Imaging in Nephrology

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Imaging is fundamental to the management of patients with renal disease, and access to increasingly sophisticated techniques is growing. As a consequence of this, renal disease is being identified coincidentally by other specialities, and patients with chronic renal problems can easily clock up large doses of radiation, gadolinium and radio-contrast. A close working relationship with radiology and nuclear medicine specialists is vital as is a thoughtful assessment of the most appropriate form of imaging and/or intervention, and a structured process is necessary for this.

The Multidisciplinary Team Meeting

The clinico-radiological meeting, or 'X-ray meeting', is a long-standing tradition in hospital medicine and provides an opportunity to meet with a radiologist to discuss the diagnosis and management of that patient along with relevant imaging and for any further imaging strategies to be decided. In modern practice, the meeting may well involve other professionals who have a role in management of specialty patients, for example, a pathologist, specialist nurse or physiotherapist, and is now known as the multidisciplinary team meeting (MDTM). Renal cancer MDTMs have become an integral part of the management of patients with renal cancer, and attendance includes a surgeon, oncologist, radiologist and pathologist, together with specialist nurses. The organisation of a cancer MDTM is tightly defined and subject to peer review for quality assurance, and there are published guidelines on the conduct of a cancer MDTM for radiologists [1].

Non-cancer MDTMs, such as the nephrology MDTM, are not subject to such tight regulation; however, the standards may still be used to guide the organisation of such an MDTM. The nephrology MDTM should be attended by both junior and consultant nephrologists and specialist nurses and be taken by a radiologist with an appropriate interest. Local practices will vary, but in a unit where vascular access for dialysis is performed, a surgeon who performs these procedures should attend and likewise if the centre performs renal transplants. Some units may run separate MDTMs for vascular access or transplant issues.

The Royal College of Radiologists recommend that all imaging to be presented at the MTDM should be reviewed by the radiologist beforehand, and where resources allow, an MDTM coordinator may be employed to prepare a list of patients beforehand. Decisions taken during an MDTM should be recorded in the patient's notes, and the MDTM coordinator may assist with this – where possible this should be done electronically with the record made visible to all members of the MDTM. The appointment of a nominated chairperson for the MDTM will allow the meeting to progress efficiently.

Radiation

Much of imaging involves the use of ionising radiation (in the form of X-rays for plain radiography, CT or fluoroscopy and gamma rays in the case of nuclear medicine) to form diagnostic images. As such, it is prudent to consider the risks and damages this poses to patients and staff. When radiation is absorbed by the tissues, the biological effects can then manifest over a much longer period of time. Doses from certain examinations can be orders of magnitude greater than the yearly average background dose for an individual, which is 2.7 mSv [2], and with serial examinations or multiphase CT, this can constitute significant risk.

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Table 3.1 Radiation dose for common imaging protocols

Examination	Effective dose (mSv)
1 day of background radiation	0.006
Chest X-ray	0.02
Abdomen X-ray	0.7
CT chest	7
CT pulmonary angiogram	15
CT KUB (low dose)	5
CT abdomen and pelvis	14
CT IVU	28
Nuclear medicine MAG3	2.6
Nuclear medicine DMSA	3.3
Whole body PET-CT	25

Adverse outcomes related to radiation risk can be divided into deterministic events and stochastic effects. Deterministic effects are those which will not happen below a certain threshold dose. Once this dose is achieved, the likelihood of the event occurring increases to a level where it is inevitable. Examples of this are cataracts and skin erythema. These events occur at relatively high doses for patients and are therefore only really of consideration in certain circumstances, for example, complex interventional procedures where there may be a long period of screening over one part of the body. This effect is not cumulative – the skin repairs itself so if the patient undergoes a further procedure in the future, skin erythema would require the same dose of radiation again. Pregnancy is a special case in that there is a threshold dose of radiation above which foetal abnormalities, such as growth retardation, Down's syndrome or spontaneous abortion, occur. The risk of this is greatest in the third to eighth week of pregnancy, and it is essential to minimise the radiation risk to any patients who are pregnant.

Stochastic effects of radiation relate to the risk of cancer or genetic abnormalities. This is manifested as a risk that increases linearly with the dose of radiation. For stochastic effects, the most useful measurement of radiation exposure is the effective dose of radiation. This is a theoretically calculated value that gives a weighted view of the radiation dose to the entire body. It cannot be measured directly; rather the values given are calculated from the known radiation output and exposure of different body parts, and the dose is measured in sieverts. The effective doses for different examinations are shown in Table 3.1. These doses are the average expected doses for each examination and will vary depending upon how modern the equipment is, the size of the patient, etc.

The risk of developing a fatal cancer is 5 % per sievert (Sv) effective dose or 1:20,000 per millisievert (mSv). This is a cumulative risk – i.e. the risk increases with subsequent exposures even if there has been a significant time period between them.

CT

Computed tomography (CT) uses X-rays to generate an image based on the density of the tissues being examined and is responsible for a large proportion (40 %) of the annual dose of ionising radiation due to medical exposures, despite representing a smaller proportion of the number of examinations performed annually. The use of CT is therefore largely dictated by concerns over radiation dose a patient may receive and IV contrast if required.

Intravenous Contrast

Most soft tissues within the body attenuate X-rays by the same amount and therefore appear as the same density or same shade of grey on an unenhanced CT scan. Intravenous contrast agents concentrate in different organs to different degrees and so improve the distinction between tissues and organs. IV contrast agents contain iodine which, due to its high atomic number relative to soft tissues within the body, appears as a denser medium. This improves visualisation of blood vessels or tissues which have a higher blood flow.

Patients requiring contrast need to be assessed for factors increasing their risk of an adverse reaction (see below). In addition, they need a cannula in situ, the size and position of which is dependent upon the type of procedure being performed (examinations such as CT pulmonary angiography for pulmonary emboli require a higher rate of contrast injection and as such a larger cannula is required). In addition there are different types of contrast media with differing toxicities, and the decision of which to use will depend upon the clinical scenario and risk factors as discussed below.

Adverse Reactions

Incidence of severe reactions is about 0.04 % with modern contrast media.

Patients at increased risk:

1. Previous reaction.
2. Asthma – increases risk of a severe reaction by 6–10 times.
3. Renal impairment (up to date eGFR or creatinine is essential).
4. Multiple allergies – patients with multiple allergies or a single severe allergy are at increased risk. Contrary to popular belief, there is no specific link with reactions to shellfish or topical iodine in acute contrast reactions. There is no evidence to support the use of prophylactic steroids.
5. Diabetes.

Metformin – as this is exclusively excreted by the kidneys, there is a theoretical risk of accumulation and subsequent lactic acidosis if a patient has a fall in eGFR secondary to IV contrast. However, there is no evidence that this is a risk in patients with a normal function. The current advice is that patients with normal renal function should continue metformin; however, in cases where eGFR < 60 ml/min or creatinine is abnormally raised, a consideration to stop metformin for 48 h after contrast should be made by the referring clinic.

Reactions

Anaphylactoid

The guidelines for treatment of acute contrast anaphylaxis are the same as for any other acute anaphylactic reaction.

Skin Reactions

Delayed reactions can occur up to 1 week after IV contrast. The significance of these is unclear and symptomatic treatment only is required.

Thyroid

Due to the high iodine content of IV contrast, patients with uncontrolled hyperthyroidism should not be administered contrast material due to a high risk of thyrotoxicosis. Prophylactic treatment can be arranged after discussion with endocrinology team.

Contrast-Induced Acute Kidney Injury (CI-AKI)

This is an uncommon consequence (incidence 1–2 %) of intravenous contrast that is due to a combination of afferent arteriolar vasoconstriction and direct toxicity of the contrast media on epithelial cells of the renal tubules, and creatinine usually peaks 72 h post-contrast.

Risk Factors Increasing Chance of CI-AKI

(a) Chronic kidney disease – eGFR <60 ml/min/1.73 m^2
(b) Age >75 years
(c) Cardiac failure
(d) Nephrotoxic drugs
(e) Hypovolaemia
(f) Sepsis
(g) High dose of contrast
(h) Multiple doses

In cases where there is an increased risk, the first consideration is whether a different imaging modality such as MRI or ultrasound will answer the clinical question or whether the CT can be performed without IV contrast. If contrast must be administered, the management focusses on prevention as there is no specific treatment after the event.

For patients with eGFR <60 ml/min, preventative measures should be used (with the use of *low-osmolality* contrast agents). For eGFR <30, iodinated contrast media should be avoided if possible with the caveat that making the correct diagnosis may take precedence over the risk of AKI (if the patient is already on haemodialysis, then the risk of AKI is less important but even then due consideration should be given to preserving renal function where possible).

If IV contrast needs to be administered, the following preventative measures are currently recommended by the renal association:

Volume expansion – IV 0.9 % sodium chloride at a rate of 1 ml/kg/h for 12 h pre- and post-contrast and intravenous isotonic sodium bicarbonate have both been shown to significantly reduce the risk of CI-AKI [3].

No reliable data have yet been produced to support the use of one versus the other [4]. The most important issue is dose reduction and having a robust system for ensuring the patient is well hydrated. There is currently no compelling evidence to support the use of *N*-acetylcysteine (NAC) in preventing CI-AKI; although there is conflicting evidence, a large randomised controlled trial showed NAC to have no effect in reducing CI-AKI [5].

Nephrotoxic Drugs: Withhold Any Potentially Nephrotoxic Drugs

Minimise the volume of contrast media – by selecting the appropriate examination depending upon the clinical question, the need for repeat examinations can be minimised and therefore only a single bolus of contrast needs to be administered.

Measure renal function – in stable patients, eGFR is the preferred measurement; however, in patients with AKI, this should not be used. eGFR should be measured pre-examination in those at risk and 48–72 h post-IV contrast to ensure it has remained stable.

Advantages

1. Multiplanar – CT builds the images using data about the body as a volume; therefore, the area of interest can be examined in different planes, and its relationship to other structures can be studied.
2. Speed – modern CT scanners can cover the whole body in a matter of a few seconds, making rapid examination possible which can be vital for unstable patients.
3. Availability.

Disadvantages

The major disadvantage of CT as described above is the use of radiation and associated increased risk of cancer. However, certain other factors need to be considered.

Table 3.2 Sensitivity and role of CT scanning protocols for renal pathologies

Parenchyma	Mass lesions	76 % Sensitivity for lesions <1 cm, 95 % sensitivity 1–2 cm. Allows assessment of fat, calcium and soft tissue content and enhancement pattern with IV contrast
	Vascularity	Renal perfusion can be assessed as can the renal vasculature. Anatomical delineation for pre-transplant assessment
Collecting system	Calculi	>90 % Sensitivity. Also allows assessment of other causes of flank pain
	Tumour	89–100 % Sensitivity for TCC on CT IVU
	Obstruction	Sensitive for obstruction and helps demonstrate cause; however ,US is better first-line test
Ureters	Calculi	98 % Sensitive for ureteric calculi. Also allows demonstration of inflammatory change which may indicate recent stone passage
	Tumour	CT IVU is 96 % sensitive and 99 % specific for TCC of the ureter. Also allows staging
Bladder	Wall lesions	CT IVU 79 % sensitive for bladder wall tumours
	Emptying	No role

Movement and breathing during the scan can produce blurred images obscuring pathology. As such, patients who are hyperventilating or unable to lie still due to pain or confusion can produce non-diagnostic imaging. Patients therefore need to be prepared for their scan with adequate analgesia +/− sedation if appropriate.

As most soft tissues within the body attenuate X-rays by a similar amount, it is often not possible to distinguish between normal and abnormal soft tissues on a plain CT, although this is improved by the use of IV contrast, this carries its own risks.

Protocols

The need for IV contrast and the timings of the scan after injection of contrast need to be guided by the clinical picture and question to be answered. The scan can be timed so that IV contrast is within the arteries or the venous system or delayed, so it is within the ureters or bladder depending upon what organ needs to be assessed or which pathological process is suspected – Table 3.2 describes the sensitivity of CT for different aspects of the renal system. The protocol of the CT examination is therefore tailored by the clinical details. Examples of some commonly used protocols are below:

CT KUB

This is a lower-dose procedure which does not involve the use of intravenous contrast for the detection of renal tract calculi. The decreased dose reduces the sharpness of the scan slightly and the lack of IV contrast reduces soft tissue contrast, so this is not optimal for looking at the parenchyma of the kidneys or other solid organs.

Contrast-Enhanced Abdomen

The 'standard' abdominal/pelvic CT involves IV contrast and is timed so the majority of the contrast is within the venous system. This is good for distinguishing lesions from normal soft tissue.

CT IVU

This is a multiphase protocol. It involves an unenhanced phase to detect calculi, followed by a venous/nephrogenic phase to study the renal parenchyma and finally a delayed phase that displays the collecting system and ureters. There is a relatively high radiation dose, so patient selection is important.

CT Angiogram

This involves timing the scan so the IV contrast is within the arterial system. One of the main uses is for delineating arterial anatomy for assessment prior to live renal transplant donation.

MRI

Because it does not rely upon the differential absorption of X-rays by tissues, rather giving images more dependent upon the chemical makeup of the tissue, MRI gives excellent contrast between soft tissue structures. As such, it is very useful for imaging and assessing tumours and soft tissue masses. The addition of gadolinium contrast can show enhancement patterns of lesions as well as visualising vessels to assess for anatomy and stenosis.

Contraindications

Due to the high magnetic field used, there are risks with MR imaging and metallic objects. There is variability in what orthopaedic and cardiac implants can safely be imaged with MRI (Table 3.3), and as such it is vital to obtain accurate records of any medical, cosmetic or other implants.

MRI Contrast

Incidence of anaphylactoid reactions with gadolinium is <0.01 % with an increased risk in patients with previous

Table 3.3 Contraindications for MRI scanning with implants

Absolute contraindication	Pacemaker
	Otic implant
	Metal in the eye or orbit
	Implanted cardiac defibrillator
Likely contraindication	Heart valve or aneurysm clip installed before 1996
Possible contraindication	Heart valve or aneurysm clip installed after 1996
	Any type of prosthesis
Usually allowable 6–8 weeks after implantation	Passive implants, weakly ferromagnetic (e.g. coils, filters and stents; metal sutures or staples)
Usually allowable immediately after implantation	Passive implants, non-ferromagnetic (e.g. bone/joint pins, screws or rods; coils, filters and stents; metal sutures or staples)
	Rigidly fixed passive implants, weakly ferromagnetic (e.g. bone/joint pins, screws or rods)

reactions – the second reaction often being more severe. Asthma or atopy also confer a 3.7x adverse reaction rate.

Nephrogenic Systemic Fibrosis (NSF)

There is a well-documented link between exposure to gadolinium-based contrast agents (GBCAs) and development of NSF. Patients with end-stage renal failure (eGFR <15 ml/min) have a 1–7 % chance of developing NSF. Increased frequency is seen with repeated exposure. NSF has not been reported in patients with eGFR >60.

Gadolinium is toxic, and so GBCAs are formed of chelates which bind gadolinium ions. The hypothesis is that gadolinium ions are released from chelates in GBCAs due to the prolonged clearance time in patients with renal failure, as a result of displacement of the gadolinium ion by another metallic ion such as calcium or zinc, in a process known as transmetallation. The gadolinium ion binds with free anions and precipitates out in various tissues resulting in fibrosis.

Clinical features include initial pain, pruritus, swelling and erythema, usually starting in the legs. This progresses to thickening and fibrosis of the skin and subcutaneous tissues and fibrosis of internal organs. Time of onset ranges from the day of exposure to several months. Patients with eGFR <60 who are not on dialysis or patients with chronic renal failure on dialysis are considered high risk. In these patients, alternative imaging tests or MRI without gadolinium should first be considered. If there are no alternatives, dose should be limited to 0.1 mmol/kg with a low-toxicity agent – some GBCAs are based on a chelate with a cyclical structure rather than a linear structure, and these so-called cyclical agents appear to be less susceptible to transmetallation. In patients already on dialysis, post-examination dialysis within a few hours is recommended; however, this will not clear gadolinium completely (approximately 9 h of dialysis is required to completely clear the gadolinium dose). In patients not already on dialysis, post-examination dialysis has not been shown to have any effect on the incidence of NSF.

Pros and Cons

Advantages

1. Good soft tissue contrast.
2. No ionising radiation – for younger patient or patients undergoing serial scans for follow-up purposes, MRI is preferable to minimise the radiation exposure.

Disadvantages

1. Time – whereas a CT scan takes a matter of seconds to perform, MRI takes many minutes to obtain the different sequences and planes necessary. As such, patients are required to lie still, making it unsuitable for patients in pain who are unable to lie flat or confused/agitated patients.
2. Availability – due to the high cost of MRI scanners combined with the time taken for each examination, availability is much less readily available than for other imaging modalities.
3. Claustrophobia – the bore of the scanner, inside which the patient is placed for imaging, is about 60 cm, smaller and longer than a CT. This can be very disconcerting for claustrophobic patients, and sedation may therefore be required. In addition, the narrow bore makes it unsuitable or obese patients. Wide-bore or open MRI scanners are available at specialist institutes however to address these factors, although image quality is usually poorer with these types of magnets.

Generally MRI is used for assessing soft tissue lesions and the vascular system in renal imaging. Table 3.4 demonstrates the sensitivity of MRI for different renal pathologies.

Nuclear Medicine

Nuclear medicine examinations also involves the use of radiation; however, instead of projecting a beam of X-rays through the patient as in plain radiography or CT, an unstable isotope (often technetium-99 m) is chemically bound to a pharmaceutical with affinity for the relevant target organ. This is then ingested or injected, and as the radioisotope decays, it releases gamma rays. These gamma rays are detected by a gamma camera, and the image is constructed over time. As the pharmaceutical can be selected specifically for the area of interest, this allows either static or dynamic imaging (as in the case of MAG3) and places a greater

Table 3.4 Sensitivity and role of MRI for specific renal pathologies

Parenchyma	Mass lesions	100 % Sensitivity and 94 % specificity for solid mass detection
	Scarring	
Collecting system	Calculi	No role
	Tumour	No role
	Obstruction	MRU increasingly used for anatomical and functional assessment of obstruction
Ureters	Calculi	
	Tumour	
	Obstruction	
Bladder	Wall lesions	Excellent for assessing invasion of tumour beyond bladder and involvement of local structures
	Emptying	No role
Vasculature		87 % Sensitive and 69 % specific for RAS. Often overestimates the degree of stenosis
		MR venography is useful for demonstrating venous anomalies but also for assessing the central thoracic veins when considering fistulas or long-term IV access for haemodialysis
		MRA and MRV are also used to assess the pelvic vasculature when planning renal transplantation, in conjunction with unenhanced CT (MR does not show calcification in vessels well)

Table 3.5 Role of nuclear medicine in renal imaging

Parenchyma	Mass lesions	PET-CT useful for staging metastatic disease or recurrent disease
	Scarring	DMSA is gold standard for assessment of focal renal scarring
	Vascularity	
	Function	MAG3 for assessment of function and excretion. DMSA shows relative function
Collecting system	Calculi	No role
	Tumour	No role
	Obstruction	
Ureters	Calculi	No role
	Tumour	
	Obstruction	MAG3 for assessing drainage and function of the kidney. Will demonstrate obstruction
Bladder	Wall lesions	
	Emptying	

emphasis on function rather than anatomical detail. Table 3.5 describes the different applications of nuclear medicine examinations to various aspects of the renal system.

Pros and Cons

Advantages

Functional data is obtained – the uptake and excretion of the radiopharmaceutical is dependent upon the function of the organ, giving an indication of the physiological process within that organ.

Disadvantages

1. Radiation – the use of ionising radiation has risks as described above. In addition, the added risk with nuclear medicine is that the radiopharmaceutical and subsequently the patient's bodily fluids are radioactive, increasing risk to other patients, carers and staff members.
2. Anatomical resolution – whilst it does give good dynamic data regarding organ function, the spatial resolution is quite poor giving low anatomical detail. As such, some investigations are combined with CT (e.g. PET-CT) to enable spatial localisation of the physiological data shown by the nuclear medicine component.
3. Time – many of the scans require a large amount of time to acquire the necessary data.
4. Renal impairment – the sensitivity of all radionuclide imaging techniques is diminished in moderate to severe renal dysfunction.

MAG3

MAG3 (mercaptoacetyltriglycine) is chelated with radioactive technetium-99m to form the radiopharmaceutical. It is cleared from the body by the kidneys via both glomerular filtration and tubular secretion.

This type of scan is useful as a dynamic renal study to assess renal perfusion, divided function, drainage and ureteric clearance. The patient is initially asked to empty their bladder and then the radiopharmaceutical is administered whilst they are on the gamma camera. The whole examination takes about 20–40 min after administration of the radiopharmaceutical during which time acquisitions are taken to show curves of activity related to time within the kidneys, known as a renogram. This is supplemented with static images of the kidneys, ureter and bladder. A diuretic (furosemide 0.5 mg/kg maximum dose 40 mg given 20 min prior to scanning in a well-hydrated patient) is used if clinical suspicion of obstruction or if a kidney is seen to not have drained satisfactorily during the scan, as this will diurese the radiopharmaceutical into the collecting system. If it still does not clear, this demonstrates an obstruction to drainage of the collecting system.

The dynamic nature of the scan allows gross assessment of the parenchymal perfusion and morphology and good dynamic visualisation of the parenchymal clearance and collecting system drainage.

DMSA

In this examination, dimercaptosuccinic acid is chelated with technetium-99 m to form the radiopharmaceutical. After injection, this concentrates within the renal parenchyma and becomes bound to proximal tubular cells. It is then slowly excreted within the urine.

Unlike the dynamic nature of MAG3, DMSA is used to assess the renal parenchyma for anatomy or scarring. As such, it is useful in cases of horseshoe or solitary kidneys or for localisation of an ectopic kidney. It is also used to assess renal scarring and parenchymal damage in acute pyelonephritis and later postinfection. The relative function of the two kidneys is also calculated.

Once the radiopharmaceutical is injected, the patient waits approximately 3 h for it to accumulate within the kidneys. Images are then acquired with a gamma camera.

Ultrasound

Medical sonography uses high-frequency sound waves (>20 kHz). Fluid (e.g. bladder or cystic structures) does not reflect any sound allowing it to pass through, and this therefore appears as black. Bone or calcification reflects the sound, and this appears as a white area.

Doppler sonography uses the Doppler effect to detect flow and is thus a highly useful non-invasive way to examine gross effects in arterial supply and venous drainage.

Because of its versatile nature, ultrasound can supply a myriad of information concerning pathological lesions (Table 3.6). As it does not use ionising radiation, it displays different properties of tissues than CT does, relying on their reflectivity rather than their X-ray absorbance. It is therefore excellent at distinguishing between solid and cystic lesions, studying the kidneys for evidence of hydronephrosis and giving information on the size and parenchymal thickness of the kidneys with any structural abnormalities.

Table 3.6 Role of ultrasound in renal imaging

Parenchyma	Mass lesions	20 % Sensitivity for lesions <1 cm, 70 % 1–2 cm. Allows Bosniak characterisation of cystic lesions superior to CT
	Scarring	37–100 % Sensitivity when compared to DMSA
	Vascularity	Good for demonstrating general vascularity of the kidney and patency of main renal artery and vein.
		RAS – 0–70 % sensitivity in experienced operators, increasing to >90 for transplant kidneys. Ultrasound does have a role in looking for asymmetry in renal sizes to suggest RAS
Collecting system	Calculi	30–90 % Sensitive for collecting system calculi. Sensitivity poor for small calculi
	Tumour	TCC appears as solid hypoechoic mass. Can be mistaken for hydronephrosis
	Obstruction	First-line test for diagnosis and grading of hydronephrosis. Excellent visualisation of the pelvicalyceal system when dilated
Ureters	Calculi	Poor visualisation of ureters with USS makes detection of calculi difficult. Will show if there is obstruction, hydronephrosis
	Tumour	No role
Bladder	Wall lesions	63 % Sensitivity for bladder tumours, direct visualisation is therefore needed in macroscopic haematuria to exclude. Endoscopic ultrasound is more sensitive but invasive
	Emptying	Volumetric measurement of bladder pre- and post-micturition is simple and fast. Can also show bladder wall trabeculation or diverticula, which suggest chronic outflow obstruction

Pros and Cons

Pros

1. Cheap – compared to CT and MRI scanners, ultrasound machines are orders of magnitude less expensive.
2. No radiation.
3. Bedside – many small portable ultrasound machines are currently available which are versatile enough to be used as a bedside scanner for patients who are too unstable to be transferred.

Cons

1. Small field of view – with ultrasound only a single plane is seen at one time: the view directly in front of the probe. As such, it can be difficult to fully assess larger structures or properly ascertain the anatomical relationships between different objects.
2. Operator dependent – the images produced in ultrasound are very dependent upon the skill and experience of the person performing the ultrasound.
3. Image review – due to the factors above, an ultrasound can only really be interpreted by the person who has performed it. Unlike CT where the whole scan is available for review at a later point, ultrasound only allows a few selected images to be reviewed at a later date, usually attempting to demonstrate the salient pathology.

4. Patient dependent – many patient factors can degrade the ability of ultrasound to demonstrate pathology. Movement and breathing mean that it can be difficult to obtain good views of the area of interest. In addition, the subcutaneous fat within obese patients causes significant attenuation of the sound waves, meaning that visualisation of deeper structures is challenging. This can be partly compensated; however, this again depends upon operator expertise.

Special Imaging Considerations

Renal artery stenosis – ultrasound is not commonly used to image native renal artery stenosis as visualisation of the whole renal artery is technically very difficult with ultrasound. However, initial screening ultrasound can often detect a discrepancy in the size of kidneys which may indicate stenosis of the afferent artery of the smaller kidney. This can then be assessed with MR angiography. The exception to this is with transplanted kidneys as the whole artery can often easily be visualised to the point of anastomosis.

Pyelonephritis – ultrasound is not diagnostic for pyelonephritis. The kidneys do show changes under ultrasound; however, these rarely manifest early, and if the kidneys appear normal, this does not rule out a pyelonephritis. The role of ultrasound is better for detecting obstruction or renal/perirenal abscess or collection secondary to the infection.

Intravenous pyelography – this is rarely performed now, as CT is superior for most applications. The IVP is however superior to CT in the diagnosis of medullary sponge kidney and papillary necrosis, as the superior spatial resolution of film radiography over CT better demonstrates the typical findings of both these conditions.

Interventional Radiology

Many nephrology and dialysis patients will undergo a procedure in interventional radiology (IR) during their diagnosis and treatment, and the planning and work-up of these patients are important in order to maximise the benefit and reduce the risk from the IR procedure. When a patient is referred to the IR department, clinical information should be comprehensive and relevant so that the radiologist can decide whether or not the proposed treatment is indicated or indeed feasible. Often the case of the patient will have been discussed at a nephrology or vascular access MDTM, but for those that are not, a discussion with a radiologist prior to referral will assist in requesting the correct procedure and will also allow any specific steps in patient preparation that are necessary.

Some general points on clinical information and preparation are listed in Table 3.7. It is worth noting that many departments will have their own guidelines which may vary from these. There are also specific notes about common procedures, including complications, that may be encountered.

Table 3.7 General preparations for interventional radiology

Clinical information:	Relevant history and indications, diagnostic question or therapeutic aim. Significant patient history, e.g. confusion, high levels of patient anxiety, previous procedures, bleeding diathesis, allergies
Need for interpreter	Important and frequently forgotten issue
Infection risk	Hepatitis C and B and HIV, MRSA, VRE, ESBL
Requirements	For example, oxygen, monitoring
Preparation	
IV access	Of sufficient size for contrast need
Nil by mouth	If having IV sedation
Coagulation	Haemoglobin, platelets, clotting screen, whether on low molecular weight or other prophylactic heparin
Urea and electrolytes	For example, degree of hyperkalaemia
Patient information	Patient information leaflet (ideally in first language), reasons for procedure discussed and explained

Patients attending the interventional radiology department should have their case notes, observation chart, drug prescription chart and any other relevant charts such as glucose monitoring chart and blood transfusion forms. Consent forms (see below) may be completed on the ward prior to attendance or in the IR department.

Consent

Patient consent is a legal requirement for non-emergency medical care, and the nature of interventional radiological procedures is such that written consent is required prior to all elective and planned urgent procedures. The act of signing the consent form usually occurs when the patient arrives in the interventional radiology department; however, the process of consent begins when the proposed treatment is initially discussed with the patient and will include an assessment of capacity of the patient to give consent, a description of the treatment proposed and the benefits and risks of that treatment. Sometimes the patient will have met the interventional radiologist during an outpatient attendance; however, in most cases the process of consent will begin with the clinical team who have referred the patient to interventional radiology; it is therefore essential that any clinician referring a patient for an interventional procedure has a good understanding of what the procedure entails. The provision of patient information leaflets is a valuable aid to the consent process. Further resources are available about the process of consent as follows:

http://www.gmc-uk.org/guidance/ethical_guidance/consent_guidance_index.asp

Standards for patient consent, particular to radiology, 2nd edition. RCR 2012
http://www.medicalprotection.org/uk/wales-factsheets/consent-the-basics

Fistuloplasty and Venoplasty

This involves accessing a stenotic or occluded segment of a native or prosthetic AV fistula and placing a guidewire across the abnormal segment to allow passage of an angioplasty balloon for venous dilatation. Access sheaths may be placed into the fistula vein, into the prosthetic graft or into an internal jugular vein or common femoral vein.

The procedure is often performed with the use of intravenous sedation and analgesia, as venous dilatation is often very painful. For a native AV fistula, no antibiotics are given as premedication; however, for an AV fistula with a prosthetic graft, antibiotic prophylaxis with gram-positive, gram-negative and anaerobic cover is commonly given.

Complications

Haemorrhage – this is not usually clinically significant at the puncture site, even when an arterialised segment of fistula vein has been punctured, as manual compression is sufficient to obtain haemostasis.

Infection – prosthetic grafts at risk; see above for antibiotic prophylaxis.

Rupture of fistula – risk greatest if there has been very recent surgical revision of the fistula or if there is infection present.

Central venous perforation – this may occur due to perforation by a guidewire or during angioplasty of a central vein and may be serious due to the potential for significant intrathoracic haemorrhage.

Nephrostomy and Antegrade Stent

Antegrade renal drainage may be used to established drainage of an obstructed kidney when retrograde drainage has been unsuccessful or cannot be attempted. No data exists which demonstrates whether antegrade or retrograde drainage is safer; however, there are specific situations when retrograde drainage may not be possible. These include extensive distal tumour, ureteric injury and reimplantation of the ureter, e.g. the transplant kidney. Urgent drainage should be considered in an obstructed infected PC system or obstructed single kidney (including transplant) with acute derangement or renal function.

The procedure requires IV analgesia, sedation and antibiotic prophylaxis.

Complications

1. Haemorrhage – may be sufficient to threaten kidney or life. Bleeding may occur from the kidney or from the abdominal wall.
2. Infection – puncture of an obstructed and infected PC system may result in septic shower and rapid instability of the patient.
3. Deterioration in renal function – haemorrhage may lead to loss of the kidney or renal compression and reduced function. Renal damage may also occur due to secondary infection.

Permacath (See Video on Line Insertion)

Vascular access for haemodialysis may be performed by radiologists, nephrologists, surgeons or other paramedical staff groups, such as nurses, who have had appropriate training. Patients who have had multiple lines however eventually lose the common sites for line insertion, such as the jugular veins, and there may also be stenoses or occlusions of the brachiocephalic veins, SVC, IVC or iliac veins. These patients may need associated venoplasty to facilitate line insertion, or an unusual access site such as a translumbar IVC line, and some may require insertion of a line surgically, for example, directly into an iliac vein.

Antibiotic prophylaxis is not usually given for line insertion.

Mesenteric, Coeliac, Splenic, Renal, Iliac and Femoral Angiography, Angioplasty and Stent Insertion

Renal angiography is used for diagnosis of conditions such as renal vasculitis, fibromusculodysplasia and renal artery stenosis and is usually done with a transfemoral approach. It is safe, with a complication rate of 1 % for femoral arterial injury and <1 % for renal arterial damage. Mesenteric angiography is often performed at the same time when investigating vasculitis.

Renal angioplasty is indicated for the treatment of fibromuscular dysplasia; however, stent insertion is not performed for this indication due to the potential provocation of neointimal hyperplasia within the stent leading to in-stent restenosis.

The finding of the Angioplasty and STenting for Renal Artery Lesions (ASTRAL) trial resulted in a large reduction in the number of patients with atherosclerotic renal artery stenosis being treated with angioplasty and stent insertion. The trial showed no benefit of intervention over medical therapy in both preventing deterioration of renal function and treating hypertension. Despite this, there are still situations in

which angioplasty with/without stent insertion may be appropriate:

- Transplant renal artery stenosis – intervention may lead to stabilisation of renal function. Stent insertion is not usually performed due to the difficulty in treating in-stent restenosis should this occur.
- Renal artery stenosis with flash pulmonary oedema – stent insertion may reduce episodes of pulmonary oedema.
- New deterioration of renal function in established renovascular disease.
- Severe stenosis and singe kidney with significant impairment of renal function.

Many patients with renal disease require peripheral arterial revascularisation. The preparation is the same as for renal angiography, although the complication rate is higher, at 4 %.

Complications include arterial damage or haemorrhage at the puncture site and distal embolisation following angioplasty, which at worst may be limb threatening (<1 %). Antibiotic prophylaxis is not usually necessary.

Summary

Renal imaging and intervention just gets better and better and increasingly cross-sectional imaging will be combined with functional imagining, further aiding diagnosis and management.

Governance issues in terms of consent, total burden of radiation or gadolinium, MDT working and documentation all need to be considered by nephrologists and renal departments. Radiologists and nephrologists should consider ways of prospectively documenting cummulative doses of radiation and gadolinium for renal patients.

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