Renal Imaging in the elderly. Normal findings and pathology.

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Learning objectives

1. To illustrate the typical imaging findings of the kidney in the elderly patients;

2. To illustrate the typical features of the main renal pathologies in the elderly patient;
Background

Population aging is taking place throughout the world, and about 13% of the 76 million persons in the United States were aged 65 years and older [1]. In Europe there is the oldest population in the world, with almost 25% of European projected to be aged 65 years or older by 2030. In particular, Italy and Germany are estimated to have the oldest population in Europe. The progressive increase in the proportion of a population that is elderly depends on changes in the survival of older persons and in the birthrate [1]. The increasingly greater life expectancy of the population has been mainly determined by the reduced mortality at older ages. The five leading causes of death, including heart disease, cancer, stroke, chronic lower respiratory tract disease, and Alzheimer’s disease, account for 69.5% of all death [1]. The renal causes of death account only for 2% of all deaths and for 4% of chronic conditions in persons aged > 65 years, even though these represent an important cause of disability and comorbidity in the older patients.

Due to the progressive increase in the mean age of the population it is very important to know the morphologic changes of the kidney according to the aging. As a matter of fact, older individuals, often with a compromised renal reserve and substantial comorbidities, are the norm in the hospitalized population [2].

The functional alterations of the aged kidney are characterized principally by a progressive reduction of renal blood flow from about 600 to 300 mL/min/1.73 m$^2$, and of glomerular filtration rate (GFR) from 130 mL/min to 60-80 mL/min. An accurate quantitation of the GFR should always be performed in the elderly patient before injection of iodinated and gadolinium-based contrast agents. Moreover, when exposed to iodinated contrast agents, non-steroidal anti-inflammatory drugs, aminoglycosides or emodynamic challenges (e.g., surgery and anesthesia, sepsis, volume depletion), this at-risk patient population often develops an abrupt decline in GFR. The kidneys undergo involutorial changes with age. There is a gradual decline in kidney weight starting after the age of 50 years, with the most marked decrease occurring between the seventh and eight decade. The progressive loss of kidney mass appears to affect the renal cortex more than renal medulla [3]. Microscopically there is a reduction in the number of glomeruli and an increase in glomerular sclerosis with increasing age [4]. The glomerular sclerosis in the elderly is different from the diabetic intercapillary diffuse sclerosis and focal glomerulosclerosis, and corresponds to a progressive glomerular hyalinization such that glomeruli become shrunken, eosinophilic and hypocellular masses. The increase in the percentage of sclerotic glomeruli has been attributed to the protein-rich diet characteristic of modern society which probably determines a state of chronic glomerular hyperfiltration, and hyperperfusion. A further cause would be the glomerual ischemia secondary to the changes of the renal blood flow occurring with ages. The presence of atherosclerosis increases the incidence of glomerular sclerosis, raising the possibility that the glomerular sclerosis in the elderly is nothing other than a reflection of vascular disease and thus
should be considered a secondary phenomenon. On electron microscopic analysis, there is an increase in focal thickening of both glomerular and tubular basement membranes, probably due to the accumulation of type IV collagen [3]. The loss of glomerular mass is proportional to the loss of tubular mass, so that the tubular balance is well preserved. The outer cortical glomeruli are more extensively involved than the deeper glomeruli. Moreover, in addition to glomerular sclerosis there is a gradual increase in the interstitial fibrosis.

Although most would agree there is a decrease in the total number of glomeruli, there is a very wide scatter in the data, and many elderly people seem to retain the same number of glomeruli as expected in younger persons [4]. The average thickness of the glomerular basement membrane increases with age, but this does not appear to be associated with any change in function. The volume of the mesangium increases but as this is accompanied by a decrease in glomerular volume, it is difficult to draw any significant conclusion. The most significant changes appear in the juxtamedullary glomeruli. Changes also take place in the tubules where there may be irregular thickening of the basement membrane and, particularly in the distal tubule, the formation of diverticula. There is overall reduction in the tubular volume, and this seems to parallel the reduction in glomerular volume. The interstitium may contain areas of tubular atrophy and fibrosis.

Renal arteries develop intimal thickening and reduplication of the elastic lamina. Increasing tortuosity and tapering of the interlobular arteries have been reported. Changes have been recognized in afferent arterioles, and there is evidence that there are differences between those arterioles supplying juxtaglomerular glomeruli and more cortical glomeruli. It would appear that with increasing age shunts develop between the afferent and efferent arterioles in the juxtamedullary glomeruli, whereas in the cortical glomeruli the vessels become obliterated. The significance of these findings are unclear, as it is difficult to separate out changes which may have been engendered by hypertension and those due to aging alone [4].
1. Morphologic alterations in the kidney of an elderly patient

Aging induces in the kidney a progressive, functional, and anatomic decay that does not have a particular clinical impact. The fundamental alterations of renal morphology in the elderly patients include size reduction, parenchymal thickness reduction, margin irregularities, and increased cortico-medullary differentiation. In particular, the most important morphologic alteration of the aged kidney is the volume reduction, approximately 20%-30% in 80-years old man, and a loss of weight that decreases from 250-270 g to 180-200 g after age 65 [5].

On gray-scale ultrasound (US) the kidney appear frequently reduced in their largest dimension (within the range of 9 - 9.5 cm) and present a clear reduction in the renal parenchymal thickness due to reduced perfusion of renal parenchyma related to nephroangiosclerosis. The renal capsule becomes thicker and there is an increase of the renal sinus fatty tissue, in particular at the level of the renal hilum (Figure 1 on page 17). The cortico-medullary differentiation is increased due to the relative higher echogenicity of the renal cortex compared to medulla due to nephroangiosclerosis (Figure 1 on page 17; Figure 2 on page 17). There is also evidence of irregular margins (Figure 2 on page 17; Figure 3a on page 18), frequently with a pseudolobular appearance or coexisting with renal parenchyma scars (Figure 3b on page 18). Focal irregularities due to previous renal cortical infarctions are frequently identified (Figure 3b on page 18; Figure 4 on page 19).

On contrast-enhanced CT reduced cortical thickness is frequently identified (Figure 5 on page 19), often with evidence of renal scar due to previous renal infarcts (Figure 6 on page 20). Renal parenchymal retention cysts (Figure 7 on page 21) and renal sinus cysts (Figure 8 on page 22) are frequently indentified and probably develop because of inflammatory reactions and infections that occur in the distal tract of the tubuli [6]. On CT-urography these fundamental morphological changes are frequently associated with calyceal alterations with narrowing of the first order calyces, and multiple cysts of the renal sinus (Figure 9 on page 23).

2. Nephroangiosclerosis

Nephroangiosclerosis (nephrosclerosis) is a term employed to indicate a general hardening of the kidney due to overgrowth and contraction of interstitial connective tissue. Nephrosclerosis may be compared to the artheriosclerosis of the small renal arteries and it is due to renovascular disease, mainly chronic hypertension. The renal vascular alterations of hypertension depend on the severity of the blood pressure elevation and
whether the process accelerates to malignant hypertension. Arteriolosclerosis of small cortical renal arteries, interlobar, arcuate and interlobular, is a common feature of kidney in patients with systemic arterial hypertension and particularly in elderly patients [7]. In nephroangiosclerosis both kidneys are usually symmetrically reduced in their diameters with cortical scars. Cortical echogenicity is increased with increased or reduced cortico-medullary differentiation according to the grade of echogenicity of renal medulla.

Color and power Doppler ultrasound reveal non-specific reduction of renal parenchyma vascularization (Figure 10 on page 24). If compared to the younger population, renal RIs are typically increased (>0.7 and frequently around 0.8) (Figure 11 on page 25; Figure 12 on page 26). Renal perforating arteries and veins [8] are much more visible in kidneys of nephroangiosclerotic patients in comparison with normal subjects, since they enlarge in nephroangiosclerosis and present normally directed flows from the kidney towards renal capsule. Renal RIs are increased with values ranging from 0.8 and 0.98.

3. Renovascular disease

a. Renal artery stenosis

The geriatric population is affected by many vascular diseases, since the incidence of atherosclerosis increases with age [1, 2]. Generally, the imaging of vascular diseases in the elderly is complicated by the presence of coexisting diseases, while the image quality is degraded due to obesity and limited patient compliance. Renovascular hypertension accounts for 0.5% to 5% of patients who have hypertension. The renovascular disease may manifest as asymptomatic renal artery stenosis, intractable or uncontrollable hypertension requiring multiple medications, or ischemic nephropathy with progressive loss of renal function [9]. In the young patient the most common cause of renovascular hypertension is fibromuscular dysplasia, while in the elderly the most common cause is atherosclerosis mainly localized in the ostial or proximal tract of the renal artery.

Color Doppler ultrasound (US), helical computed tomographic (CT) angiography, angiotensin converting enzyme inhibitor scintigraphy with captopril, and magnetic resonance (MR) angiography have been assessed in the diagnosis of renal artery stenosis. Digital subtraction angiography remains the gold standard for the diagnosis of renal artery stenosis, and it is part of any endovascular intervention. Contrast-enhanced CT and MR imaging angiographic techniques have improved in their detection of renal artery stenosis and MR angiography is generally considered more sensitive for renal artery stenosis than US [10]. Anyway, kidney disease limits the use of contrast agents during CT and MR imaging examinations, and this is particularly true in the elderly patients. Moreover, coexistent cardiopulmonary disease, such as congestive heart failure, arrhythmias, and chronic obstructive lung diseases, limit the ability of the elderly to hold breath during image acquisition [9]. Additionally, the cardiopulmonary diseases may preclude the use of some of the imaging modalities because of the inherent contraindications, such as pacemakers in MR examinations. Consequently, color Doppler
US is the principal imaging technique employed in the elderly for renovascular disease diagnosis.

The velocitometric analysis of Doppler trace derived from renal arteries is of primary importance to identify renal artery stenosis. Direct Doppler criteria have been proposed for the detection of renal arterial stenosis, including an increased peak systolic velocity (> 150 - 180 cm/sec) ([Figure 13 on page 27]) and end diastolic velocity at the level of the stenosis [11, 12], post-stenotic flow disturbance resulting in spectral broadening and reversed flow [11], increased ratio (# 3.5) of peak systolic velocity in renal artery and aorta (renal-aortic ratio), and the presence of turbulence within the renal artery [13, 14]. Although this technique is easy to perform, its accuracy is questionable because the lack of an early systolic peak has a low sensitivity for moderate stenoses, and the waveform is dependent on the maintenance of vessel compliance, which limits its effectiveness in elderly patients and patients with atherosclerosis [15, 16].

Downstream hemodynamic repercussions of renal artery stenosis in the distal intrarenal arterial bed may be identified by Doppler US and may provide an indirect diagnosis of renal artery stenosis. Numerous parameters are still debated (Correas et al. 1999) except in cases of critical stenosis (>80%). In fact, even though intraparenchymal arteries examination is technically easier than the evaluation of the main renal artery, Doppler US findings in interlobar-arcuate renal cortical arteries are less reliable than Doppler US findings on stenotic site, since downstream repercussions are absent in 20% of principal renal artery tight stenosis (>80%), for a well-developed collateral blood supply. The assessment of the morphology of the Doppler trace since, in the presence of an hemodynamically significant renal artery stenosis, the Doppler trace measured at post-stenotic or intrarenal tract of renal artery reveal a "tardus et parvus" [15, 17] profile, consisting in an increased time to reach the peak of the trace (acceleration time > 70 ms) with loss of early systolic peak and decreased acceleration index (< 300 cm/s²). Poststenotic pulsus tardus is caused by the compliance of the poststenotic vessel wall in conjunction with the stenosis, which produces the tardus effect by damping the high-frequency components of the arterial waveform. This information allows to identify those conditions which may produce false-positive or false-negative results when the tardus phenomenon is used to predict hemodynamically significant upstream stenosis [15]. This is the case of the loss of vascular compliance in severe diffuse atherosclerosis or elderly patients which may prevent the tardus-parvus phenomenon decreasing the sensitivity of color Doppler US [12]. Other findings which may be observed in the intraparenchymal arteries in the presence of renal artery stenosis is a decreased resistive indices in interlobar-arcuate renal cortical arteries with increased side difference higher than 10% [11].

Contrast-enhanced CT angiography (CTA) and MR imaging angiography (MRA) CTA is also very sensitive and specific for the demonstration of renal artery occlusion.
Additional views provided by CTA allow for display of the renal arteries in multiple planes and projections, often necessary for depiction of stenosis (Figure 13 on page 27). Calcified plaques limit the CT evaluation of luminal narrowing. In particular in cases with extensive calcification, as it is frequently observed in the elderly patients, renal artery stenosis can be obscured by MIP rendering techniques and requires careful evaluation with the volume rendered images. CTA can also depict secondary signs of renal artery stenosis, including poststenotic dilatation and renal parenchymal changes of atrophy and decreased cortical enhancement. CTA is also very helpful in the post treatment evaluation of renal stent grafts, and can usually delineate between the highly attenuating graft material and the intraluminal contrast material.

MRA is well suited for evaluation of renal artery stenosis in the elderly. Calcified atheromatous plaques do not hamper the assessment of the arterial lumen. MR angiography provides information about the size of the kidney, collateral vessels, and post-stenotic dilatation. Contrast-enhanced axial MR imaging can directly show the narrowing of the stenosis, and reformatted multiplanar imaging is often used. Both MIP and volume rendering are useful and complimentary in the evaluation of renal artery stenosis. Axial images alone are not sufficient for the evaluation renal artery stenosis because the renal arteries often have a tortuous course especially in the elderly patient. Multiplanar reformations are very useful, in particular to show renal artery occlusion (Figure 13 on page 27).

b. Renal infarction

Nontraumatic acute renal infarction may present the same symptoms of stone colic or acute pyelonephritis. Renal infarction may be caused by tight stenosis or occlusion of segmental or of the main renal artery, or by renal artery embolization due to renal angioplasty, atrial fibrillation and cardiac valvular defects. Other causes of renal infarction are vasculitis, systemic lupus erythematosus, drug-induced vasculitis, paraneoplastic syndrome, hypercoagulable state, or acute venous occlusion [18]. Fever and leucocytosis are common is the volume of infarcted renal parenchyma is substantial. Both CT and angiography are reference imaging techniques in renal infarcts detection, whereas US presents a lower sensitivity. Even though large renal infarcts may be hypoechoic in comparison with the viable renal parenchyma, segmental renal infarcts are usually isoechoic or rarely hyperechoic if haemorrhagic component is present.

Both color and power Doppler may increase diagnostic capabilities of US in detecting renal infarcts, especially in elderly or obese patients and in patients with renal diseases. In renal infarct, color and power Doppler reveal absolute absence of renal cortical flows; however, it can be very difficult to differentiate renal segmental infarct from areas which appear poorly perfused due to underlying parenchymal disease, deep renal position and artifacts. Even though large renal perfusion defects or infarcts may be hypoechoic in comparison with the viable renal parenchyma, segmental renal infarcts are usually isoechoic or rarely hyperechoic if haemorrhagic component is present. Renal infarcts
often reveal a wedge shape with capsular base. Even though baseline color Doppler US and power Doppler US present overt limitations to detect renal perfusion defects due to the low sensitivity to low-velocity and low-amplitude flow states, they may increase diagnostic capabilities of US in detecting renal infarcts, especially in elderly or obese patients and in patients with renal diseases. In renal infarct, color Doppler US and power Doppler US reveal absolute absence of renal cortical flows, even though it is very difficult to differentiate renal segmental infarct from areas which appear poorly perfused due to underlying parenchymal disease, deep renal position and artefacts. Moreover, color Doppler US presents a low accuracy in detection of small renal infarcts in the subcapsular region for limited spatial resolution and in the superior renal pole for the high Doppler angle and for the depth position [19].

Recent advances in microbubble-based contrast agents, and dedicated contrast specific modes, have determined the achievement of increased image contrast in tissues. By transmitting at the fundamental frequency and receiving selectively harmonic frequencies, the background signal from stationary tissues is markedly suppressed resulting in a greater signal-to-noise ratio and a better visibility of renal infarcts. Blooming and flash artifacts are eliminated, shadowing artifacts are lessened, both spatial and temporal resolution are improved and the brightness of gray-scale pixel does not depend on angle-dependent frequency shift estimates. Differently from iodinated contrast agent and gadolinium-based contrast agents, microbubbles are pure intravascular agents which are not excreted in renal tubules, and may be safely employed in patients with advanced chronic renal failure which is frequently observed in the elderly. Microbubble-based contrast agents and contrast-specific imaging techniques improves significantly the diagnostic confidence level in identifying non-perfused renal parenchymal zones and allow a reliable depiction of renal perfusion defects (Figure 14 on page 28). Renal perfusion defects due to renal parenchyma infarction appear as single or multiple focal wedge-shaped areas of absent, diminished or delayed contrast enhancement in comparison to the adjacent renal parenchima after microbubble injection [20].

Contrast-enhanced CT is the reference imaging technique in renal infarcts detection. The parenchymal appearance of renal perfusion defects depends on the site of arterial occlusion, according if segmental (Figure 14 on page 28) or the main renal artery are involved (Figure 15 on page 29) and on thrombus age [18]. Contrast-material enhanced CT shows the absence of enhancement in the affected renal tissue. Acute renal infarctions typically appear as wedge-shaped areas of decreased attenuation, while after the acute phase of renal infarction, atrophy begins and the infarcted tissue contracts, leaving a cortical scar. Contrast material-enhanced CT represents a reference standard imaging technique to detect renal infarcts, which appear as focal wedge-shaped hypovascular lesions in normally perfused renal parenchyma. Chronic renal artery stenosis with persistent renal parenchyma hypoperfusion led to progressive shrinkage of the parenchyma with absent residual function (Figure 16 on page 30).

c. Atheroembolic renal disease
Atheroembolic renal disease (renal artery atheroembolization) is a complication of severe ulcerative atheromatosis of the abdominal aorta [21] or may be due to renal angioplasty, atrial fibrillation and cardiac valvular defects [22]. Atheroemboli localize in vessels smaller than interlobular arteries, so that renal infarction does not occur and clinical picture is frequently bland [21] even though acute renal failure is the mode of presentation in most cases. Atheroembolic renal disease with acute renal failure may develop during or immediately after intravascular surgical intervention, intravascular interventional procedures (e.g. renal angioplasty), or anticoagulation due to atheroemboli detached from the renal artery wall. The most common clinical manifestation is sudden onset of flank or back pain with or without hematuria, proteinuria, fever and leukocytosis.

Color and power Doppler US is a first-line imaging procedure to detect renal perfusion defect, but present clear limitations due to the relative insensitivity to low-velocity and low-amplitude flow states [23]. Coley et al. [24] found a global accuracy of color Doppler US for detection of partial renal infarction of 20%. Contrast-enhanced color and power Doppler US are limited by blooming and flash artifacts, which may be attenuated by reducing the instrument gain settings also diminishing the detection of focal abnormalities in renal blood flow [23]. Contrast-enhanced CT (Figure 17 on page 31) is the reference imaging technique to identify renal perfusion defects [18]. Contrast-enhanced US (Figure 18 on page 31) represents a very sensitive and reliable imaging techniques in revealing the renal parenchyma perfusion defects due to renal artery embolization [20]. Renal perfusion defects may appear as multiple focal wedge-shaped areas of absent, diminished or delayed contrast enhancement in comparison to the adjacent renal parenchyma after microbubble injection [20].

4. Renal vein thrombosis

Renal vein thrombosis in elderly patients, as in adults and differently from infants, is typically of insidious onset and is almost always overimposed on an established disease [21]. Causes of renal vein thrombosis in the elderly patients include idiopathic nephrotic syndrome, especially that due to membranous glomerulonephritis, volume loss due to dehydratation (often aggravated by diuretic therapy) with altered renal blood flow, hypercoagulable states (malignancy), renal cell carcinoma, or extrinsic compression of the renal vein (rereooperitoneal fibrosis, lymphoma, etc.). The process may progress without any clinical sign. Mild abdominal or back pain may be present, but severe pain is uncommon. Pulmonary emboli occur during the course of approximately 50% of patients with chronic renal vein thrombosis and are frequently the first manifestation of this condition [21].

Diagnosis of renal vein thrombosis relies on visualization of an echogenic thrombus within a dilated renal vein devoid of flow signals on CD evaluation. Both kidneys are usually enlarged with reduced cortical-medullary differentiation on gray-scale US. Doppler spectral analysis of renal arteries may reveal slightly increased RIs and normal parenchymal venous flows, since collateral venous supplies open after renal vein
thrombosis. Absent or reversed end-diastolic flow in renal interlobar-arcuate arteries has been described in transplanted kidney which lack collateral venous supply. US contrast agents facilitate identification of renal vein patency and thrombosis in cases of technical failure and enhance detection of collateral venous blood supply. A mass is evident in the renal vein with renal enlargement and delayed renal function.

CTA and MRA shows complete occlusion of the renal vein [18] which appears dilated and heterogenous while the infacted kidney appears enlarged and with a diffuse alteration of the nephrographic phase (Figure 19 on page 32). Renal vein involvement by tumor (Figure 20 on page 33) is frequently identified in elderly patients and it is crucial in the determination of surgical options for removing a renal tumor. The renal veins are well depicted on CT during the corticomedullary or nephrographic phase of contrast enhancement.

5. Renal failure

a. Acute renal failure

In the elderly the kidneys are more vulnerable when other pathologies occur, and in particular atherosclerosis, arterial hypertension, diabetes mellitus, bacterial infections, and malnutrition. Most cases of acute renal failure in the elderly patients are caused by drugs or are secondary to dehydration especially in patients with hypertensive intrarenal nephrosclerosis. In elderly patients the differentiation between renal and prerenal cause of acute renal failure may be difficult, because the RIs are usually elevated for the preexisting renal parenchyma disease. Moreover, an elderly patient with severe and prolonged prerenal acute renal failure leading to acute tubular necrosis may present increased RIs.

The acute renal failure is a common complication of hypertensive nephrosclerosis in elderly patients with mild chronic renal failure [25]. Worsening renal function may be precipitated by the treatment of hypertension, mainly with angiotensin converting enzyme (ACE) inhibitors or by other cause such as nephrotoxic drug or dehydration (Figure 13 on page 27). The evidence of acute renal failure without an apparent cause following therapy with ACE inhibitors highly suggests renal artery stenosis in well-hydrated elderly patients. Other possible causes of acute renal failure in these patients are renal artery thrombosis or atheroembolic renal disease. Doppler US examination is the first imaging modality to be employed in these patients to rule our renal artery stenosis. Identification of kidneys of two different sizes is suggestive of ischemic disease.

The demonstration of increased flow velocity at the level of renal artery stenosis is diagnostic. Anyway, the Doppler evaluation of intrarenal and renal perforating arteries can be useful in these patients since the direct assessment of the main renal artery may be difficult due to bowel gas interposition and incomplete patient compliance. The intrarenal vessels may show an altered waveform morphology defined pulsus tardus and
parvus consisting in an increased time to reach the peak of the trace (acceleration time > 70 ms) with loss of early systolic peak and decreased acceleration index (< 300 cm/\(s^2\)). Perforating arteries are vessels connecting the capsular plexus with the interlobar and interlobular arteries which became hypertrophic in those pathologic conditions that reduce the blood flow through the renal artery. Perforating arteries with flow toward the kidney have been detected and interrogated in about 60% of kidneys with renal artery stenosis of hypertensive elderly patients with acute renal failure. On the other hand, in the kidneys with no ischemic arterial lesions, only perforating arteries with flow toward the renal capsule were identified [8].

Acute cortical necrosis is a rare cause of acute renal failure, usually occurring in extremely ill individuals, often as a result of obstetric complications, hemorrhagic shock, disseminated intravascular coagulation, severe trauma, sepsis, shock, or burns. Contrast-enhanced US or CT (Figure 21 on page 34) has been shown to be diagnostic of acute cortical necrosis showing necrosis of the renal cortex with sparing of the renal medulla appearing as enhancing renal medulla, nonenhancing renal cortex and a thin rim of subcapsular tissue, and absent contrast excretion of the iodinated contrast agent [26]. Necrosis results from constriction of small intracortical blood vessels with preferential flow of blood away from the renal cortex. The likelihood that normal renal function will return is low. Usually, the involved kidney becomes shrunken and scarred. Cortical nephrocalcinosis may then develop [27].

Cholesterinic renal embolization represents an acute diffuse renal vessel embolization, frequently manifesting with acute renal failure. Clinical diagnosis include the presence of livedo reticularis due to distal embolization in the lower extremities and cholesterol crystals on the eye fundus examination. Color Doppler US examination is not useful to diagnose this pathologic entity due to the small size of renal perfusion defects. In cholesterinic renal embolization the identification of small renal perfusion defects in the renal sub-capsular region is penalized by the limited spatial resolution of US which can not identify renal perfusion defects smaller than 5 mm since in this clinical situation the renal perfusions defects are often very small to be detected by contrast-enhanced US. Anyway, if larger or equal to 5 mm renal perfusions defects may be identified on contrast-enhanced US after microbubble injection (Figure 22 on page 34). Microbubble-based agents should be always employed to exclude renal infarcts in every old patient presenting with a renal colic-like pain in the flank region.

b. Chronic renal failure

The proportion of elderly individuals is growing rapidly in all societies and the incidence of chronic kidney disease among elderly people increases constantly [28]. Therefore, the accurate monitoring of kidney function, that is, glomerular filtration rate, in elderly people is therefore of considerable clinical interest in order to detect individuals who are at risk for developing chronic kidney disease. The management of end-stage renal failure in the elderly should not be significantly different from that in younger patients...
and should be based on the capacity for rehabilitation rather than any arbitrary age. Chronic kidney disease is an important problem in the elderly and is associated with a high risk of kidney failure, cardiovascular disease, and death [29]. The disorder is indicated either by a glomerular filtration rate (GFR) of less than 60 ml per minute per 1.73 m$^2$ of body-surface area or by the presence of kidney damage, assessed most commonly by the finding of albuminuria for three or more consecutive months [30, 31, 32]. Among persons 60 to 69 years of age, approximately 18 percent have albuminuria and 7 percent have an estimated GFR of less than 60 ml per minute per 1.73 m$^2$. In persons 70 years of age or older, those percentages increase to 30 and 26, respectively [29]. Risk factors for chronic kidney disease include an age of more than 60 years, hypertension, diabetes, cardiovascular disease, and a family history of the disease. Recommendations for evaluating people at increased risk are to measure urine albumin to assess kidney damage and to estimate the GFR with an equation based on the level of serum creatinine [32]. Older adults who suffer an acute injury to the kidneys - from trauma, surgery, or illness - are at dramatically increased risk of later end stage renal disease.

Special care should be used in patients with chronic renal failure when the i.v. injection of iodinated or gadolinium-based agents is planned. Iodinated contrast agents should be employed in patients with chronic renal failure only before and after proper hydration, while gadolinium-based contrast agents should not be employed in patients with a GFR value below 30 mL/min. Differently from iodinated contrast agent and gadolinium-based contrast agents, microbubbles may be safely employed in patients with advanced chronic renal failure especially in the evaluation of renal masses and perfusion defects.

US reveals reduced renal length and cortical thickness and an hyperechoic renal parenchyma with a poor visibility of renal pyramids and of renal sinus. Doppler US reveals a reduced parenchymal perfusion and increased resistive indices (RIs) values. In the elderly patients with mild chronic renal failure the acute renal failure represents a common complication of hypertensive nephrosclerosis [25]. Worsening renal function may be precipitated by the treatment of hypertension, mainly with angiotensin converting enzyme (ACE) inhibitors or by other cause such as nephrotoxic drug or dehydration.

Elderly patients with mild chronic renal failure may easily develop acute renal failure as a common complication of hypertensive nephrosclerosis. Worsening renal function may be precipitated by the treatment of hypertension, mainly with angiotensin converting enzyme (ACE) inhibitors or by other cause such as nephrotoxic drug or dehydration. The evidence of acute renal failure without an apparent cause following therapy with ACE inhibitors highly suggests renal artery stenosis in well-hydrated patients. Doppler US examination is the first imaging modality to be employed in these patients to rule our renal artery stenosis. Other possible causes of acute renal failure in patients with mild chronic renal failure are renal artery thrombosis or atheroembolic renal disease. Many urological interventions can precipitate or exacerbate chronic kidney disease, most notably radical nephrectomy which is greatly overused.
6. Obstructive uropathy

In the elderly patient acute urinary tract obstruction can occur anywhere in the urinary tract from the renal papilla to the urethral meatus and may be determined by a plenty of causes. As in younger patients, obstruction may be completely asymptomatic even though, most frequently, it manifest with clear clinical symptoms.

Due to nephrosclerosis or dehydratation frequently present in the elderly patients, hydronephrosis may also be absent in the acute obstruction of the urinary tract. The most important causes of urinary tract obstruction in the elderly patients are urinary stones, tumors of the urinary tract and ureter, and benign prostatic hyperplasia (Figure 23 on page 35).

The obstruction of the urinary tract, if not treated, usually determines a progressive atrophy of the renal parenchyma which is frequently observed in the elderly patient. Chronic obstructive uropathy (Figure 24 on page 35) may be determined by the tumoral infiltration of the ureteral wall, or to chronic incomplete obstruction of the ureter which may be suddenly complicated by an acute event such as infection.

7. Renal infections

Acute pyelonephritis is an infectious disease involving both renal parenchyma and renal pelvis mucosa which can be diffuse or focal. Diffuse pyelonephritis is an infection involving the entire kidney even though the severity of the process may vary in extension (in one or both kidneys). Focal pyelonephritis is a localized infections of the kidney appearing as a wedge or round shaped parenchymal lesion which can regress if well treated or evolve to a collection extending toward the peri and pararenal spaces. Focal and diffuse pyelonephritis may resolve with evidence of normal renal parenchyma or scaring, or may evolve with liquefaction and formation of nephric or perinephric abscesses.

Pyelonephritis is the most common cause of gram-negative bacteremia in elderly patients admitted to a community hospital. Acute pyelonephritis can be severe in the elderly as in people who are diabetic or immunosuppressed with frequent evidence of renal abscesses (Figure 25 on page 36). Appropriate antibiotic therapy and, of equal importance, a lack of serious associated medical illnesses contributed to the 97% survival. An increased incidence of bacteremia and septic shock distinguish acute, symptomatic, bacterial pyelonephritis in elderly from that in young patients, and particularly in women [33].

Pyonephrosis is the most common complication of pyelonephritis in elderlerly patient when ureteral obstruction is present. Urinary tract obstruction due to an urinary stone is the most common cause of pyonephrosis (Figure 26 on page 37).

8. Neoplastic pathologies
Frequently the urologists are confronted with an elderly patient (# 75 years of age) with a renal mass seeking treatment. As the population ages, co-morbidities become more confounding in predicting patient outcome to therapy, and may influence the application of surgical therapy with curative intent to elderly patients [34]. Epidemiological studies show an increasing incidence of renal cell carcinoma over the past two decades, and interestingly, this increase has included a larger proportion of elderly people. The presentation of renal cancer has evolved. There has been an increase in the incidence of cases in the USA and several European countries and at the same time a shift to incidentally diagnosed, smaller, localized tumors in a slightly older population [35].

Generally, in the elderly patients there is an increase in neoplastic disorders including clear-cell-type renal carcinoma and transitional cell carcinoma. The median age of presentation of renal cell carcinoma is in the 6th decade of life. On the other hand, transitional cell carcinoma of the upper urinary tract is commonly seen in older patient, usually between the sixth and eight decade of life. This increased incidence is mainly due to the more widespread use of imaging technology [36]. Most renal tumors are completely asymptomatic, and are found incidentally in the elderly patients during imaging of the upper abdomen, mainly with US or CT (Figure 27 on page 38). There is a great variance of growth rate with the majority of small renal tumors (# 3 cm in diameter), even though the growth rate of small renal lesions in the elderly is low (0.35 cm per year with a median range of 0-10 cm) also with a low incidence of distant metastases [37]. On the other hand the majority of larger renal tumors usually present local invasiveness (Figure 28 on page 39; Figure 29 on page 39; Figure 30 on page 40) and distant metastases (Figure 31 on page 40; Figure 32 on page 41). A "wait and see" observational approach for renal masses 1.5 cm or smaller in the elderly can be suggested [38].

Transitional cell carcinomas of the renal pelvis or calices are relatively rare tumors of the kidney, and their incidence is reported to be 5 - 12% of all malignant tumors of the kidney and 5% of all urothelial tumors [39, 40]. It is commonly seen in older patient (Figure 33 on page 42), usually between the sixth and eight decade of life. The incidence in men exceeds that in women and the usual sex ratio is between 2 : 1 and 4 : 1 [40]. Over 85 - 90% of upper urinary tract tumors are TCCs, with the renal pelvis being more commonly involved than the ureter [22].

Renal lymphoma occurs in all age groups, even though the disease usually affects adults (average age: 60 years) and frequently the elderly patient. Renal involvement with lymphoma occurs much more commonly with non-Hodgkin disease, the majority of patients having intermediate or high-grade lymphomas including Burkitt and histiocytic types [41]. Lymphoma that is isolated to the kidney as a primary site of involvement is quite rare, whereas additional sites of extranodal involvement are common and are seen in most patients at the time of diagnosis. Lymphoma typically involves the kidney in one of several recognizable patterns including multiple renal masses, solitary masses, diffuse renal infiltration, renal invasion from contiguous retroperitoneal disease (Figure 34 on
page 43), perirenal disease, or atypical patterns of renal involvement with invasion of the renal pelvis (Figure 35 on page 44).
Fig. 0: Figure 1. Fundamental morphologic alterations of the kidney in the elderly patient. Gray-scale ultrasound, longitudinal scan. Reduction of renal cortical thickness and increase of the renal sinus fatty tissue, in particular evident at the renal hilum.

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**Fig. 0:** Figure 2a, b. 66 years-old patient with normal creatinine levels. Longitudinal gray-scale ultrasound scan of the right (a) and of the left kidney (b). Increased corticomedullary differentiation due to the increased echogenicity of the renal cortex (a, b) with clear marginal irregularities (arrows) in the left kidney.

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**Fig. 0:** Figure 3a, b. Different grades of renal margin irregularities. Longitudinal gray-scale ultrasound scan. (a) Reduction of the renal parenchyma thickness with renal contour irregularities (arrows), and increased cortico-medullary differentiation. (b) Diffuse renal margin irregularities also with evidence of renal parenchymal scars (arrows) due to previous regional infarctions.
**Fig. 0:** Figure 4a, b. Fundamental morphologic alterations of the kidney in the elderly patient. (a) Gray-scale ultrasound. Increased echogenicity of the renal parenchyma with reduced corticomedullary differentiation. (b) Power Doppler ultrasound. Reduced parenchymal vascularization at the level of the subcapsular region.
**Fig. 0:** Figure 5. Fundamental morphologic alterations of the kidney in the elderly patient. Contrast-enhanced CT, excretory phase. Coronal reformation. Diffuse reduction of the renal cortical thickness with overt focal irregularities of renal margins (arrows).

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**Fig. 0:** Figure 6a, b. Multiple renal scarring due to previous vascular infarcts in the kidneys of a 80-years old patient. Contrast-enhanced CT, corticomedullary phase. (a) Transverse plane. Both kidneys present irregular margins due to underlying nephrosclerosis and overt renal parenchyma scarring due to previous renal infarctions (arrows). (b) Coronal reformation. The left kidney present overt parenchymal scarring (arrow).

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**Fig. 0:** Figure 7a, b. Fundamental morphologic alterations of the kidney in the elderly patient. Contrast-enhanced CT. (a) Multiple renal cortical cysts are evident on the right kidney with a reduced cortical thickness of the left kidney. (b) The left kidney presents also a cortical scar (arrow) due to a previous vascular infarct.

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Fig. 0: Figure 8a, b. Fundamental morphologic alterations of the kidney in the elderly patient. (a) Gray-scale ultrasound. Longitudinal scan of the left kidney. Multiple cysts of renal sinus (arrows). (b) Contrast-enhanced CT, nephrographic phase. Multiple renal sinus cysts (arrows) are evident on both kidneys.

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**Fig. 0:** Figure 9a, b: Fundamental morphologic alterations of the kidney in the elderly patient. Contrast-enhanced CT, excretory phase. Coronal reformation. Multiple cysts of renal sinus with narrowing of the renal calyces, associated to irregular margins due to underlying nephrosclerosis and previous renal infarctions.

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Fig. 0: Figure 10a, b. Fundamental morphologic alterations of the kidney in the elderly patient. Renal morphological changes due to nephrosclerosis. (a) Gray-scale US, longitudinal scan. Reduction of renal cortical thickness with diffuse irregularities of renal margins. (b) Color Doppler. Reduction of renal cortical vascularization at color Doppler analysis due to nephrosclerosis.

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Fig. 0: Figure 11a-d. Fundamental morphologic alterations of the kidney in the elderly patient. Reduction of the renal parenchyma thickness reduction, margin irregularities, and increased cortico-medullary differentiation are evident on gray-scale US (a). (b) Color Doppler US, longitudinal scan. Reduction of renal cortical vascularization. (c, d) Doppler interrogation of the intrarenal segmental arteries with increased arterial resistive indices.

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Fig. 0: Figure 12. Fundamental morphologic alterations of the kidney in the elderly patient. Color Doppler US with Doppler interrogation of a renal segmental artery. Increased arterial resistive index measured at the level of one renal segmental artery of the lower renal pole.

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Fig. 0: Figure 13a-c. Renal artery stenosis in a 80-years old male patient. Worsening renal function was precipitated by the treatment of hypertension with angiotensin converting enzyme (ACE) inhibitors. (a) Doppler interrogation reveals aliasing at the level of the ostial tract of the left renal artery with spectral broadening of the Doppler trace. (b) CT angiography. Stenosis of the left renal artery is confirmed (arrow). (c) MR angiography. 3D Maximum Intensity Projection. Stenosis of the left renal artery is confirmed (arrow).

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**Fig. 0:** Figure 14a, b. (a) Contrast-enhanced ultrasound after sulphur hexafluoride-filled microbubble injection. (b) Contrast-enhanced CT angiography, corticomedullary phase. The left kidney shows partial parenchyma infarction (arrow) in a 72-years old woman with atrial fibrillation.

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Fig. 0: Figure 15a, b. Renal artery thrombosis in a 75-years old male patient. (a) Contrast-enhanced CT angiography. Coronal reformation. The left renal artery is occluded by a complex thrombus with relative avascularity of the left kidney. (b) Contrast-enhanced CT. Corticomedullary phase shows a complete renal infarction.

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**Fig. 0:** Figure 16. Renal shrinkage due to chronic vascular hypoperfusion due to the tight stenosis of the left renal artery. Contrast-enhanced CT. Corticomedullary phase. The left kidney (arrow) appears small and without any sign of function (contrast excretion).

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**Fig. 0:** Figure 17a, b. Contrast-enhanced CT. Multiple renal parenchyma perfusion defects (arrows) due to diffuse septic embolization are evident on both kidneys of a 85-years old patient.

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Fig. 0: Figure 18a - h. Renal artery embolization in a 82-years old male patient presenting at the emergency unit with acute flank pain on right side. (a - d) Contrast-enhanced ultrasound after sulphur hexafluoride-filled microbubble injection. (e - h) Contrast-enhanced CT, nephrographic phase. Multiple bilateral renal parenchyma perfusion defects (arrows), involving mainly the right kidney, due to embolization of an ulcerated plaque of the thoracic aorta.

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**Fig. 19:** Thrombosis of the right renal vein. Contrast-enhanced CT. Nephrographic phase. The renal vein appears dilated and heterogenous while the right kidney appears enlarged and with diffuse alteration of the nephrographic phase.

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**Fig. 20a, b.** Thrombosis of the left renal vein due to infiltrating papillary renal cell carcinoma. (a) Unenhanced CT. (b) Contrast-enhanced CT. Contrast-enhanced CT. Nephrographic phase. The renal vein appears dilated and heterogenous (small arrow) while the left kidney (large arrow) appears enlarged and with diffuse alteration of the nephrographic phase. The inferior vena cava (small arrow) is also involved and appears occluded by a tumoral thrombus.
Fig. 0: Figure 21a-d. Renal acute cortical necrosis. Eighty year-old patient with aortic encoprosthesis was admitted to the emergency unit with acute renal failure. Absence of contrast enhancement in the superficial cortex of the left kidney is identified after microbubbles injection (a). (b, c) Contrast-enhanced CT confirmed the existence of diffuse renal cortical necrosis in the left kidney.

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Fig. 0: Figure 22a-d. Cholesterinic renal embolization in a 70-years old female patient presenting with acute renal failure. Contrast-enhanced US after microbubble-based agent injection (contrast specific mode: Pulse Inversion Mode). Baseline color Doppler
US (a, b) does not allow the identification of renal perfusion defects. Contrast-enhanced US (c, d) allows a reliable depiction of renal perfusion defect (arrow).

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**Fig. 0:** Figure 23. Static-fluid MR urography in a 85-years old man patient with benign prostatic hyperplasia. Bilateral fourth-grade hydronephrosis.

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**Fig. 0:** Figure 24. Chronic urinary tract obstruction of the right kidney (arrow) due to tissue scarring of the lower ureter. The kidney appears small and without any sign of function (contrast excretion). Perirenal strands with dilatation and wall thickening of the renal pelvis are also evident on the right kidney.

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**Fig. 0:** Figure 25a, b. Pyelonephritis with diffuse abscessual evolution in a 70-year-old diabetic women presenting with septic shock. (a) Contrast-enhanced CT during the nephrographic phase after iodinated contrast injection. Both kidneys appear involved by multiple abscessual lesions (arrows). (b) Gross autopic specimen confirming multiple renal abscesses (arrows).

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Fig. 0: Figure 26a - f. Pyonephrosis in a 82-year-old women presenting with acute right flank pain. Gray-scale US, longitudinal (a) and transverse scan (b). The right kidney presents dilatation of the lower urinary tract (white arrow) with diffuse corpuscular echogenic content, and evidence of renal stones (black arrow) lying in the renal pelvis with posterior acoustic shadowing. (c-f) Contrast-enhanced CT, nephrographic phase. The right kidney (large arrow) presents increased dimensions, multiple renal stones lying in the renal pelvis, and dilatation and diffuse thickening of the renal pelvis. Renal parenchyma presents also some abscesses (small arrows) due to infection diffusion to the renal parenchyma.

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Fig. 0: Figure 27a - c. Small renal tumor incidentally found in a 67-years old male patient. Unenhanced CT (a), and contrast-enhanced CT during corticomedullary (b) and nephrographic phase (c). (a) A solid renal mass (arrow) isodense with the adjacent renal parenchyma is identified on the right kidney. Absent contrast enhancement is identified both during corticomedullary (b) and nephrographic phase (c). Papillary cell-type renal cell carcinoma is identified after partial nephrectomy.

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Fig. 0: Figure 28a, b. Clear-cell type renal cell carcinoma in a 75-years old man with hematuria. Local tumoral invasiveness. (a) Contrast-enhanced CT. Nephrographic phase shows a renal mass (arrow) on the right kidney with invasion of the renal pelvis. (b) Photograph of gross specimen. Evidence of invasion of the renal pelvis which justified the presenting symptom hematuria.

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**Fig. 0:** Figure 29a, b. Clear-cell type renal cell carcinoma in a 70-years old man. Local tumoral invasiveness. (a) Contrast-enhanced CT. Nephrographic phase shows the large renal mass (arrow) on the right kidney with invasion of the renal pelvis and of the perirenal fat. (b) Photograph of gross specimen with evidence of invasion of the renal pelvis and extra-renal growth of the tumor.

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**Fig. 0:** Figure 30a, b. Clear-cell type renal cell carcinoma in a 82-years old man. Local tumoral invasiveness. Contrast-enhanced CT. (a) Transverse plane. (b) Sagittal plane. Corticomedullary phase shows a large solid renal mass of the right kidney invading the adjacent liver parenchyma (arrow).

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Fig. 0: Figure 31a - c. Clear-cell type renal cell carcinoma in a 73-years old man with hematuria. (a) Contrast-enhanced CT. Nephrographic phase shows a renal mass (arrow) on the lower pole of the left kidney. (b) A large adrenal metastases is identified on CT (large arrow) with a central necrotic component (small arrow). k = kidney, upper pole. (c) Macroscopic specimen of the tumor.

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Fig. 0: Figure 32a - d. Clear-cell type renal cell carcinoma in a 77-years old man. (a) Contrast-enhanced CT. Nephrographic phase shows an heterogeneous large renal mass on the lower pole of the right kidney. (a, b) Multiple enlarged lymph-nodes (small white arrow) are identified in the retrocaval nodal site. (c) Floating thrombus (large white arrow) in the inferior vena cava is also present. (d) Distant bone metastasis is visualized on the right acetabulum (large arrow).

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Fig. 0: Figure 33. Transitional renal cell carcinoma in a 70-years old man with hematuria. (a) Contrast-enhanced CT. Coronal (a) and sagittal reformations (b). A solid endoluminal tumor (arrow) in the pelvis of the left kidney.

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Fig. 0: Figure 34a, b. Renal lymphoma in a 67-years old male patient with a known non-Hodgkin disease retroperitoneal disease. (a) Contrast-enhanced CT, transverse plane. Direct and extensive renal parenchyma invasion from contiguous retroperitoneal disease. (b) Photograph of gross specimen from autopsy. Gross pathologic examination reveals yellow / gray tumor with extensive renal parenchyma invasion.

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Fig. 0: Figure 35. Renal lymphoma in a 75-years old male patient with acute right flank pain. (a) Contrast-enhanced CT, transverse plane. (b) Coronal reformations. Perirenal lymphoma expressing as ab initio peripheral invasion of the right renal pelvis (arrows) with encasement of the intra-renal urinary tract.

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Conclusion

The kidney in the elderly patient presents some typical findings, while the most common renal pathologies present some peculiar features in the elderly patient.
Personal Information

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References


