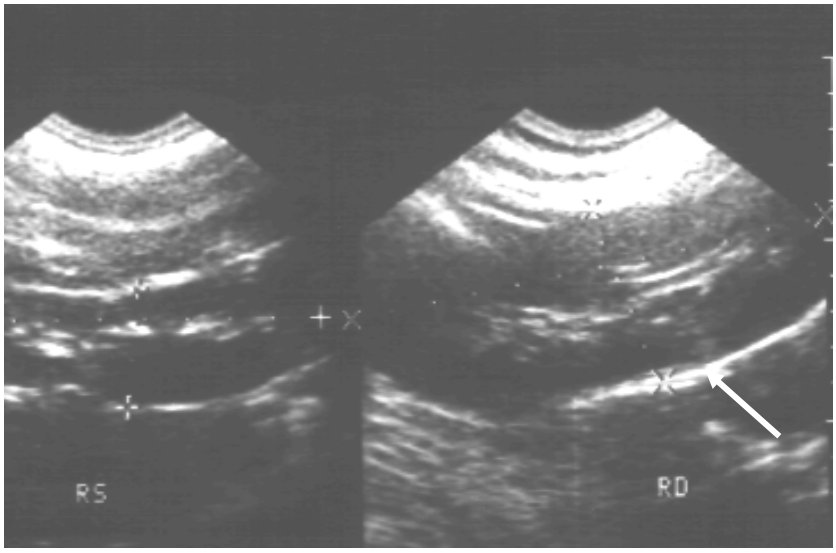

Fig. 9.21. Acute pyelonephritis. Sonograms of kidneys. Enlarged parenchyma of a right kidney (26 mm) (arrow). Compare with left kidney. Acute pyelonephritis

In ultrasound the abscess is detected as hypoechoic or mixed echogenicity often with fluid debris which alters with position and with increased “through transmission” beneath (fig. 9.22). The initial sonographic change is alteration of the echogenicity focally within the kidney. Abscess walls look like a hyperehcoic ring. CT without enhancement shows the hypodensity zone within the limits of an abscess cavity (fig. 9.23).

Abscess walls with contrast agent application are enhanced and contents are not present. MRI gives the similar information.

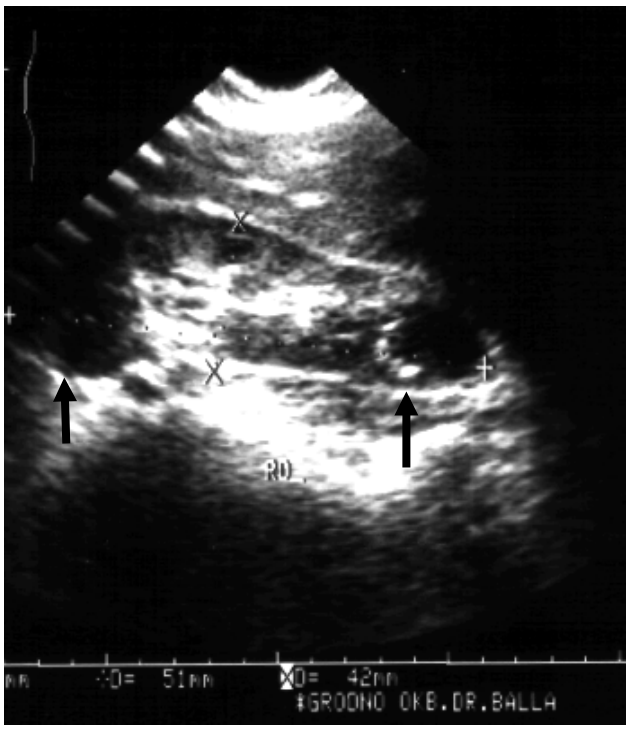

Fig. 9.22. Abscess of kidney. Sonogram along a long axis of right kidney. Abscess of kidney as hypoechoic zones with indistinct contours (arrows)

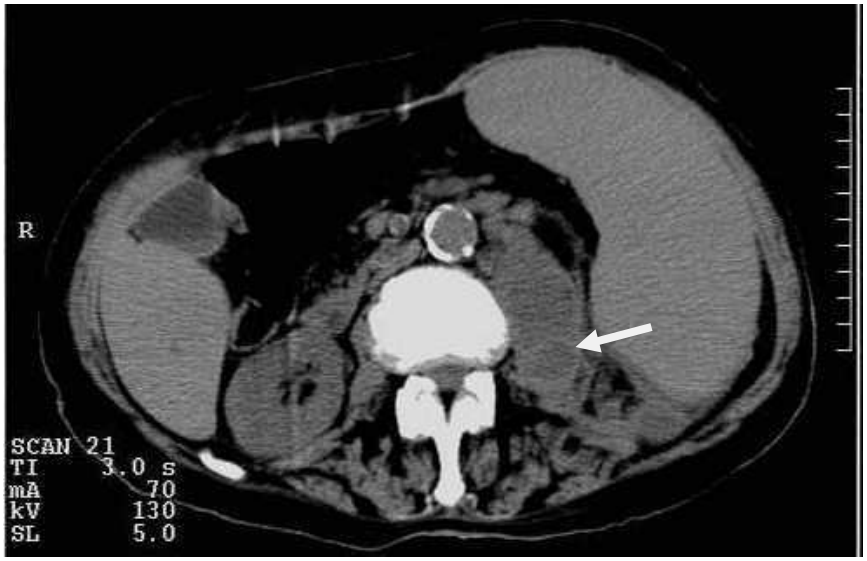

Fig. 9.23. Abscess of kidney. Computer tomogram of the abdomen cavity at the level of L2. Left kidney is deformed with presence of pseudocystic ormations. Abscess in left kidney.

The chronic pyelonephritis. Disease seldom arises in patients with unchanged urinary tract. Visualization is applied, mainly, for specification of nephrosclerosis evidence. IU detects reduction of one or both kidneys sizes, deformation of renal pelvis and calices. Intravenous urography doesn't show renal scarring precisely in comparison with scintigraphy.

Scintigraphy marks atrophy of the parenchyma (fig. 9.24) and fibrosis areas. CT detects renal fibrosis and roughness of a kidney contour. Ultrasonic scanning helps to distinguish pyelonephritis from hypoplasia displaying change of a kidney structure. In hypoplasia MRI shows steady reduction of the renal artery and its branches.

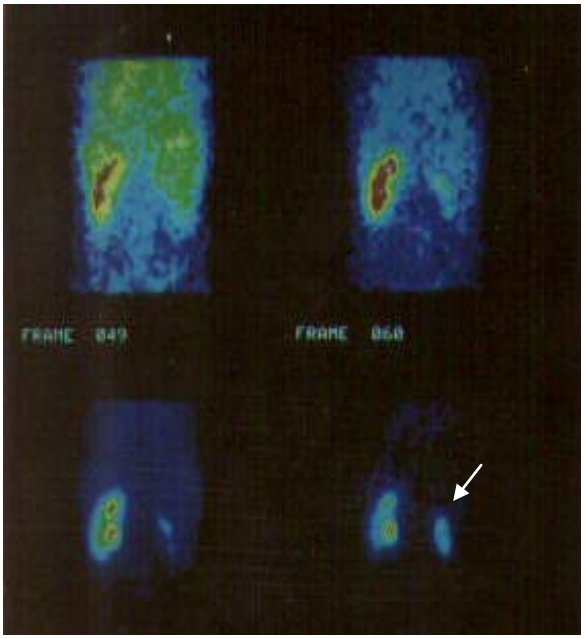

Fig. 9.24. Dynamic scintigraphy of kidneys with ^{99}mTc-DTPA. Sharp infringement of functional activity of right kidney parenchyma (arrow). Chronic pyelonephritis

Tuberculosis of the kidney. Tuberculosis of the kidney in its early stages may produce nonspecific changes such as papillary necrosis. With progression of the disease, the more characteristic findings of stricture of a renal pelvis, caliceal amputation, and cavitation may occur (fig. 9.25).

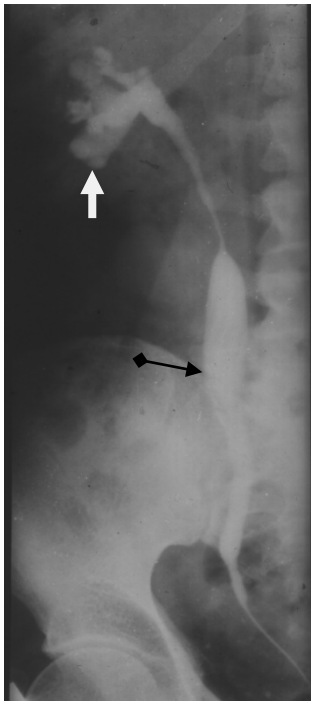

Fig. 9.25. Retrograde ureteropyelography. Cavitation in bottom pole of right kidney (arrow), the upper segment of ureter is narrowed, average and bottom are expanded (arrows with a rhombus). Tuderculosis of right kidney and the ureter

Tuberculosis also causes ureteral strictures. A combination of renal and ureteral abnormalities such as strictures should suggest the diagnosis. The end stage of renal tuberculosis is a small, shrunken, nonfunctioning kidney that often contains calcific debris (“putty kidney”) (fig. 9.26).

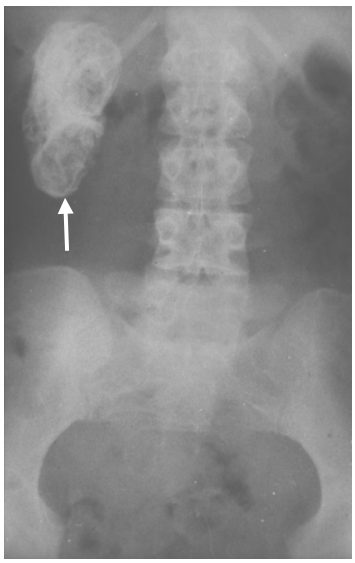

Fig. 9.26. Nonfunctioning right kidney containing calcific debris ("putty kidney") is present (arrow). Renal tuberculosis

Changes of chronic bladder inflammation include thickening and irregularity of the wall secondary to muscular and mucosal hypertrophy.

Nephrological diseases of a kidney

Acute glomerulonephritis. Kidneys are enlarged, reduced or their sizes do not vary. Biopsy of kidneys in many cases is necessary for exact diagnosis. Each patient with renal insufficiency should undergo ultrasonic scanning.

Examination with contrast substances (urography, CT) should be avoided in patients with the reduced kidneys function as contrast preparations can promote the further decrease of kidneys function.

Early sign of acute glomerulonephritis is decrease of glomerular filtration, detected with the help of ^{99m}Tc-DTPA.

Urinary calculus.

Stone formation may occur due to metabolic abnormality, structural disorders or recurrent urinary tract infection. Because approximately 90% of all urinary tract calculi are radiopaque, the plain film of the abdomen is the keystone of radiological diagnosis (fig. 9.27, 9.28).

Numerous extraurinary calcific densities that overlie the urinary tract may be confused with urinary calculus, the commonly encountered ones being calcified costal cartilages, gallstones and vascular calcifications. An intravenous urography can localize a calculus to the kidney or ureter, and evaluate the degree of obstruction the stone is producing. After intravenous contrast administration, stones may be either completely or partially obscured by excreted contrast or appear as a filling defect. The degree of obstructive uropathy often bears no relation to the size of a ureteric calculus. Perhaps the most consistent urographic finding with a ureteric calculus is the presence of a continuous column of opacified ureter expending from the renal

pelvis to the site of the calculus. Some degree of ureterectasis is usually also present if ureteric obstruction has been present for more than a few hours.

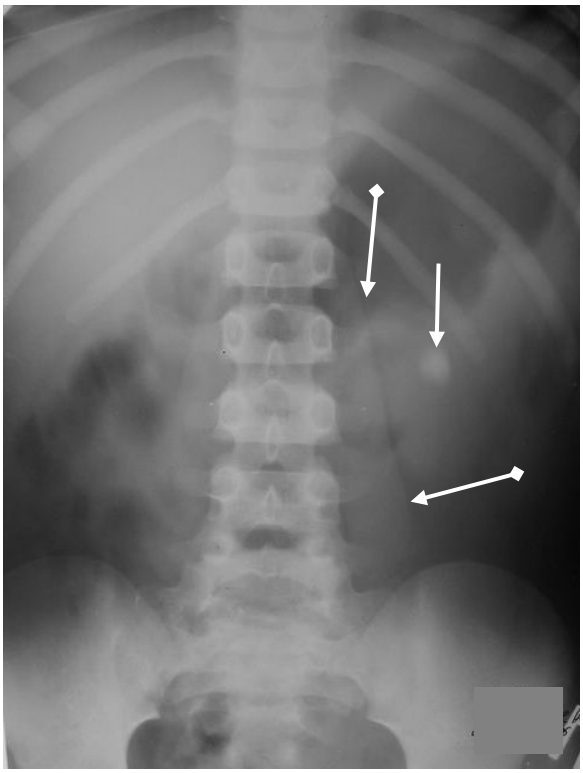

Fig. 9.27. X-ray film of the abdomen cavity. The intensive spherical shadow with precise contours is detected in the area of a left kidney (arrow). Psoas (arrows with a rhombus). A stone. Urolithiasis

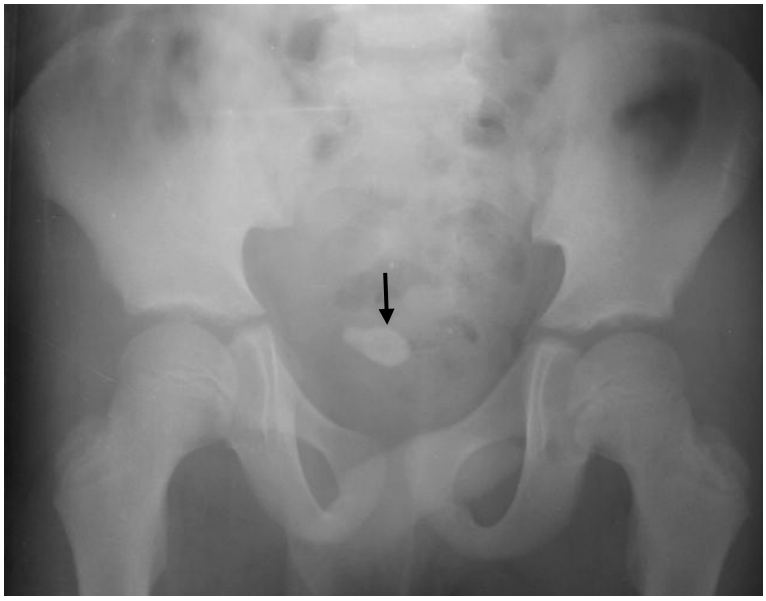

Fig. 9.28. X-ray film of the pelvis. In the bladder area the intensive spherical shadow with precise contours is detected (arrow). A bladder stone. Urolithiasis

Ultrasonography can differentiate renal calculi from other causes of pyelocalyceal filling defects such as tumours or blood clots. The sonographic diagnosis of a calculus is based on the demonstration of a highly echogenic focus that produces an acoustic shadow (fig. 9.29). Stones as small as 0,5 cm can be reliably detected in this manner. This technique assumes greatest importance when faced with

a nonopaque filling defect on urography. Tumours and clots lack a distal acoustic shadow.

Recently, it has become apparent that noncontrast helical CT (HCT) has major advantages over intravenous urography in the evaluation of patients with urolithiasis. Noncontrast HCT studies can be completed much more rapidly than intravenous urography, as there is no need for oral or intravenous contrast administration or other patient preparation. Virtually all types of urinary tract calculi contain enough calcium

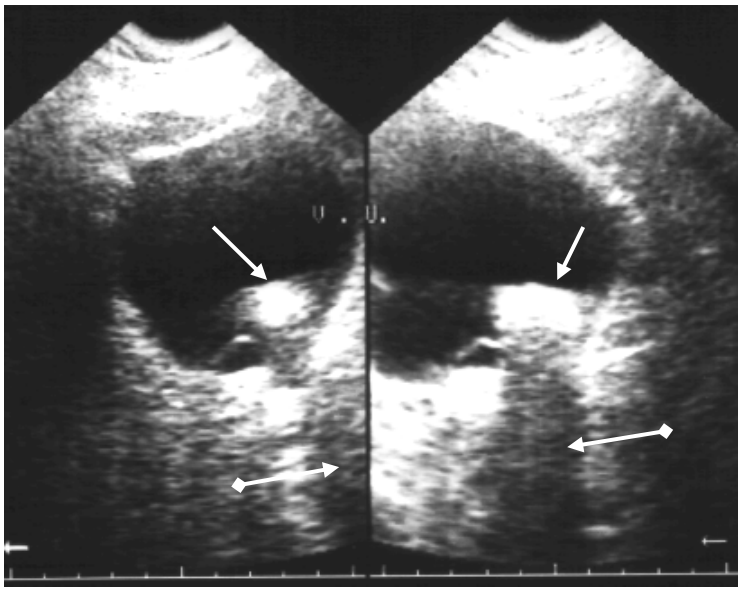

Fig. 9.29. Sonograms of the bladder. A stone in the bladder as hyperechoic area is defined (arrows). Hypoechoic acoustic shadow (arrows with rhombus). Urolithiasis

to be visibly hyperdense on noncontrast HCT. It has been demonstrated that stones are more accurately detected with noncontrast HCT than standard radiography, intravenous urography, or sonography. Noncontrast HCT provides no direct functional information. MR imaging has not yet had a major impact in this area because stones lack mobile protons and generate no signal with standard MR imaging techniques.

Renal cell carcinoma. Renal cell carcinoma, (RCC) is the most common renal tumour, comprising approximately 85% of all primary malignant renal neoplasms. Renal tumours are usually solitary, although bilateral tumours are encountered in approximately 2% of patients. Before wide spread use of cross-sectional imaging (US, CT, MRI), renal cell cancer often presented as an advanced disease at the time of diagnosis. Today, however, there has been a shift to a smaller size and lower stage of renal cell cancer at the time of diagnosis. RCC may be locally aggressive, extending into the renal veins and inferior vena cava or invading adjacent soft tissue structures. RCC can metastasize by lymphatic and haematogenous routes. Common sites of haematogenous metastases include bone, liver, and lungs. Nodal metastases

commonly involve pararenal and para-aortic nodes and may also include mediastinal and pulmonary hila nodes.

Imaging plays an important part in the detection, characterization and staging of renal cell cancer. Although the IU is still often used as the initial study in the search for renal masses, it has been shown that in the presence of a CT-confirmed renal mass, detection by IU is only 21% when the lesion is smaller than 2 cm, 52% when the lesion is 2–3 cm, and 85% when the lesion is 3 cm or more in diameter. A normal IU, therefore, does not exclude the presence of a renal mass.

IU detects following characteristic tumour signs:

1) kidney enlargement, increase in distance between cavities of a kidney and its contour, displacement of a kidney, rotation around of a longitudinal axis;

2) deformation of renal pelvis, defect of its filling, serrated pelvis contours;

3) changes on the part of calices: partial or full disappearance; narrowing or expansion, and displacement of calices;

4) change of the ureter position and its narrowing in the upper part due to the big tumour of a kidney bottom pole and metastases in regional lymph nodes.

US demonstrates detection of 60% of lesions smaller than 2 cm and 83% of lesions between 2 and 3 cm in size. Lesion detection on contrast-enhanced MRI (90–97%) equals that of CT (89 – 99%). US, CT, and MRI have all been used with varying degrees of success in the characterization of renal masses. On US, the appearance of renal cell carcinoma is variable. Approximately 86% of tumours are isoechoic, 4% are hyperechoic, and the remainder are hypoechoic as compared to the adjacent renal parenchyma.

Ultrasonic scanning is an initial method of visualization of RCC. RCC on ultrasonic scanningis defined as a mass of wrong spherical or oval form with rough contours. In most cases kidney cancer has nonhomogenous structure; in parenchyma additional echoes appear, caused by cysts and necrosis sites, calcifications, haemorrhages. Deformation of a kidney and its enlargement is visualized. Deformation, displacement or reduction of renal pelvis and calices is quite often detected (fig. 9.30).

Ultrasonic as an initial method of visualization of kidneys allows:

• to find out the majority of cancer tumours;

• to distinguish them (beginning with 4-5 cm tumours) from benign tumours with nonhomogeneous structure;

• to detect metastasises in lymph nodes and the liver;

• to exclude the second kidney lesion.

Colour Doppler sonography using frequency shift determinations has demonstrated some utility in differentiating benign from malignant lesions. Power

Doppler sonography, which is even more sensitive to flow than conventional colour Doppler imaging, may provide additional information in characterizing renal lesions. Although US is useful in characterizing renal masses, it is inadequate in staging renal cell carcinoma.

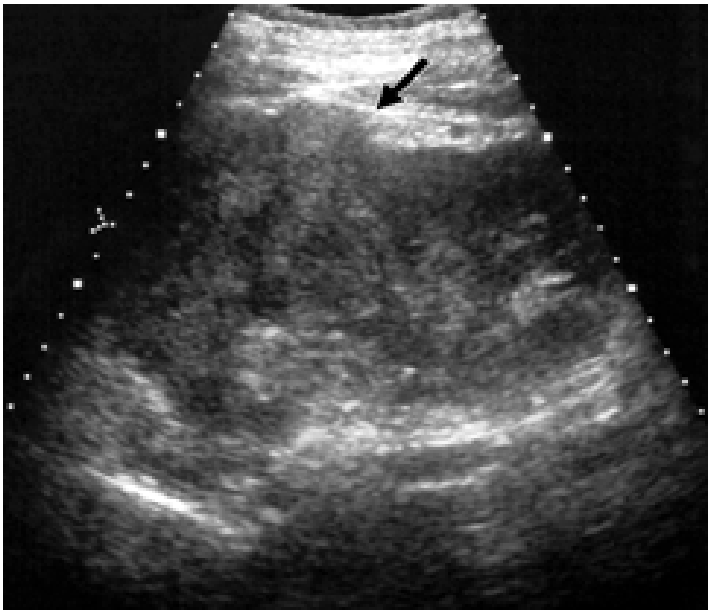

Fig. 9.30. Longitudinal ultrasound image through the right kidney demonstrates a heterogenous lobulated ill-defined mass arising from the upper pole (arrow) due to renal cell carcinoma. Renal cell carcinoma [101]

Benign tumours of a kidney, as a rule, hyperechoic, homogeneous with smooth contours (fig. 9.31).

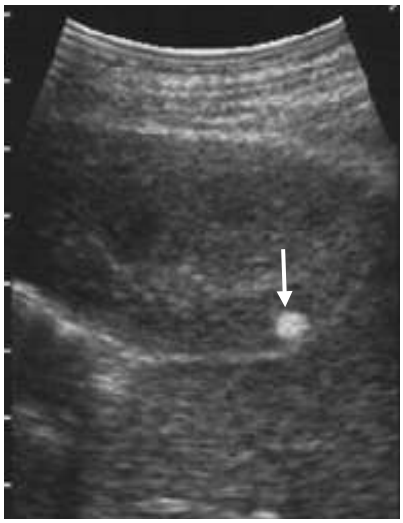

Fig. 9.31.Sonogram of a left kidney. In area of a left kidney parenchyma hyperechoic mass with precise contours is detected (arrows). An angiomyolipoma (a benign tumour) of left kidney

The CT appearance of renal cell carcinoma varies with tumour size and vascularity. When large enough, these tumours appear as masses that alter renal contour or intrarenal architecture (fig.9.32). Detection of small lesions is facilitated by rapid sequence scanning techniques during administration of contrast material because abnormal enhancement may be evident even when renal contours are

normal. Heterogeneous enhancement is characteristic, but after administration of contrast medium, renal cell carcinomas typically appear less dense than surrounding renal tissue. Large intralesional vascular channels and retroperitoneal collateral vessels may also be present. Initial experience with spiral CT suggests that this technology may offer more complete CT characterization of small indeterminate renal masses.

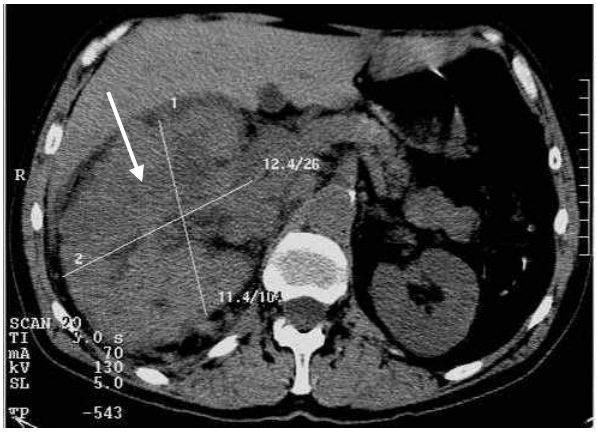

Fig. 9.32. Computer tomogram of the abdominal cavity at the level of L2 vertebrae. The right kidney is appreciable enlarged, contours are rough, structureis nonhomogenous (arrow). Renal cell carcinoma.

On MRI, renal cell carcinomas demonstrate variable signal characteristics depending on the degree of tumour vascularity and the presence or absence of haemorrhage, necrosis, calcification or iron particles in the tumour cells. In the absence of haemorrhage or necrosis, RCC tends to be isointense to normal renal parenchyma on both T1- and T2-weighted images. When intra tumoural haemorrhage or necrosis is present, signal intensity can be heterogeneous on both T1- and T2-weighted images. Haemorrhage from a RCC may result in deposition of iron in the kidney and lower the signal intensity of the tumour on both T1- and T2-weighted images. This effect is not specific for renal cell carcinoma and may be seen with any haemorrhagic lesion or with systemic haemolysis. The differential diagnosis for a renal lesion appearing hypointense on both T1- and T2-weighted sequences also includes fibroma, milk of calcium cysts, and other calcified renal lesions. Intralesional calcifications are not well depicted on MRI. Renal cell carcinomas have been well depicted on postcontrast T1-weighted fat suppressed images. On gadolinium contrast-enhanced MRI scans, tumours generally enhance to a lesser degree than the surrounding renal parenchyma.

Imaging plays an important role in renal cancer treatment decision. The decision as to the type of surgery (nephron sparing; simple or radical nephrectomy) that can be performed in patients with renal cell carcinoma is helped by imaging. Because surgery provides the only effective therapy and because survival depends on local and distant extent, precise staging is critical for preoperative planning and prognosis.

Although CT has been the test of choice for staging renal cell carcinoma. MRI appears to have a similar accuracy. Combined transverse and sagittal MRI planes are optimal for the evaluation of venous anatomy and the normal tissue – tumour interfaces.

The particular uses of MRI staging include determination of the origin of the mass, evaluation of vascular patency, detection of perihilar lymph node metastases and evaluation of direct tumour invasion to adjacent organs. On CT and MRI, diagnosis of lymph node metastases is based on detection of lymph node enlargement with nodes measuring larger than 1 cm in diameter in short axis considered abnormal. Approximately 60% of nodes measuring greater than 1 cm in transverse diameter, in the setting of RCC, however, have been shown to be inflammatory or hyperplastic in nature rather than metastatic. Lymph node enlargement due to inflammation/hyperplasia or to metastasis cannot be distinguished on the basis of imaging findings. MRI is a sensitive tool for determining the presence and extent of tumour thrombus and for demonstrating invasion of the wall of the inferior vena cava.

In the assessment of thrombus extension into the renal vein or inferior vena cava, MRI has replaced venography. In renal cell carcinoma, thrombus extends into the inferior vena cava in 4–10% of cases. Typically, tumour thrombi enlarge the renal vein and inferior vena cava and cause the density of these vessels to be heterogeneous. The accuracy in the determination of inferior vena cava thrombus is 100% on MR imaging compared to 88% and 78% for CT and ultrasound, respectively. MR accuracy in determination of renal vein thrombus is lower at 88%. On MRI tumour thrombi are usually isointense to the primary tumour.

Visualization of tumour extension to the liver, spleen and psoas muscle is also improved with MR imaging. The accuracy of MR imaging is similar to that of CT in patients with stage I and stage II disease, but with more advanced disease (stage III and IV), particularly involving a large tumour mass, MR staging has proven superior.

Because CT is less expensive and more widely available, CT remains the preferred cross-sectional imaging procedure for the detection, characterization and staging of renal lesions. Three-dimensional imaging and display of renal tumours using spiral CT has also recently been shown to serve as a surgical aid when planning partial nephrectomy.

MRI is reserved for those cases where CT staging is inconclusive, especially with respect to vascular extension and direct tumour invasion of neighbouring tissue or in patients with renal failure, or where there are other contraindications for the use of iodinated contrast media.

Arteriography in modern practice apply at tumours of kidneys seldom: for definition of anatomy of vessels at a planned resection of a kidney and embolization before surgery treatment.

Cysts. Simple renal cyst most often space-occupying lesions of a kidney. They come to light more than at 50 % of cases of patients with 50 years old are more senior. US signs of cyst include: absence of non-uniform structure, smooth and equal walls, density of contents meets to a liquid, distal acoustic enhancement (fig. 9.33).

In general, renal cysts appear as nonspecific space-occupying lesions at intravenous urography, a well-defined anechoic lesion with distal acoustic enhancement at US, a non-enhancing discrete fluid density lesion at CT, and a non-enhancing well-circumscribed lesion of fluid signal intensity characteristics at MRI.

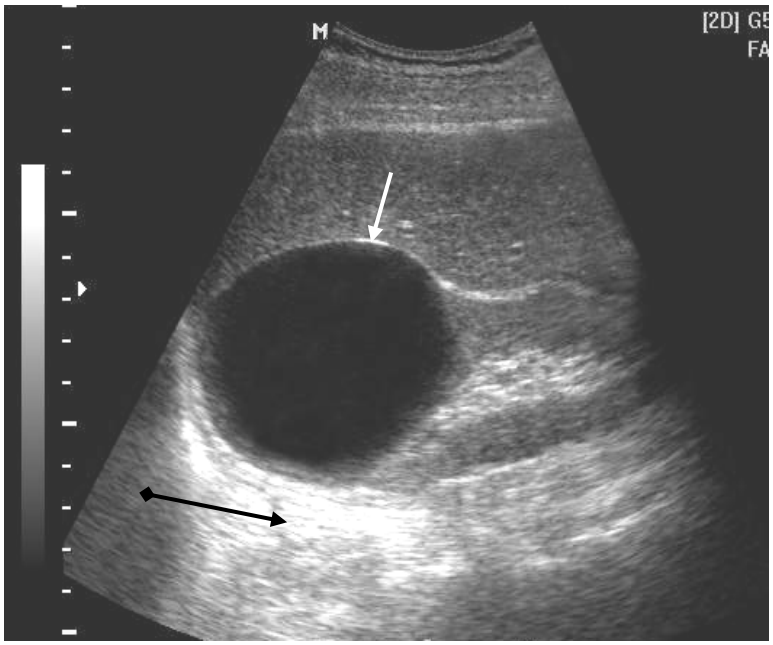

Fig. 9.33. US of right kidney. Cyst (arrow). Area of distal acoustic enhancement (arrow with rhombus)

Pharmacological-ultrasonic mode with application of diuretic drug – furosemidum promotes differentiation diverticulum of calices and hydrocalix (expansion after furosemidum) from cysts.

Nephroscintigraphy shows a zone of the lowered accumulation of a preparation.

Renal trauma part of a major abdominal trauma, occurring in 8–10% of all blunt and penetrating abdominal injuries. Most blunt renal injury results from blunt impact trauma. When renal imaging is considered after trauma, CT is the optimal modality. Limited IU may be performed to document the presence of two functioning kidneys if the patient's clinical status does not allow for performance of CT.

Ultrasound not typically used in the acute assessment of potential renal injury, but can be used to follow previously documented renal injuries, such as extrarenal haematoma or urinoma, as well as to follow the course of post-traumatic hydronephrosis**.** In the acute setting portable sonography can be used to document the presence or absence of a kidney when one is not visualized by IU. Further, Doppler sonography can be used to assess the patency of the renal artery and vein if a nonfunctioning or delayed-functioning kidney is seen by intravenous urography or CT scan. Generally, MRI does not have a role in the acute assessment of renal trauma. Surgical staging classifications for renal injury have been adapted to include observations from CT examination (fig. 9.34).

Grade 1. Renal trauma refers to minor renal injuries including focal or global renal contusion; superficial lacerations that do not extend to the collecting system;

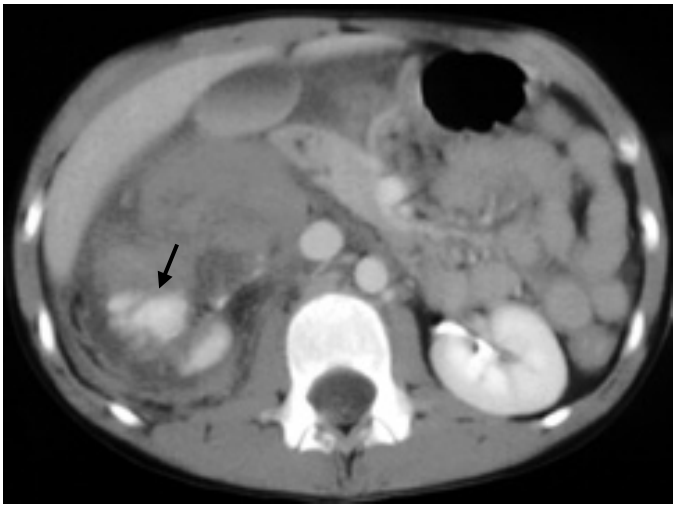

Fig. 9.34. Axial contrast-enhanced CT section shows a large haematoma surrounding the fractured lower pole of the right kidney (arrow). Renal trauma [99]

small or limited perinephric or subcapsular haematomas; and segmental renal ischaemic infarcts.These grade 1 injuries comprise 75–98% of renal injury seen with blunt trauma. Renal contusions generally appear as ill-defined areas of diminished attenuation with irregular margins. Oedema associated with contusions may delay renal urine excretion focally resulting in an irregular or striated-appearing nephrogram on CT scan. Contusions may also be accompanied by disruption of collecting tubules with focal interstitial staining of the renal parenchyma with contrast-enhanced urine (renal intravasation) that may be detected on follow-up noncontrast-enhanced CT scan studies. Segmental renal infarcts are relatively uncommon and primarily affect the upper pole. Often these are associated with stretching and thrombotic occlusion of segmental intrarenal, capsular, accessory renal artery, or main renal artery branch injuries. Segmental infarcts appear as focal, well demarcated, nonenhancing regions of parenchyma that are wedge-shaped and

tend to involve the renal poles. In general, grade 1 injuries are managed with observation.

Grade 2. Renal trauma (fig. 9.35) refers to major renal injuries including deep lacerations of the renal parenchyma that extend into the collecting system, limited extravasation of urine, and moderate to large perinephric or subcapsular haematoma. It is important to distinguish renal contrast extravasation from active haemorrhage. Renal contrast leak can typically be identified arising directly from a disruption in the renal collecting system. Contrast arising from the arterial or venous haemorrhage often appears before the renal collecting system is opacified, verifying its vascular origin. The management of major renal injury typically depends on the clinical picture and evolution of the injury with time.

Grade 3. Renal trauma refers to catastrophic renal injuries including major renal pedicle injuries involving either the renal artery or vein, renal parenchymal fragmentation with extensive haemorrhage, active haemorrhage of renal origin, and renal pelvic or disruption of the proximal ureter.

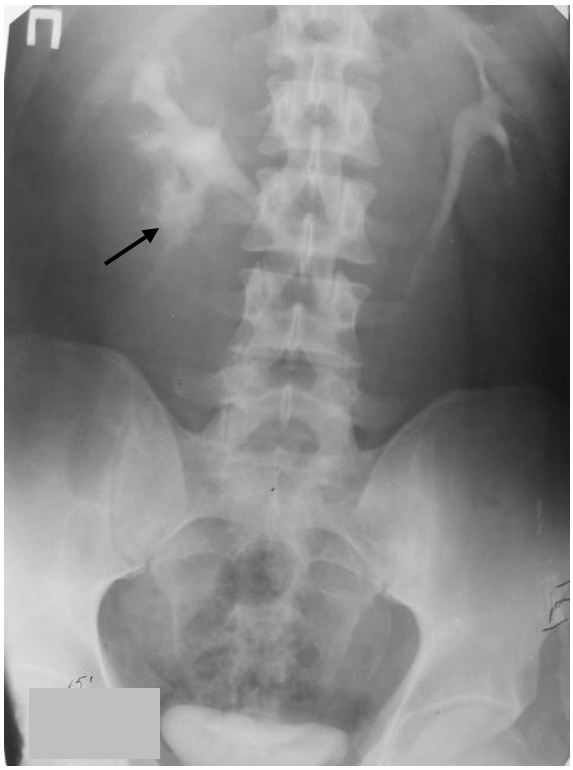

Fig. 9.35. Intravenous urography. In the field of the bottom pole of a right kidney a clump of a contrast irregular-shaped agent is detected (arrow). Trauma of a right kidney. Parenchyma breaks in a right kidney in a projection of the bottom and average big cups. Renal trauma

The injury typically occurs in the proximal third of the renal artery. CT scan findings are usually diagnostic demonstrating no or only patchy peripheral renal parenchymal enhancement from intact collateral vessels. The kidney may be intact but smaller than normal owing to lack of inflowing blood and may be displaced laterally from its usual location. Angiographic confirmation of renal artery occlusion is not necessary and only serves to diminish further any chance for successful renal

revascularization. Revascularization is most likely to be successful within 2 hours of injury. Delayed revascularization hours to days after injury is occasionally successful. Main renal vein injury may produce extensive perirenal haemorrhage or if thrombosed may lead to an enlarged kidney with a delayed, but progressively dense nephrogram, ongoing haemorrhage seen as patchy areas of dense contrast material surrounded by less dense haematoma.

Severe renal fragmentation is considered a catastrophic injury. If CT or renal scintigraphy indicates minimal residual renal function, or if ongoing haemorrhage or gross urine leakage accompany severe parenchymal disruption, nephrectomy is required.

Hydronephrosis. Hydronephrosis, dilatation of the intrarenal collecting system (fig. 9.36). It may be divided into obstructed and nonobstructed. In the former group, the obstruction may be mechanical or functional and may occur any where in the collecting system. If the obstruction occurs more distally in the ureter, then hydroureter (dilatation of the ureter due to a distal obstruction) is also seen. Among the diverse causes, the more common ones include: urolithiasis, tumour, stricture, vesicoureteric reflux, congenital abnomalities (ureteropelvic junction obstruction, posterior urethral valves), and extrinsic compression (retroperitoneal fibrosis or lymphandenopathy). Nonobstructed hydronephrosis, also known as "urinary ileus", may be associated with previous obstruction or urinary infection.

In the acute state, the affected kidney is enlarged and of smooth contour. Atrophy and fibrosis are seen with long-standing hydronephrosis. Infection is a serious complication of hydronephrosis. An infected and obstructed collecting system is known as pyonephrosis, and the affected patient can quickly succumb to sepsis.

Hydronephrosis is easily detected by ultrasound (fig. 9.37). A dilated intrarenal collecting system is imaged as enlarged anechoic fluid structures, which communicate with each other to form the renal pelvis. In contrast, the multiple cysts in polycystic renal disease are separate and do not communicate with each other. Internal echoes are seen in the dilated collecting system in the setting of pyonephrosis. While ultrasound usually cannot distinguish between obstructed and nonobstructed hydronephrosis, excretory urography may provide additional information in that it may demonstrate the level of obstruction. Forniceal rupture is a complication of hydronephrosis in excretory urography; it may result from a sudden increase in urine volume due to contrast-induced diuresis.

Hydronephrosis can also be imaged by CT or MRI, though the expense of MRI precludes its use given the usefulness of the other imaging modalities for this purpose. CT is particularly helpful when imaging hydronephrosis due to obstruction

from an abdominal or pelvic tumour. Not only can it depict the level of obstruction, CT can often demonstrate the cause and its extent, as well as mass effect upon the adjacent structures.

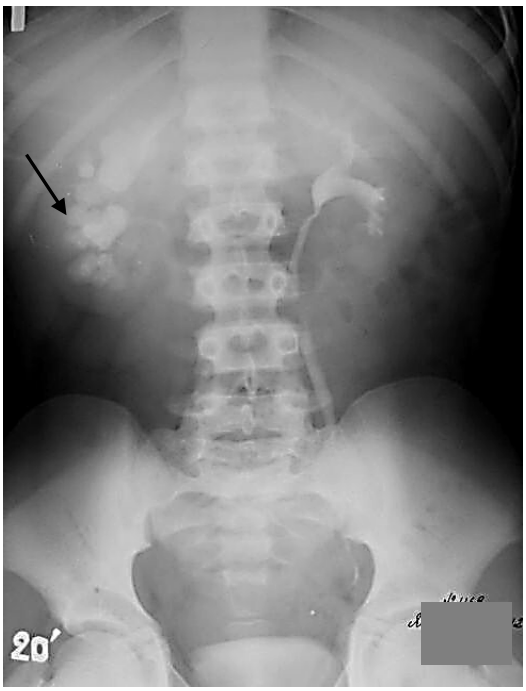

Fig. 9.36. Intravenous urography. Sharp expansion and deformation of cups in a right kidney (arrow). Dilatation of the intrarenal collecting system. Hydronephrosis

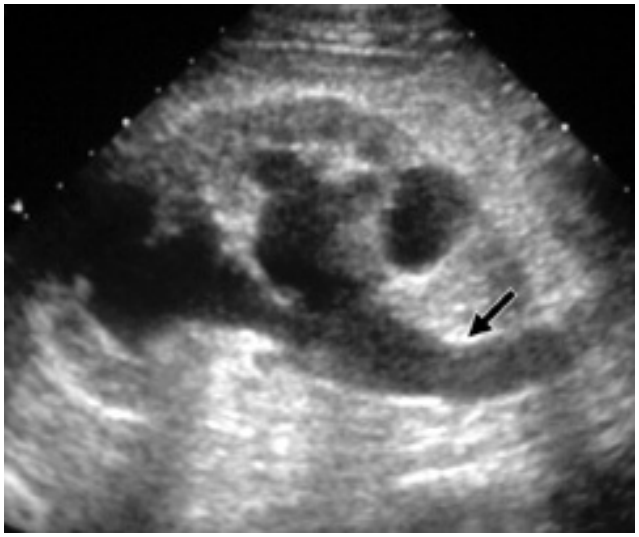

Fig. 9.37. Longitudinal ultrasound image of the kidney, showing a moderate degree of hydronephrosis and hydroureter (arrow) [101]