Current applications of interventional radiology

Interventional radiology uses a range of radiological techniques to precisely and accurately diagnose and treat pathologies. This article discusses patient preparation and selection and highlights its strengths and weaknesses as well as introducing its use in each of the systems of the body.

Radiology is a key specialty both in emergency care and in managing more chronic conditions. With the improved ability to see inside the human body, the ability to treat diseases using imaging has followed in parallel. Interventional radiology is a rapidly expanding area of medicine using imaging guidance (including computed tomography, ultrasound, X-ray fluoroscopy and magnetic resonance imaging using magnetic resonance compatible equipment) to target treatments and attain diagnoses. Most interventional techniques are minimally invasive and provide an alternative to traditional methods of open or even laparoscopic surgery.

Interventional radiology has now been formally recognized by the General Medical Council as a subspecialty, with the British Society of Interventional Radiology being founded specifically to promote and develop the practice of interventional radiology by providing access to high quality information on interventional radiology for patients and all health-care professionals, including the National Institute for Health and Clinical Excellence, and by supporting audit, research, education and training in interventional radiology.

Owing to the rapid increase in interventional radiology and its involvement in all forms of medicine, it remains an area that is relatively poorly appreciated by medical students and junior medical staff. Although medical students are aware of interventional radiology, their exposure and understanding is limited (Ghatan et al, 2010) and further developments are required to address deficiencies in their curriculum (Leong et al, 2009). This article gives a brief introduction to interventional radiology and its application in day-to-day medical practice.

Who are interventional radiologists?

Interventional radiologists are fully registered radiologists who have subspecialized in minimally invasive treatments. They combine medical and surgical knowledge with expertise in the available imaging techniques to treat and diagnose diseases percutaneously. Currently interventional training is confined to radiology but, in the future, physicians and surgeons may be able to access joint training in interventional radiology, broadening the spectrum of involved clinicians.

This specialty requires a combination of diagnostic image interpretation across all the modalities and the manipulation and navigation of needles, wires and catheters using the best form of selected imaging guidance to achieve the best result for the patient, for example, the ability to identify a postoperative abscess or collection from post-surgical changes using ultrasound or computed tomography and then identify and drain the collection using imaging guidance. Many conditions that once required open surgery, anaesthesia and the ensuing postoperative complications can now be avoided using interventional radiology.

Strengths and weaknesses of interventional radiology

Table 1 outlines the strengths and weaknesses of interventional radiology. Interventional radiology often negates the need for open or minimally invasive surgery and this has many potential benefits. However, it often requires the use of ionizing radiation (computed tomography and fluoroscopy) and its use is not without risk not only to the patient but also to the physician and staff who are present. It is because of these risks that radiologists, with their knowledge of and training in radiation safety and physics, are the specialists best equipped for its use. It is essential that the operator has specific training in radiation physics and safety, keeping doses to a minimum (Cardella et al, 2003).

Patient preparation for interventional procedures

As with surgery, patient preparation for any procedure is key to safety and a successful outcome, and preoperative assessment is of great importance. Each patient must be carefully evaluated, identifying and preparing for those patients most at risk.

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The Royal College of Radiologists (2007) produce the referral guidelines, *Making the best use of clinical radiology services*, to help clinicians working in primary care to choose the most appropriate imaging or intervention for their patients, with the National Institute for Health and Clinical Excellence also making recommendations about whether many interventional procedures used for diagnosis or treatment are safe enough and work well enough for routine use.

High risk patients

There are occasions where interventional radiology is not always the answer and may lead to the deterioration in a patient's condition rather than improvement. High risk patients include those with a history of anaphylaxis to contrast or patients with renal failure or a coagulopathy. It is up to the interventional radiologist and the multidisciplinary team to decide which patients would receive the greatest benefit and in which the risks of the procedure outweigh the benefits. Individual cases must be considered and reviewed on their own merits.

Blood tests

Simple screening blood tests that should be performed before intervention include clotting studies and tests of renal function. Clotting studies should be checked for:

- Patients with evidence of or a history of a coagulopathy
- A patient who is taking anticoagulants (e.g. warfarin)
- Patients with conditions which may affect clotting (e.g. sepsis or liver disease).

Table 1. Strengths and weaknesses of interventional radiology

Strengths	Minimally invasive treatment entails	Significantly decreased postoperative pain with	Increased postoperative mobility
			Decreased risk of thromboembolic disease
			Improved lung function and reduced risk of chest infections
		Decreased recovery time	
		Earlier return to normal activities of daily living and work	
		Procedures can be performed on an outpatient basis or require only a short hospital stay	
	Reduced risks as compared to open procedures		
	Most procedures are cheaper than surgical alternatives		
	General anaesthesia is not usually required		
Weaknesses	Compared to open surgery, there is a loss of tactility as procedures can only be performed using digital screens. The procedure is performed as a two-dimensional procedure and may require the X-ray tube or any imaging modality rotating into multiple different planes to gauge position in relation to the pathology		
	The use of iodinated contrast and its risks (see later)		
	Not all techniques are widely available because of limited resources		
	The use of ionizing radiation (although ultrasound guidance will avoid this) which could affect patient safety and that of the physician and surrounding staff		

The need to correct a coagulopathy will depend on the procedure involved and the severity of the situation.

Renal function should be checked before any diagnostic or interventional procedure involving the use of contrast (see below).

Fasting

Patients should fast for approximately 4–6 hours before any procedure.

Consent

Consent is a complex area. Patients must be cooperative, able to lie flat and still and must have the capacity to make a decision about treatment. Ideally, consent should be acquired before the procedure, allowing the patient time to reflect and ask questions, but this is not always possible in emergency situations.

Contrast

Contrast agents are used to enhance structures, define the anatomy and permit the visualization of structures that would otherwise not be seen. In interventional radiology most are commonly injected down catheters (e.g. nephrostomy) or into arteries or veins.

The use of contrast media is common place but guidelines must be followed if the detrimental effects of contrast media are to be avoided. Mortality has been known following injection of contrast media but is extremely rare. The effects of contrast media can be divided into two categories – direct effects and idiosyncratic reactions:

- The direct effect of contrast media mainly involves the kidneys and its excretion. Contrast-induced nephrotoxicity is the occurrence of renal failure following injection of iodinated contrast medium. It is confined mainly to at-risk groups (e.g. patients with pre-existing renal impairment or diabetics) and can be avoided by careful patient selection, pre-procedural re-hydration or using newer lower osmolality contrast agents which have reduced nephrotoxicity.
- Idiosyncratic reactions are independent of the dose and generally occur within 20 minutes of administration. Because immunoglobulin E is not involved, these are not true anaphylactic reactions but the reactions have the same manifestations. These symptoms range from minor or mild symptoms (urticaria, pruritis and nausea) to severe symptoms (bronchospasm, laryngeal oedema, arrhythmias and even death).

Sedation and pain management

As the majority of procedures are performed with the patient conscious, sedation and pain management techniques are vital for patient comfort, relief of anxiety or distress, potentially painful or prolonged procedures (e.g. nephrostomy, biliary stenting), and patients who are unlikely to cooperate (e.g. children). Optimized sedation and analgesia are required for procedural safety and success.

Anaesthesia can be provided orally as a pre-medication, locally (e.g. lignocaine) or systemically in the form of opioids or benzodiazepines. The most common sedative drugs are benzodiazepines such as midazolam. Midazolam is administered intravenously and properties include anxiolysis, hypnosis and antegrade amnesia. Midazolam is not an analgesic and is commonly combined with opioids, such as fentanyl, for painful procedures when analgesia and sedation are required.

Procedures are generally performed in the absence of an anaesthetist, meaning that a skilled team (interventional radiologist, nurses and radiographers) must be present and competent in not only administering these medications but in monitoring patients, airway support, cardiopulmonary resuscitation and the ability to manage complications resulting from over-administration.

Before administration of sedation or pain relief, all patients are pre-assessed for requirements of sedation and pain relief for the procedure. Sedation can only be given in the presence of trained staff with facilities available for continuous monitoring (blood pressure, pulse and oxygen saturations) not only during the procedure but in recovery afterwards.

Pathology

Vascular intervention

Catheter angiography

Angiography is the use of imaging modalities to view the vasculature of the body. It can be performed by three different modalities – computed tomography angiography, magnetic resonance angiography or X-ray fluoroscopy.

Diagnosis is usually made with computed tomography or magnetic resonance angiography as they are both non-invasive and widely available. Catheter angiography is generally performed with a view to proceeding to intervention, e.g. angiography proceeding to angioplasty or embolization. This is one of the distinct advantages catheter angiography has over computed tomography angiography and magnetic resonance angiography as it allows simultaneous diagnosis and treatment as well as providing improved anatomical detail.

Vascular access is usually acquired by direct needle puncture of the femoral artery or brachial artery and access acquired by the Seldinger technique. A wire is inserted through the needle into the vessel, followed by a catheter which is manipulated into the selected vessel to be examined using fluoroscopy and intravenous contrast.

Angioplasty and vascular stenting

Angioplasty and vascular stenting improve blood flow by widening stenotic or occluded blood vessels. Following catheter angiography which identifies the stenosis, a catheter with an expandable balloon tip is passed across the stenosis and inflated. This technique is primarily used for the treatment of peripheral vascular disease. The principle behind angioplasty is to split the atheromatous plaque which subsequently stretches and then tears the intima and media, increasing the diameter and subsequently improving flow (*Figures 1a* and *b*).

Vascular stents are permanent small tubes, made from wire metal scaffolds, placed to help vessels remain patent and support the vessel wall. They are used to treat dissections, stenoses, aneurysms (e.g. endovascular aneurysm repair) and arterial rupture.

Endovascular aneurysm repair is a new and rapidly evolving technique for the treatment of aortic aneurysms in the elective and emergency setting (*Figure 2a–c*) and is a combined radiological and surgical procedure. Using fluoroscopy, a stent is placed across the aneurysm diverting blood through the stent and into the lower limbs. This technique has not only reduced patient hospital stay, but has decreased 30-day operative mortality from 4.3% for open repair to 1.8% for endovascular repair (United Kingdom EVAR Trial Investigators et al, 2010).

Thrombolysis

Thrombolysis is the use of pharmacological therapy to break down clots to improve blood flow and prevent or halt ischaemia. Unlike thrombolysis following myocardial infarction, catheters are placed within the occluded vessel to direct thrombolytic therapy specifically at the point of interest, e.g. acute on chronic limb ischaemia secondary to thrombosis, graft or fistula thrombosis, or pulmonary embolism. Care must be taken with the use

Figure 1. a. A pre-procedure lower limb angiogram demonstrating high grade stenoses (arrows) in the distal superficial femoral artery at the level of the adductor canal with formation of collateral vessels. b. A post-procedure angiogram demonstrating patency of the artery following angioplasty.

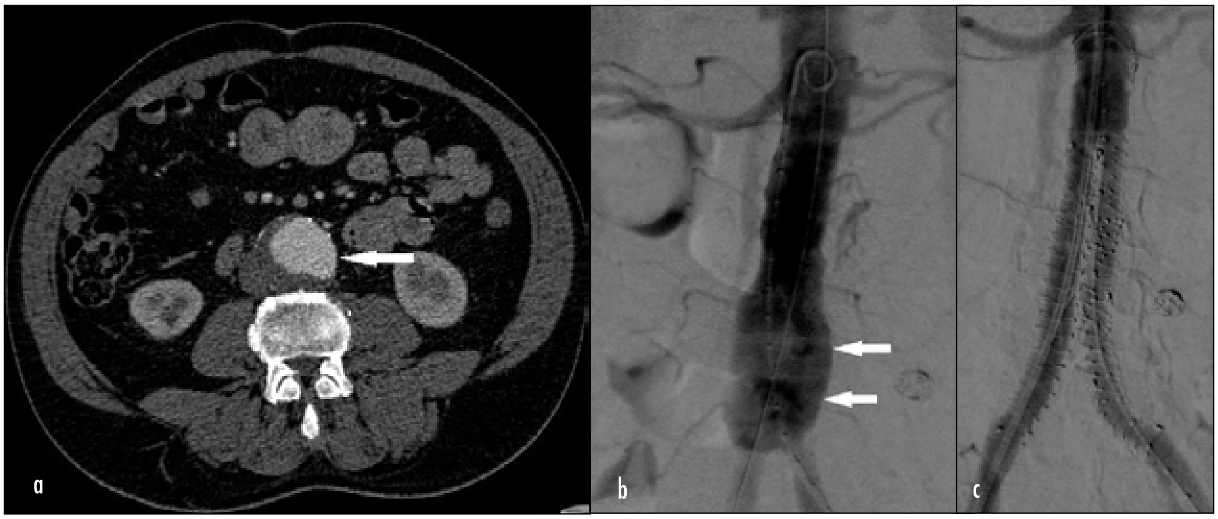


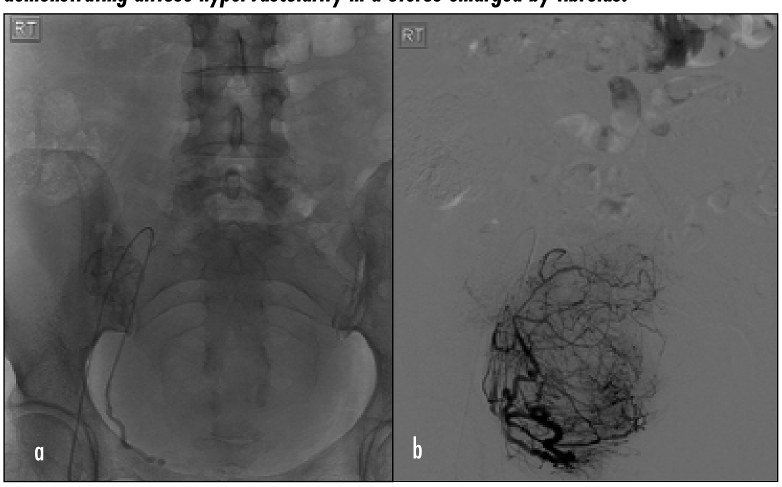
Figure 2. a. Axial contrast-enhanced computed tomography scan of the aorta showing an infrarenal abdominal aortic aneurysm (arrow). b. Pre-procedural angiogram of the aorta demonstrating the aortic aneurysm (arrows). c. Post-procedural angiogram of the aorta with the stent graft within the aorta and limbs of the graft within the common iliac arteries. Contrast demonstrates preferential flow down the stent graft.

of thrombolytic agents with regard to haemorrhage and contraindications, such as major trauma or recent surgery, must be excluded before starting treatment to prevent catastrophic complications.

Embolization

Embolization is the use of embolic agents, such as coils, balloons, particles or liquids, to deliberately occlude one or more blood vessels. Following selective angiography, a catheter is placed into the vessel and embolic agents are released. A thorough knowledge of vascular anatomy is required, as once the embolic agents are deployed, the procedure is irreversible and distal ischaemia will ensue. It is an important technique in the emergency setting and is used to control or prevent haemorrhage (e.g. post-partum haemorrhage, splenic or pelvic trauma, uterine artery embolization or neurological intervention for the control of cerebral aneurysmal haemorrhage).

Figure 3. a. A catheter has been passed via the right femoral artery into the right internal iliac artery followed by selective catheterization of the right uterine artery. b. Digital subtraction angiogram following selective injection via the right uterine artery demonstrating diffuse hypervascularity in a uterus enlarged by fibroids.



Uterine artery embolization has been used for a number of years for the treatment of post-partum haemorrhage, trauma or tumours. It is now become a rapidly increasing technique for the treatment of fibroids, avoiding the need for women to undergo hysterectomy and the complications of major gynaecological surgery (National Institute for Health and Clinical Excellence, 2004). The uterine artery is selective catheterized in turn bilaterally and embolic particle agents are injected, causing the fibroids to infarct and shrink (*Figures 3a* and *b*).

Vascular access

Vascular access procedures are the placement of catheters within blood vessels to provide a route for delivering medications (e.g. chemotherapy, antibiotics, blood transfusions or nutrition), taking blood, dialysis or central pressure monitoring over a number of days, months or years. They negate the need for repeated peripheral punctures and damage to peripheral vessels by chemotherapeutic agents. Ultrasound is used initially to locate and puncture a suitable patent vessel. A guidewire is then inserted under fluoroscopy guidance to an optimal position, over which the line is introduced and the position is finally checked before the line is secured. There are three main types of vascular access catheter:

1. A peripherally inserted central catheter line is inserted via the arm veins with the tip in the superior vena cava and is used when access is required for a few months
2. Tunnelled catheters (e.g. Hickmann, VasCath), which have a cuff which stimulates subcutaneous fibrosis to secure the catheter. They are placed in the internal jugular vein with the tip in the right atrium and used for long-term access and dialysis

3. Port catheters. These are permanent devices placed in the subcutaneous tissue of the anterior chest wall. They are used for long-term provision of medication, commonly for antibiotics for patients with cystic fibrosis.

Venous intervention

Although the majority of vascular procedures are intra-arterial, there are a number of venous interventional procedures, including placement of inferior vena cava filters, treatment of superior vena cava obstruction and transjugular intrahepatic portosystemic shunt.

Inferior vena cava filters are placed in patients who have an extensive deep vein thrombosis or pulmonary emboli, cannot be treated successfully with anticoagulants (having pulmonary emboli despite adequate anticoagulation) or who require surgery. They are placed in the inferior vena cava using fluoroscopic guidance following ultrasound-guided puncture of the femoral or internal jugular vein where they sit below the renal veins. They can be permanent or temporary. Temporary filters are used to cover high risk procedures and are removable.

The commonest cause of obstruction of the superior vena cava is usually external compression secondary to lung cancer or nodal involvement. The obstruction is successfully relieved by placing an expanding vascular stent across the obstruction.

Transjugular intrahepatic portosystemic shunt, or TIPSS, is performed for patients with cirrhotic liver disease and uncontrolled portal hypertension. Using the Seldinger technique with ultrasound access to the internal jugular vein, a shunt is created using a stent connecting a hepatic vein to the portal vein, subsequently reducing the portal pressure as blood flows from the high pressure portal system to the systemic venous system.

Complications

Although many of the complications of open surgery are avoided, interventional radiology is not without complications of its own. *Table 2* shows some general interventional complications for vascular procedures.

Table 2. General interventional complications of vascular procedures

Site involved	Complication
Puncture site	Haemorrhage or haematoma
	Infection
	False aneurysm
	Arteriovenous fistula
Intervention site	Vessel occlusion
	Vessel dissection
	Vessel rupture
Distal to intervention site	Embolization or ischaemia
	Amputation or loss of organ

Non-vascular intervention

Biopsy and fine needle aspiration

Lesions detected around the human body often require tissue diagnosis before proceeding to appropriate management. Interventional radiologists are at the forefront of attaining tissue or cell samples or assisting other specialities and use a range of modalities in order to do so.

Common examples include ultrasound-guided aspiration or biopsy which is widely used in head and neck, liver, breast or renal disease; computed tomography-guided lung biopsy, which has a good safety profile, is well tolerated and usually only requires local anaesthesia; and ultrasound-guided liver biopsy, as liver biopsy is potentially hazardous with the risk of bleeding in particular.

Drainage

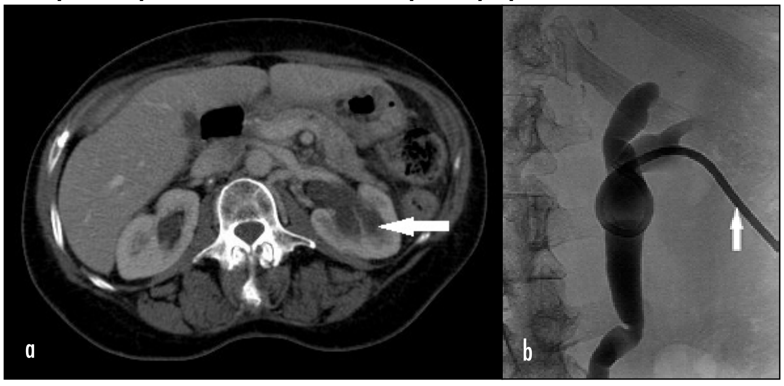
In the past, collections or abscesses used to be drained using open surgical techniques. Now with the use of modern radiological techniques, drain catheters can be placed into virtually all compartments of the body. Patients avoid further surgery, the risk of visceral injury and the complications of drains being placed 'blind'. Common examples include draining pleural effusions or ascites using ultrasound guidance or computed tomography-guided drainage of intra-abdominal collections.

Renal intervention

Renal interventional procedures include both native and transplant organs. When the ureter becomes obstructed, whether by a stone, blood clot, tumour or infection, the draining system can quickly become infected and the patient subsequently septic. The obstructed urinary system needs to be diverted and the obstruction relieved. This is achieved, before formal treatment of the underlying condition, by insertion of either a nephrostomy or a ureteral stent.

A nephrostomy is performed by inserting a wire by ultrasound or fluoroscopic guidance into the renal pelvis followed by a catheter, thus diverting urine from the obstructed system (*Figures 4a* and *b*). Ureteric stents are

Figure 4. a. Axial computed tomography of the abdomen of a patient presenting with sepsis and a left flank pain demonstrating pyonephrosis (arrow) secondary to a tumour at the left vesicoureteric junction. b. Fluoroscopic image confirming correct placement of the nephrostomy (arrow) within the left renal pelvis by injection of contrast.



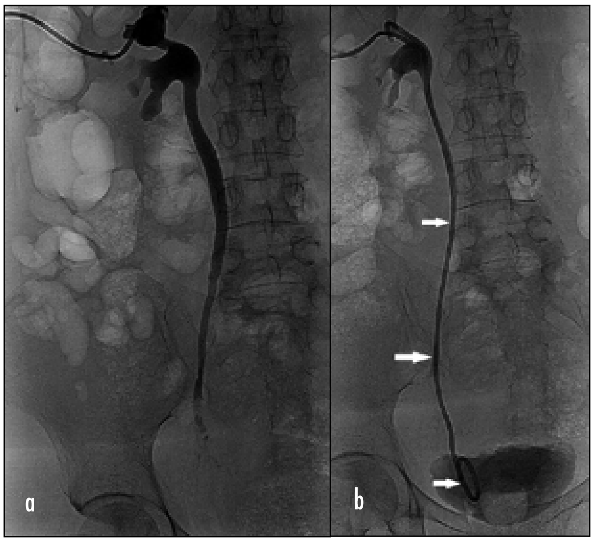


Figure 5. a. Fluoroscopic image following injection of contrast via a right nephrostomy demonstrating right distal ureteric obstruction secondary to extrinsic compression from cervical carcinoma in the lower third of the ureter. b. Fluoroscopic image demonstrating successful deployment of a right ureteric stent (arrows) with contrast flowing from the right renal pelvis into the bladder.

thin flexible tubes which are placed across the obstructing lesion under fluoroscopic guidance restoring the natural flow of urine to the bladder and relieving the obstruction (*Figures 5a* and *b*).

Renal artery stenosis (*Figure 6*) is an important cause of secondary hypertension that can be successfully treated percutaneously by balloon angioplasty.

Biliary intervention

Biliary interventional procedures are performed to relieve obstruction to blocked or narrowed bile ducts by tumours, calculi or infection. Percutaneous transhepatic cholangiography is performed by puncturing a peripheral bile duct using ultrasound guidance. Contrast is then injected and if a stenosis is identified, Seldinger

Figure 6. Selective digital subtraction angiogram of the right renal artery showing an ostial stenosis (arrow) of the right renal artery.

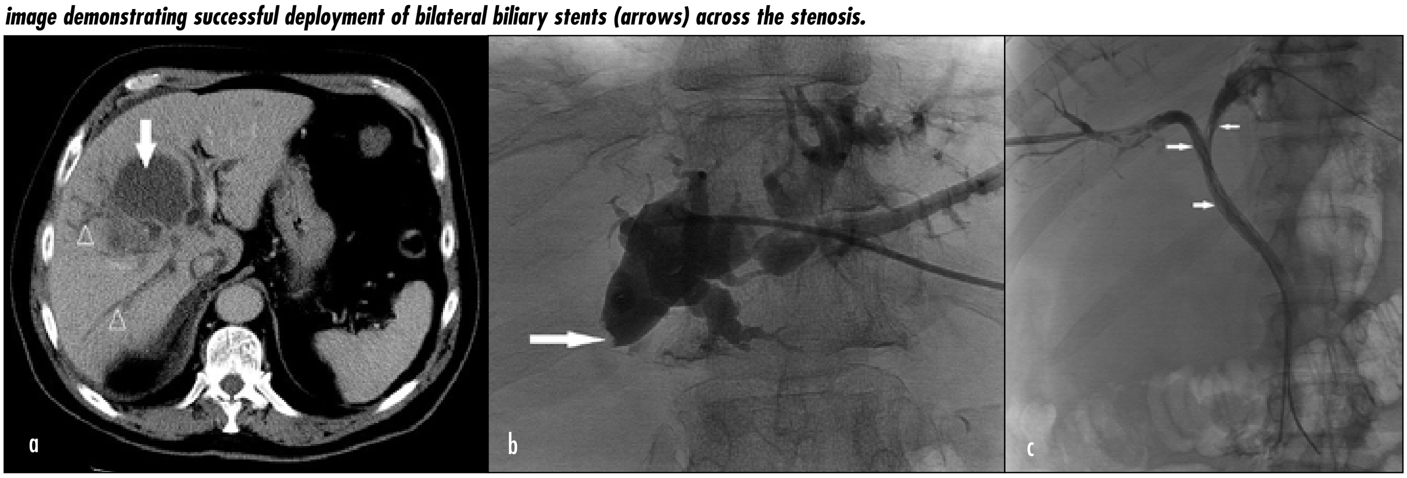
technique is used to place a stent across the obstructing lesion. If this is not possible, a catheter can be placed to relieve the obstructed biliary system and the patient's jaundice (*Figure 7a–c*).

In addition, interventional percutaneous techniques can be performed to treat acute cholecystitis or empyema of the gallbladder when a patient is too unwell or unfit to undergo open or laparoscopic surgery by placing a catheter within the gallbladder under ultrasound guidance (percutaneous cholecystostomy).

Gastrointestinal stent insertion

Gastrointestinal interventional procedures include stent placement or balloon dilatation. For benign strictures, balloon dilatation is an effective method of treatment. The technique is the same as for angioplasty, with a wire inserted across the stricture and the balloon inflated. It is generally reserved for benign disease, as balloon dilatation of malignant disease increases the risk of perforation. Examples include dilatation of benign oesophageal or anastomotic strictures, thus negating the need for open surgery to refashion the anastomosis.

Figure 7. a. Axial computed tomography demonstrating a carcinoma of the gallbladder (solid arrow) infiltrating the liver causing intrahepatic biliary duct dilatation (arrowheads). b. Percutaneous transhepatic cholangiogram demonstrating biliary obstruction at the hilum of the bile ducts (arrow). c. Fluoroscopic image demonstrating successful deployment of bilateral biliary stents (arrows) across the stenosis.



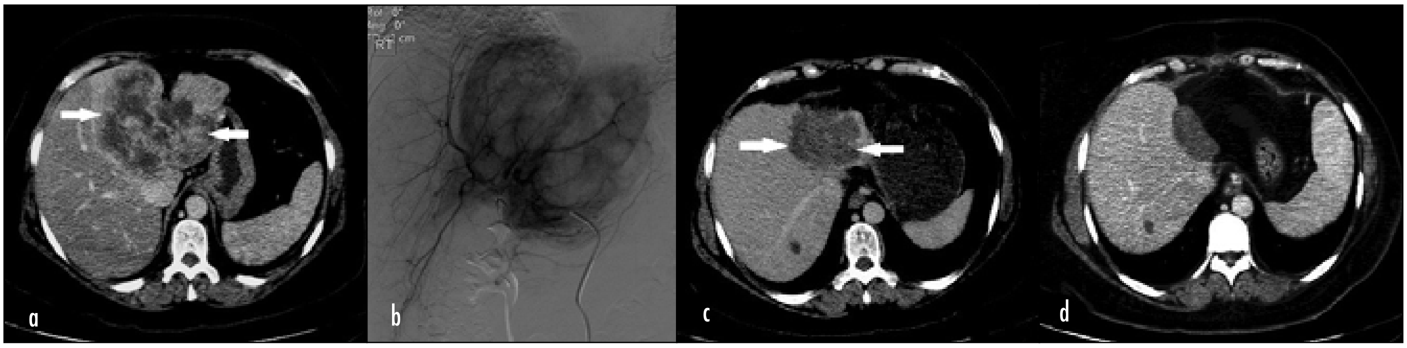


Figure 8. a. Axial computed tomography of the abdomen demonstrating a huge metastasis (arrows) from a patient with breast cancer. b. Selective angiogram of the hepatic artery demonstrating the hypervascularity of the metastasis. Radioactive microspheres were infused. c. Axial computed tomography of the abdomen showing a successful response to therapy with a huge reduction in size of the metastasis (arrows). d. Axial computed tomography of the abdomen following a successful left hepatectomy.

Stents are generally inserted as a palliative treatment under fluoroscopic guidance for obstructing lesions of the gastrointestinal tract, commonly for oesophageal or colorectal malignant tumours, or to relieve bowel obstruction and improve a patient's condition before surgery.

Oncological intervention

The management of patients with metastatic disease is challenging and individual treatments are tailored for each patient to maintain or improve the patient's quality of life. There are many rapidly expanding areas of oncological intervention which can not only fulfil these goals but can also turn metastatic into curable or resectable disease.

Primary or secondary hepatic malignancies are mainly supplied by the hepatic artery and various techniques and cytotoxic agents are being developed to be delivered trans-arterially via the hepatic artery directly to the neoplasm. Transcatheter arterial chemoembolization is the combination of embolic agents with chemotherapeutic agents. This not only occludes the blood supply to the tumour but effectively traps the chemotherapeutic agent within the tumour and has been used extensively in the management of primary hepatocellular carcinoma. Other methods include selective infusion of radioactive microspheres into the tumoral arterial vasculature of liver. This technique is currently used for both metastatic and hepatocellular carcinoma to great effect (*Figures 8a–d*).

Radiofrequency ablation uses radiowaves to direct heat and destroy tumours. Using ultrasound or computed tomography, a needle is placed directly into the tumour, and once placed the needle directs heat directly into the tumour, destroying the malignant cells. It is successfully used in a wide variety of tumours including liver, renal and lung malignancies.

Conclusions

Interventional radiology is a rapidly increasing specialty which uses the whole range of radiological techniques to precisely and accurately diagnose and treat pathologies all over the body. It offers a viable and less invasive alternative to many traditional medical and surgical therapies with potential benefits to patients. It is important that all clinicians are aware of the patient preparation, techniques and range of procedures that interventional radiology can perform. **BJHM**

Conflict of interest: none.

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KEY POINTS

- This article gives a concise overview of the applications of interventional radiology in everyday clinical practice.
- Many procedures that once required open surgery, general anaesthesia and the ensuing postoperative complications can be avoided using interventional radiology.
- Patients must be treated on their own merits and patient preparation and preoperative assessment is vital for patient safety and procedural outcome.