Interventional Radiology Curriculum for Medical Students

Third Edition

A brief overview of the most common clinical conditions handled by IRs

CIRSE

August 2024

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Introduction

In order to make medical students aware of the ever-increasing role of IR in hospital medicine and to provide guidance on the learning outcomes required to prepare medical students for their role during residency years, CIRSE published the first edition of the Interventional Radiology Curriculum for Medical Students in 2012.
In recognition of the rapid growth that IR has experienced since then, CIRSE tasked the European Trainee Forum with revising this document and developing an updated version.

This revised curriculum highlights the main areas of IR and outlines a variety of the most common clinical conditions routinely handled by interventional radiologists. It aims to support medical students planning on pursuing a career in IR and those who may participate in a multidisciplinary approach to patient care in the future.

In order to get a structured overview, each topic is examined under the following headings:

- Clinical presentation
- Imaging before the procedure
- IR treatment options
- Clinical care and follow-up

For a comprehensive overview of IR, students are encouraged to view the CIRSE European Curriculum and Syllabus for Interventional Radiology.

Interventional Radiology – A career fit for the future

1 Basics of devices and materials used in IR

Interventional radiology (IR) is a medical specialty that uses imaging techniques to guide minimally invasive surgical procedures. Here are the main devices used in interventional radiology:

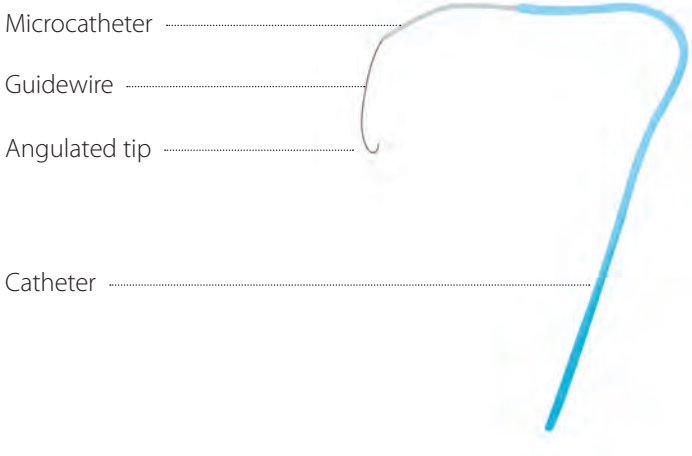
1.1 Catheters and microcatheters

Catheters are long, thin tubes that can be inserted into blood vessels or other body cavities. They come in various shapes and sizes depending on the procedure, typically ranging from 4 to 5 French (1 Fr = 0.33 mm). They are used to inject contrast material and perform angiograms, and also to provide support and a pathway for other devices.
Microcatheters are very small, flexible catheters typically ranging from 1.2 to 2.8 French (Fr) in diameter (1 Fr = 0.33 mm). They are designed to navigate through the smaller, more tortuous vascular pathways that standard catheters cannot access.

1.2 Guidewires

Guidewires are thin, flexible wires that help navigate catheters through blood vessels. They come in different stiffnesses and coatings to facilitate smooth passage through the vascular system. A more flexible guide will aid navigation in tortuous anatomy, while more stiffness will allow better torqueability (the tip of the wire will turn when you turn the proximal end of the guidewire). They come in various sizes (some for catheters, some for microcatheters), with different shapes of distal tips to help navigation through vessels.

Guidewire 2.0-2.9 Fr. microcatheter 4-5 Fr. catheter

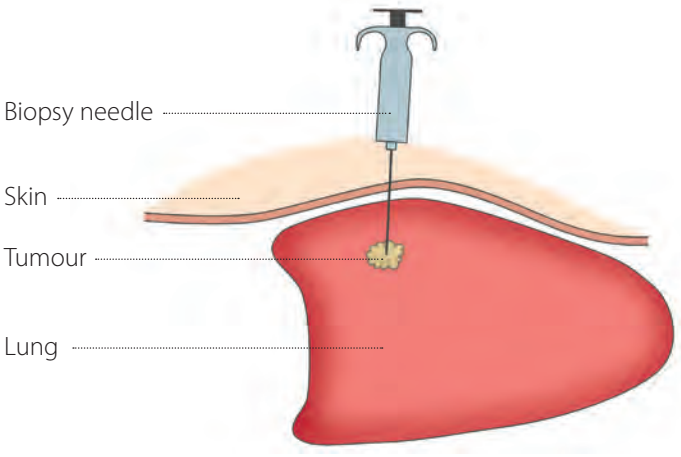


Example of figure (comes from: Tashi , S., Tan, Z. & Gogna, A. Use of the triple coaxial (triaxial) microcatheter system in superselective arterial embolization for complex interventional cases: an initial experience with the system. CVIR Endovasc 5, 67 (2022). https://doi.org/10.1186/s42155-022-00340-z)

1.3 Needles

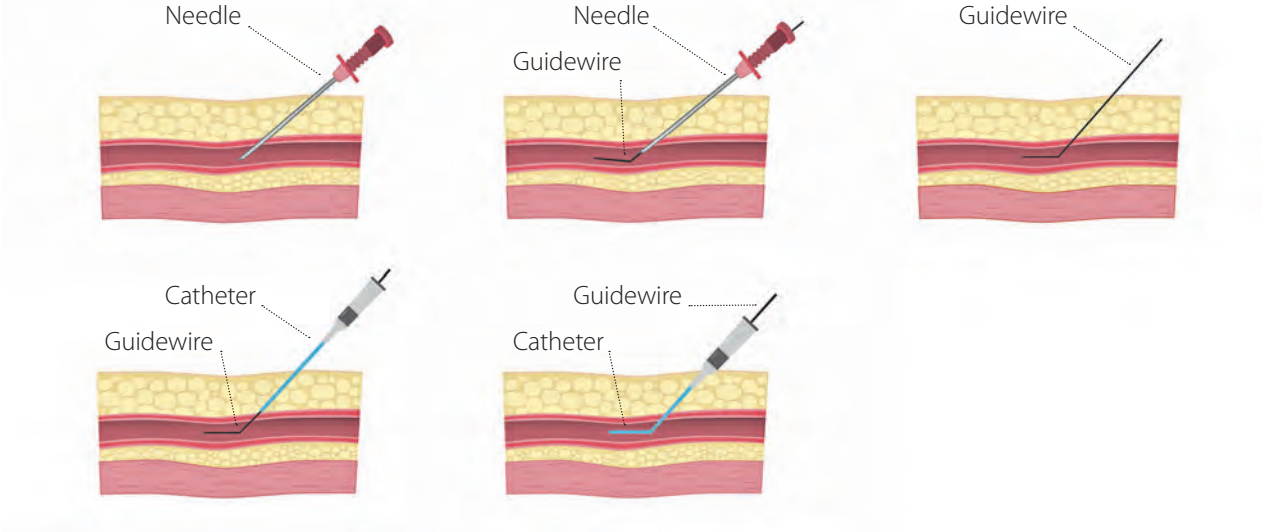
Different types of needles are used for various IR procedures:

- **Biopsy needles:** Used to collect tissue samples.



- **Aspiration needles:** Used to remove fluids from cysts or abscesses.
- **Access needles:** Used to gain vascular access by creating a pathway for the insertion of guidewires and catheters. (**Seldinger Technique:** A method where a guidewire is inserted through the needle, followed by the removal of the needle and the advancement of a catheter over the guidewire.) [1]

Example of the Seldinger technique

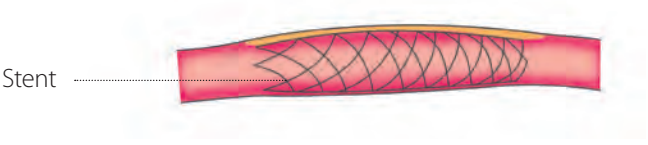


- **Ablation needles:** radiofrequency ablation needles, microwave ablation needles, cryoablation needles and electroporation ablation needles.

1.4 Stents

Stents are mesh-like tubes that are inserted into narrowed or blocked vessels to keep them open. They can be:

- **Bare-metal stents:** Made of metal without any coating.
- **Drug-eluting stents:** Coated with medication that helps prevent restenosis (re-narrowing of the vessel).

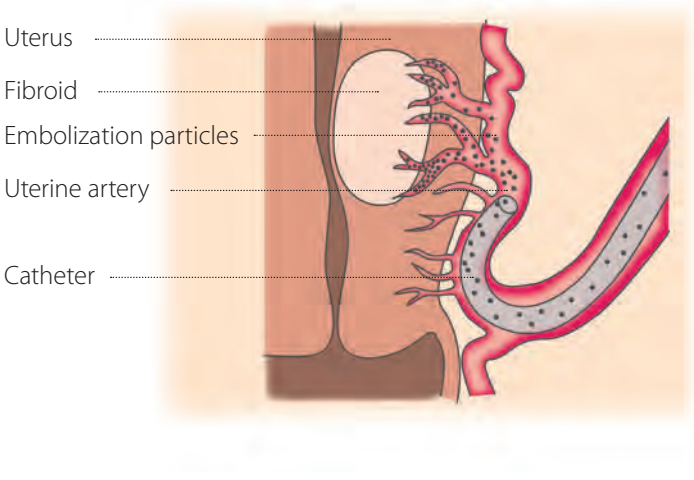


1.5 Embolization materials

Embolization is a critical technique in interventional radiology that involves the deliberate occlusion of blood vessels to achieve therapeutic goals such as controlling bleeding, reducing blood flow to tumours, or treating vascular malformations.

- **Coils:** Coils are made of metal, typically platinum or stainless steel. These small, coiled wires are designed to induce thrombosis by providing a scaffold for clot formation within blood vessels. Coils can be bare or covered with fibres or hydrogel to enhance their thrombogenic properties. The deployment of coils involves precise placement within the target vessel using microcatheters under fluoroscopic guidance.
- **Particles:** Particles are small, biocompatible embolic materials made from substances like polyvinyl alcohol (PVA) or tris-acryl gelatine microspheres. These particles are available in various sizes, allowing for selective occlusion of vessels based on their calibre. Particles are delivered through a catheter under imaging guidance, ensuring they reach the target site effectively.

Uterine fibroid embolization (UFE)

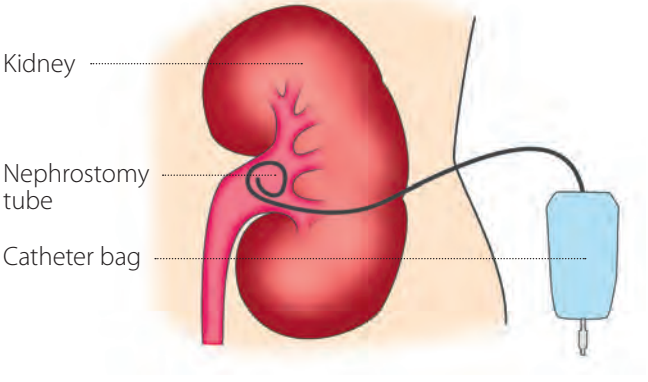


- **Gelfoam:** Gelfoam is an absorbable gelatine sponge that can be cut into small pieces or used as a slurry for embolization. It provides temporary occlusion of blood vessels, typically resorbed by the body within weeks to months. Gelfoam is often used in situations requiring temporary vessel occlusion, such as preoperative reduction of blood flow or temporary control of bleeding in trauma or gastrointestinal procedures. The preparation and delivery of gelfoam involve mixing it with contrast and saline fluid, then injecting it through a catheter to the target site under imaging guidance.
- **Liquid embolic agents:** Liquid embolic agents, including Onyx™ or Squid™ (ethylene-vinyl alcohol copolymer), n-Butyl Cyanoacrylate (NBCA), and Ethiodized Oil (Lipiodol), are used for rapid and effective occlusion of blood vessels. Squid™, Onyx™ and NBCA solidify upon contact with blood or over time, forming a permanent occlusion. These agents are injected through microcatheters under imaging guidance to ensure precise delivery and solidification at the desired site.

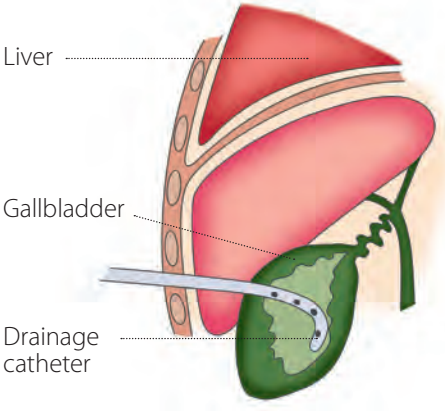
1.6 Drains

Catheters are designed to drain fluids from abscesses or other fluid collections. Drains come in various sizes (gauges) and shapes to suit different clinical needs. For example, pigtail catheters have a coiled end to anchor the catheter within a cavity, while straight catheters are used for direct drainage.

Percutaneous nephrostomy



Cholecystostomy (drainage)



A nephrostomy catheter

2 Vascular IR

2.1 Peripheral Vascular Disease

Clinical presentation including classification:

- Peripheral vascular disease (PVD) is a disease of the arteries which affects the extremities, usually the lower limbs. The most common cause is atherosclerotic disease, with risk factors such as cigarette smoking, hypertension, hypercholesterolaemia, and diabetes mellitus.
  It can present with or without concomitant coronary artery disease or cerebrovascular disease.
- PVD is classified based on the presentation of intermittent claudication (IC), which is pain usually found in the calves, buttocks or thighs when walking. It progresses to disabling claudication and eventually to critical limb ischaemia (CLI). CLI represents an advanced stage of the disease with pain that cannot be relieved by standard analgesia. It can appear with or without the presence of tissue loss, this includes ulceration and/or gangrene. Untreated CLI often leads to limb loss from amputation.
- PVD can also be classified based on the ankle brachial pressure index (ABPI). The normal ABPI ranges from 0.9-1.1. An ABPI of <0.8 represents PVD with a reduction in ABPI with IC [2–3]. CLI is also defined with an ABPI of <0.3 or an absolute pressure of <50 mmHg at the ankle or a toe systolic pressure of <30 mmHg in a person with diabetes [4].
- Fontaine classification system categorises PVD based on clinical symptoms [5].

Fontaine Classification

Grade	Symptoms
Stage I	Asymptomatic, incomplete blood vessel obstruction
Stage II	Mild claudication pain in limb
Stage IIA	Claudication at a distance >200 m
Stage IIB	Claudication at a distance <200 m
Stage III	Rest pain, mostly in the feet
Stage IV	Necrosis and/or gangrene of the limb

- The Rutherford classification categorises PVD into acute and chronic limb ischaemia and highlights the different treatment algorithms for each presentation [6].

Rutherford Classification

Grade	Category	Clinical description
0	0	Asymptomatic
I	1	Mild claudication
I	2	Moderate claudication
I	3	Severe claudication
II	4	Ischaemic rest pain
III	5	Minor tissue loss – nonhealing ulcer, focal gangrene with diffuse pedal ischaemia
III	6	Major tissue loss – extending above trans metatarsal level, frank gangrene

Imaging findings before intervention:
- Duplex ultrasound is often the first modality of imaging.
- Computed tomography angiography (CTA) or magnetic resonance angiography (MRA) are the next modalities of imaging. Digital subtraction angiography (DSA) is preferred for treatment with concomitant balloon angioplasty and/or stenting of narrowed or blocked blood vessels.

IR treatment options:
- Endovascular procedures are performed through a small access in the groin. If needed, after recanalization of the stenotic or occluded segment, the artery is dilated with a balloon followed by a stent. Newer developments include drug-coated balloons to improve patency and atherectomy to debulk calcifications.

Angioplasty and stenting

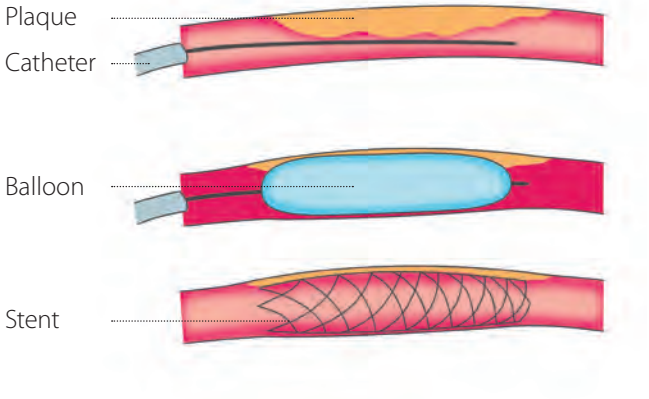


Image 1. Example of an arterial angioplasty and stenting.

Clinical care and/or follow-up:
- Follow-up is conducted in a clinic to review symptoms, check medication (typically an antiplatelet drug and a statin), examine the leg perfusion and control the angioplasty result with Duplex ultrasound.

2.2 Aortic disease

Clinical presentation including classification:
Aortic diseases include aortic aneurysms, which are the pathological dilation of the vessel. They also include the most common aortic disease, a rupture or dissection, which is the formation of a false lumen in the vessel wall of the aorta.

- Aneurysms are defined as the dilatation of a blood vessel, usually greater than 50% of the normal diameter [7].
- Aortic aneurysms can be classified based upon their location in the aorta (thoracic/abdominal; supra/infra-renal; with/without involvement of carotid/subclavian vessels). There is also a distinction made between true aneurysms which involve all 3 layers of the blood vessel, and false/pseudo aneurysms which arise due to trauma or infection.
- Abdominal aortic aneurysms (AAA) are the most common type of aneurysms and aortic disease. They are seen more frequently in men than women (4:1) and typically affect older patients [7]. These are thought to be atherosclerotic in nature with cigarette smoking as a common risk factor.

Imaging findings before intervention:

- Aortic diseases, especially aneurysms, are usually asymptomatic and detected incidentally on ultrasound (US) or CT scanning. To accurately determine the pathology and the treatment plan, the gold standard for imagining is CTA.
- On CTA, the specific aortic disease and its morphology are studied to assess suitability for endovascular repair and device selection.
- Aneurysms can also first present once they rupture. Ruptured aneurysms carry a high mortality rate of between 80-90% [6]. In the United States of America, screening with US for men between the ages of 65-75 who have smoked is offered, whereas in the United Kingdom and Sweden, all men at the age of 65 are offered AAA screening [8–9].

IR treatment options:

Depending on the location of the problem (thoracic aorta, abdominal aorta in the vicinity of the origin of the abdominal arteries, or the abdominal aorta below the renal arteries), the use of a thoracic endovascular aortic repair device (TEVAR), fenestrated/branched endovascular aortic repair device (F/BEVAR), or an endovascular aortic repair device (EVAR) is warranted [10].

All previously mentioned endovascular treatment options are an alternative to open surgery.

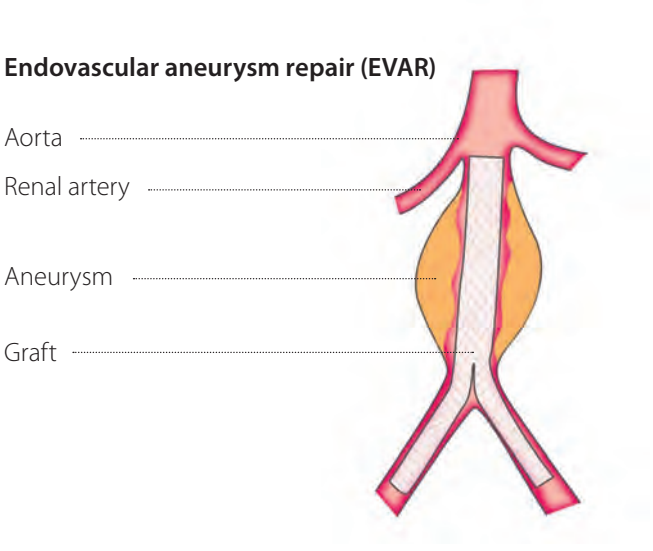


Image 2. Example of an endovascular aneurysm repair for an infrarenal abdominal aortic aneurysm.

Clinical care and/or follow-up:

- Follow-up after EVAR is important to detect possible leaks into the aneurysm which will need to be fixed. The most common modality is CTA at 1 month, 6 months, and then yearly.

2.3 Venous Disease

2.3.1 Venous Thromboembolic Disease

Clinical presentation including classification:

- Sluggish blood flow, intimal injury, and hypercoagulability can lead to a venous blood clot (thrombus). If the thrombus dislocates and travels in the blood it is called an embolus. The most common thrombus sites are the legs and the pelvis. Patients usually experience pain and swelling in the affected leg, or dyspnoea and haemodynamic instability if there is a thrombus dislocation to the pulmonary arteries.

Imaging findings before intervention:

- Imaging modalities include US for peripheral and abdominal veins and CTA for pulmonary embolism. Sonographic features of acute thrombosis include dilatation and non-compressibility of the vein, hyperechoic endoluminal matter and a lack of Doppler signal. On CTA there is a partial or total filling defect of the vessel lumen.

IR treatment options:

- The standard treatment is anticoagulation.
- For extended venous thrombosis, the thrombus can be dissolved either mechanically or pharmacologically, or using a combination of both to minimize the risk of post-thrombotic syndrome [11].
- If anticoagulation is contraindicated, the blood can be filtered to prevent a pulmonary embolism using a vena cava filter.

Clinical care and/or follow-up:

- Anticoagulation is generally needed even after successful thrombolysis. Clinical follow-up and duplex ultrasounds are performed at 2 weeks and 3 months.

2.3.2 Chronic Venous Obstruction

Clinical presentation including classification:

- Clinical symptoms and presentations vary depending on the location of the obstruction or occlusion. Chronic venous obstruction may occur after venous thrombosis with insufficient recanalization. This can be due to anatomical venous variants or mechanic/external compression of the vein (e.g. tumour, May-Thurner Syndrome) [12]. The extremity before the obstruction is typically swollen and painful.

Imaging findings before intervention:

- Imaging modalities commonly include US for peripheral veins and CT venography for the inferior vena cava. Sonographic features of chronic thrombosis include obliteration and fibrosis of a vein which has a lack of Doppler signal. On CT venography, the occluded veins are small with strongly developed collaterals.

IR treatment options:

- Recanalization of the occluded vein with percutaneous transluminal angioplasty (PTA) and stenting is needed in nearly all cases to avoid recoil [13].

Clinical care and/or follow-up:

- Medical anticoagulation for several weeks. Clinical follow-up including duplex ultrasound after 3 months.

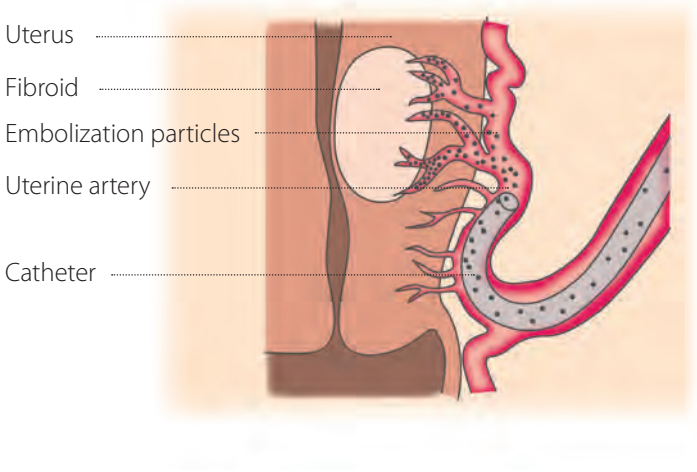
2.4 Embolization for Benign Conditions

2.4.1 Uterine Fibroid Embolization

Clinical presentation including classification:

- Fibroids are common and treatment is only necessary if they cause symptoms. Symptoms include heavy menstrual bleeding or bulk symptoms (i.e. sensation of pressure in the pelvis or urinary frequency).

Uterine fibroid embolization (UFE)



Imaging findings before intervention:

- Fibroids are solid masses within the uterine wall, they can be submucosal or subserosal. The fibroids can show areas of cystic degeneration/necrosis or calcifications. Magnetic resonance imaging (MRI) is the preferred imaging modality for determining size, vascularity and location. MRA can assess potential collaterals mainly in the ovarian arteries.

IR treatment options:

- Embolization of both uterine arteries with particles (efficacy ~ 80%) [14].

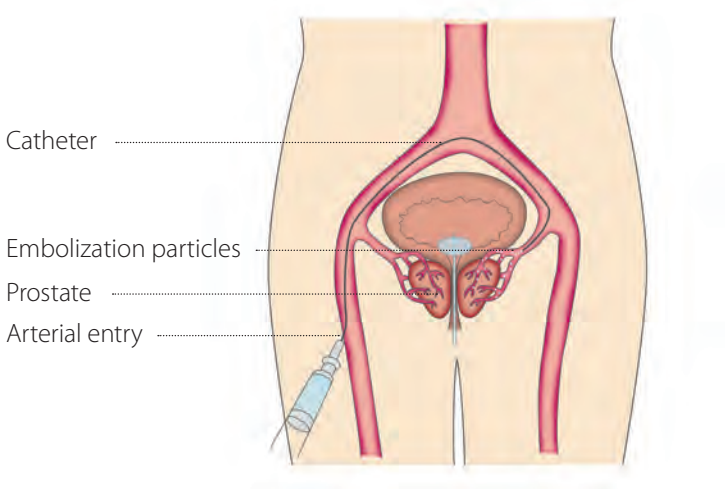
Clinical care and/or follow-up:

- Patients experience some pain for 1-2 weeks after the procedure. Thereafter, they are usually pain free with symptoms resolving within 3 months. Clinical outpatient visits are typically scheduled at 2 weeks and again at 3 or 6 months.

2.4.2 Prostate Artery Embolization

Clinical presentation including classification:

- Men with benign prostate hyperplasia (BPH) present with lower urinary tract symptoms (LUTS) consisting of storage symptoms (i.e. frequency, urgency, nocturia, urinary incontinence) or voiding symptoms (i.e. slow or intermittent urinary stream, hesitancy, terminal dribbling). The severity of the symptoms is assessed using the international prostate symptom score (IPSS) [15].



Imaging findings before intervention:

- Imaging modalities include US and MRI to determine gland size and lack of malignant features. MRA or CTA helps to assess the variable prostatic vessel anatomy before the procedure.

IR treatment options:

- Selective embolization of the prostatic arteries with small particles (efficacy ~ 80%) [16].

Clinical care and/or follow-up:

- Prostate artery embolization (PAE) is typically performed as an outpatient procedure. The symptoms improve within several months. Clinical outpatient visits are usually scheduled at 3 months, 6 months and 12 months.

2.4.3 Gastrointestinal Bleeding

Clinical presentation including classification:

- Depending on the vessel location, patients with gastrointestinal (GI) bleeding experience haematemesis and melena (usually indicates a bleed in the upper GI, proximal to ligament of Treitz) or haematochezia (indicates a bleed in the lower GI, distal to ligament of Treitz).

Imaging findings before intervention:

- CTA can detect the active bleeding site if the bleeding rate exceeds 0.3 ml/min [17]. It is visible as focal hyperdense spots on the arterial phase or pooling of contrast agent on the portal venous phase. For intermittent bleeding, a scintigraphy with labelled red blood cells can be performed.

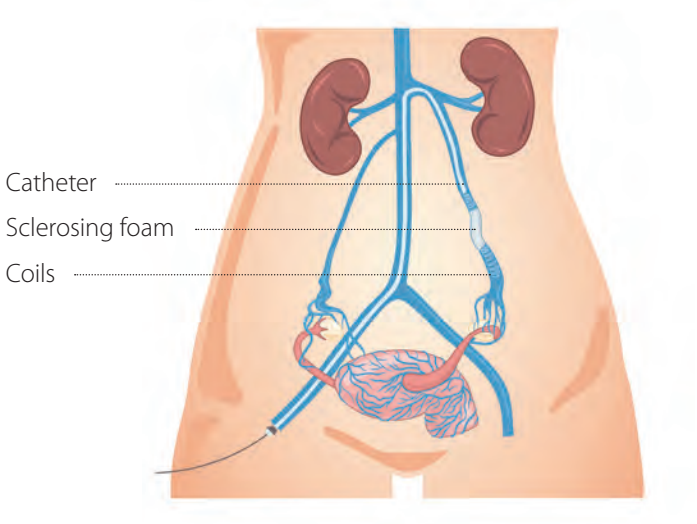
IR treatment options:
- Embolization of the bleeding site by blocking the bleeding artery. Depending on the location, the embolic agent can be temporary (e.g. gelatine sponge) or permanent (e.g. coils or glue).

Clinical care and/or follow-up:
- Bleeding should stop immediately after embolization. Short term follow-up with lab tests and clinical visits. If necessary, the embolization can be repeated.

2.4.4 Gonadal Vein Embolization

Clinical presentation including classification:
- Insufficiency of the gonadal veins can lead to testicular varicosities with subsequent pain and infertility in men, or vulvovaginal varicosities and pelvic congestion syndrome (i.e. pain, dysmenorrhea, deep dyspareunia and urinary urgency) in women.

Imaging findings before intervention:
- A testicular varicocele can be diagnosed sufficiently by US. Salient findings are serpentine dilatation of the pampiniform plexus >2-3 mm and flow reversal on Doppler sonography with Valsalva manoeuvre [18]. Sarteschi classification grades testicular varicoceles [19].
- Ovarian varicosities are best visualised on contrast-enhanced MRI. Sonography is only performed for assessment of lower extremity vein insufficiencies.



IR treatment options:
- Embolization of gonadal veins with sclerosants, coils and/or plugs (efficacy ~ 95%) [20].

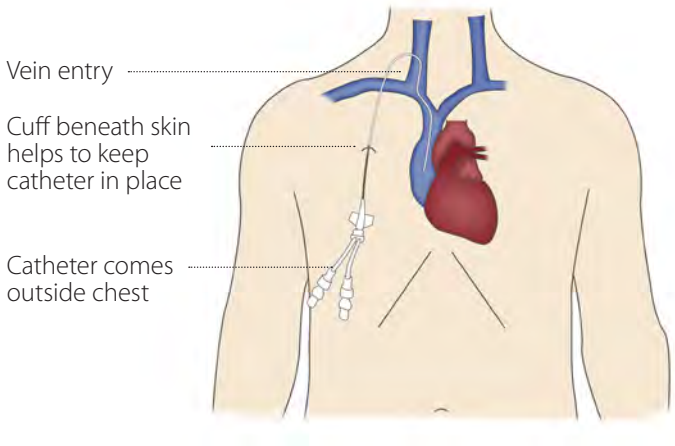
Clinical care and/or follow-up:
- Gonadal vein embolization is usually performed as an outpatient procedure. If sclerosants are used there can be some pain in the following days.
- An outpatient visit should be scheduled several weeks after the procedure.

2.5 Access

2.5.1 Central Venous Access

Clinical presentation including classification:

- Common indications for central venous access include the administration of noxious medications (e.g. chemotherapy or parenteral nutrition), haemodialysis, inadequate peripheral venous access, etc.



Imaging findings before intervention:

- Usually, no imaging is needed beforehand. Vein puncture is typically performed under US-guidance. Handling of the wire and catheter is performed under fluoroscopy.

IR treatment options:

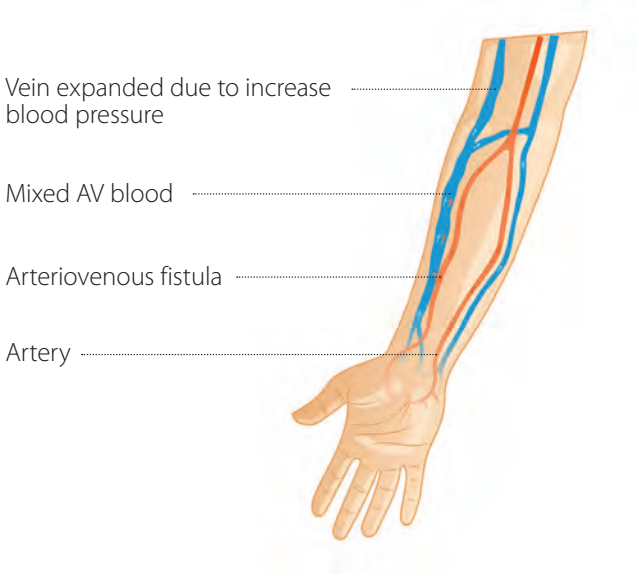
- Central venous access consists of tunnelled catheters or ports. In the latter, a reservoir is implanted subcutaneously. Another variant is peripherally inserted central lines (PICC) which are typically inserted through a superficial upper extremity vein.

Clinical care and/or follow-up:

- Outpatient or bedside visit the next day. Patients should be seen again if the access malfunctions.

2.5.2 Dialysis Shunt

Clinical presentation:
- Haemodialysis is one of the most common forms of dialysis for end-stage renal disease.
- Arteriovenous fistulas (AVFs) are created preferably between the radial artery and the cephalic vein, surgically or percutaneously by using an endovascular approach.
- AVFs may be dysfunctional due to stenosis or clotting, mostly on the venous side.



Imaging findings before intervention:
- US is used initially to determine the most suitable vein and afterwards to assess malfunctioning fistulas.

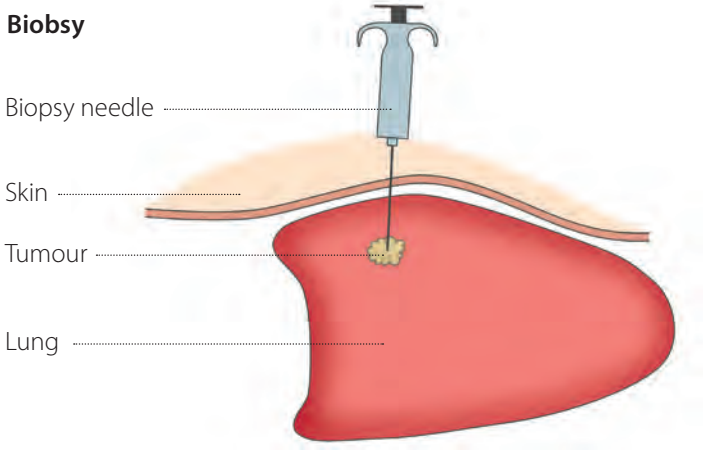
IR treatment options:
- PTA of the stenosis can be performed with or without a drug-eluting balloon (efficacy 80-90%) [21]. Occasionally stent grafts are used.

Clinical care and/or follow-up:
- Patients on dialysis are generally seen 3 times per week to check the AVF or shunts.

3 Non-Vascular IR

3.1 Biopsies and Drainages

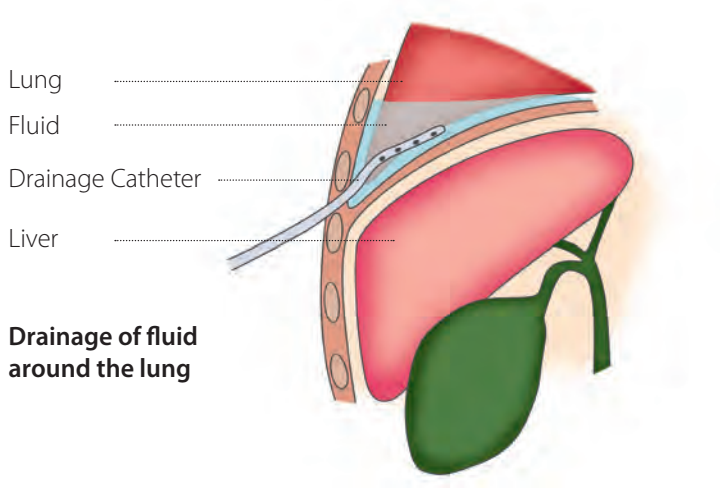
Clinical presentation:
- Biopsy: patients in which tissue sampling is necessary for determining the aetiology of a lesion before treatment.
- Drainages: patients with infected fluid collections causing sepsis (e.g. abscess, empyema, or acute cholecystitis in high-risk surgical patients), or mechanical complaints (e.g. pleural effusion or ascites).



Imaging findings before intervention:
- US, CT or MRI can show the extent of the lesions or fluid collections and also determine the best access for puncture.

IR treatment options:
- Image-guided access using US, CT, or fluoroscopy can be used to: ascertain the cytology (fine needle aspiration biopsy - FNAB) or histology (core needle biopsy) for sampling the solid lesions and enable the aspiration or drainage for sampling and/ or evacuation of fluid collections. They can also be used to place the drainage catheter in a one- step procedure (trocar technique) or using the Seldinger technique.

Clinical care and/or follow-up:
- After deep biopsy or drainage procedures, patients should be monitored for 3-24 hours.
- Further imaging is performed before drain removal, if the drain is not working, or in case of suspected complications.

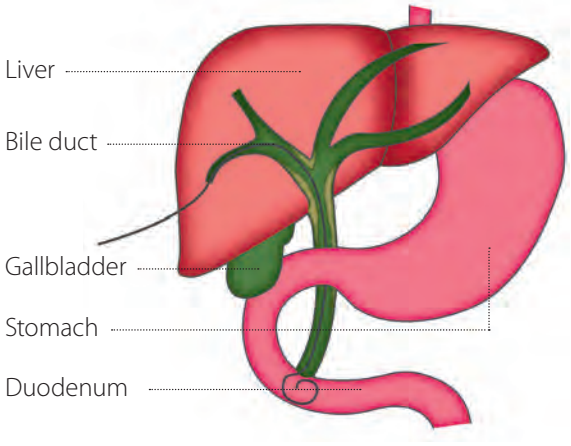


Drainage of fluid around the lung

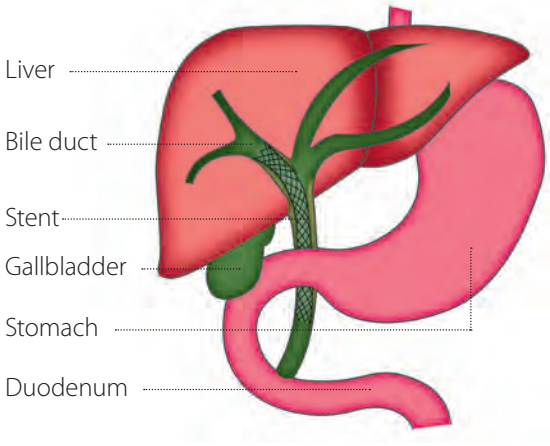
3.2 Biliary Procedures

Clinical presentation including classification:

- Patients with biliary obstruction (e.g. due to benign/malignant stenosis or biliary stone disease) can present with jaundice and/or sepsis.



Transhepatic biliary drainage



Transhepatic biliary stenting

Imaging findings before intervention:

- Magnetic resonance cholangiopancreatography (MRCP) is the best modality to assess biliary anatomy.
- The cause of obstruction and potential abscesses can be evaluated using MRI, CT or US.

IR treatment options:

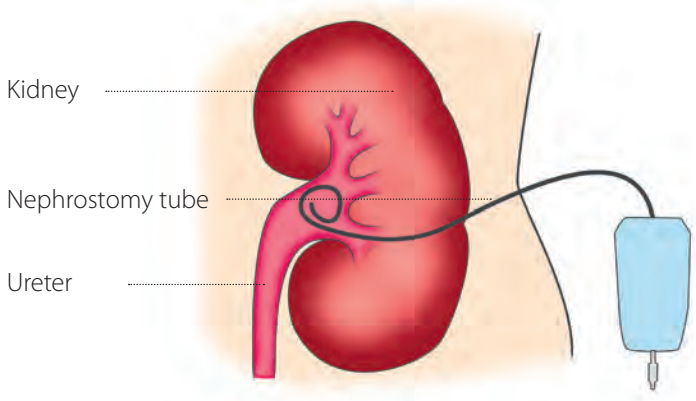
- The biliary system is accessed transhepatically under US and fluoroscopic guidance.
- Benign lesions (stones and bilio-jejunal stenosis) are usually treated with balloon dilation and drainage. Initially, a catheter with multiple side holes is inserted with the tip in the duodenum (or small bowel in case of bilio-jejunal stenosis) to allow the most effective drainage. There are both external and internal-external drains used depending on the clinical scenario.
- Malignant lesions are typically stented with a metal stent.
- Removal of biliary stones can be done through percutaneous access.

Clinical **care** and/or follow-up:

- Patients should be observed overnight after the initial biliary drainage placement.
- The biliary drainage catheter should be changed every 2-3 months because of the high viscosity of the bile.

3.3 Genitourinary Interventions

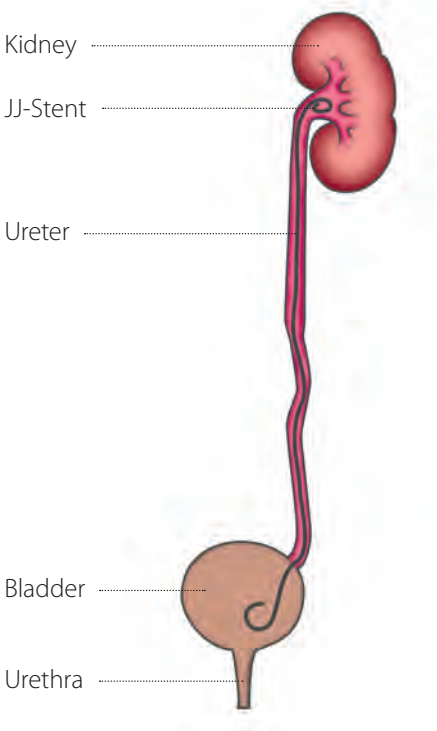
Clinical presentation:
- Ureteral obstruction (e.g. due to; kidney stones, tumours, or fibrosis) can lead to hydronephrosis, impaired renal function and even rupture of the renal collection system.
- Urinary tract leakage can occur after abdominal trauma or iatrogenic injury.



Imaging findings before intervention:
- US and non-contrast-enhanced computed tomography (NECT) are useful for identifying renal stones.
- CT urography shows the collecting systems, ureters and bladder. This helps determine the cause of the obstruction (e.g. tumour, stricture, etc.).

IR treatment options:
- An US-guided puncture is used for access to the pelvicalyceal system. Under fluoroscopic guidance, a nephrostomy catheter for external drainage can be placed, or a ureter stent can be advanced into the bladder (double J – DJ or JJ stent).

Clinical care and/or follow-up:
- Patients should be observed overnight after the initial nephrostomy catheter placement.
- The nephrostomy catheter should be changed at least every 6 months, or if it malfunctions.



4 Interventional Oncology

4.1 Ablative Therapies

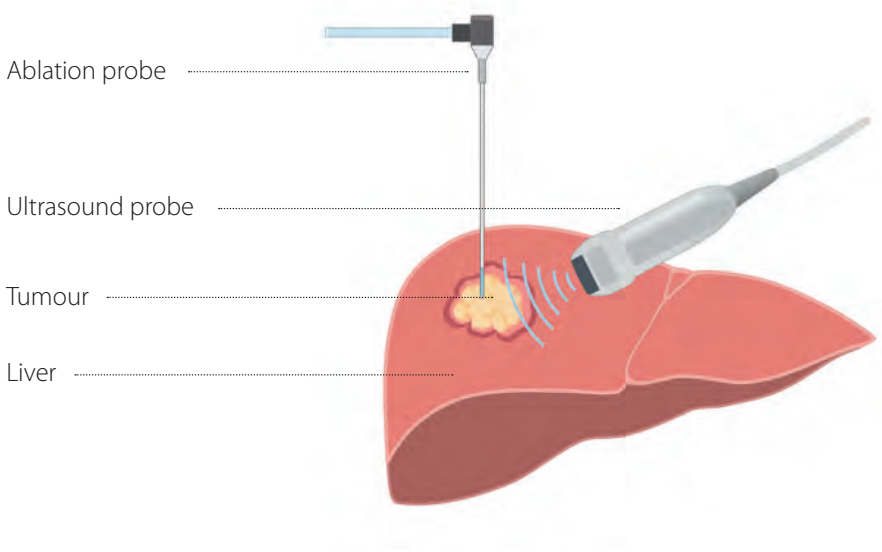
4.1.1 Liver Tumour Ablation

Clinical presentation including classification:
- Primary or secondary liver lesions are usually found during staging CT scans or US.
- Hepatocellular lesions can be classified according to the Barcelona Clinic Liver Cancer (BCLC) staging system and treatment strategy [22].

Imaging findings before intervention:
- Cross sectional images (e.g. CT, MRI) are necessary to determine the size and location of the tumours.
- CT and MRI also help to plan access and ablation of these lesions.

IR treatment options:
- The most common ablation modalities are radiofrequency (RF) or microwave (MW).
- For RF and MW, a needle has to be placed into the lesion using image-guidance such as US or CT, or a combination of both.
- After thermal ablation, the success is typically documented using contrast CT.
- Navigation systems (special software and hardware used to correctly plan the ablation, place the needle and evaluate the ablation zone) may help to achieve complete ablation of the lesions.

Clinical care and/or follow-up:
- CT control with a clinical visit to determine the outcome and recognise the potential complications such as abscesses, biloma, or bile leaks.



4.1.2 Renal Tumour Ablation

Clinical presentation:
- Renal masses are usually asymptomatic. Occasionally, they can cause back pain, macroscopic or microscopic haematuria.

Imaging findings before intervention:
- Renal tumours are commonly incidental findings during routine imaging. US and multiphase CT are the most common imaging modalities to determine whether a renal mass is malignant.

IR treatment options:
- Small renal tumours in poor surgical candidates can be treated with image-guided ablation [23].
- Besides heat (i.e. RF or MW), cold (i.e. cryotherapy) can be used. The latter has the advantage of being safer for tumours located close to the pyelo-calyceal collecting system; moreover, the ice ball can be seen in CT or MRI.

Clinical care and/or follow-up:
- A post-ablation CT is usually necessary to ensure that the targeted lesion has been treated and that no complications such as bleeding or urinary leak have occurred.

4.1.3 Lung Tumour Ablation

Clinical presentation:
- Primary lung cancer and metastatic lung disease are usually asymptomatic but can occasionally manifest with haemoptysis, especially in advanced cases.

Imaging findings before intervention:
- The chest radiograph is the main screening tool. However, CT is increasingly used for screening/staging.
- The main imaging features on CT are nodules within the lung parenchyma, with or without hilar lymphadenopathy.

IR treatment options:
- Thermal ablation of the lungs can be used to treat both primary and secondary thoracic malignancies when they are ≤ 2-3 cm; moreover, no more than 5-6 metastatic nodules per lung are treated in the same session [24].
- Good results have been reported in several studies [24].

Clinical care and/or follow-up:
- A post-ablation CT is performed within a few days to ensure adequate ablation of the targeted lesions and to ensure that no complications such as pneumothorax, pleural effusion, lung haemorrhage or the formation of a lung abscess have occurred.

4.2 Liver Malignancy Embolization

Clinical presentation including classification:

- Primary or secondary liver lesions are usually an imaging finding during staging CT scans or US. However, there are occasions when they manifest as abnormal liver blood markers or with jaundice if there is a central lesion obstructing the common bile duct.

Imaging findings before intervention:

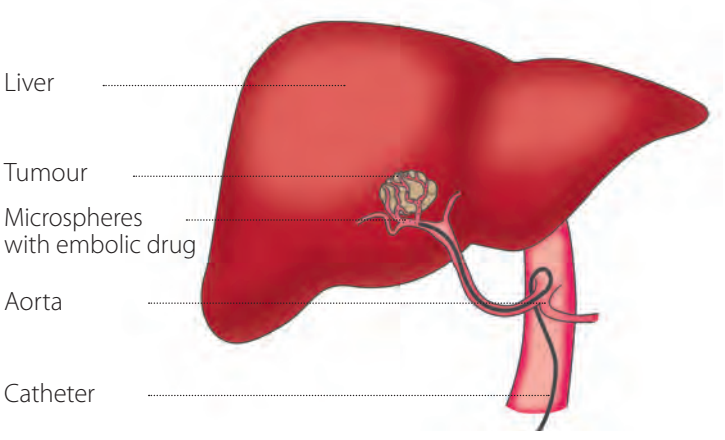
- Solitary or multiple lesions involving various components of the liver. They typically show early enhancement of contrast and a contrast washout during later phases.

IR treatment options:

- The BCLC staging system and treatment strategy outlines the treatment algorithm for hepatocellular liver lesions [22].
- The main types of transcatheter arterial embolization are:
  - Transcatheter arterial embolization (TAE): The branches of the artery supplying the liver tumour/s are selectively cannulated and then occluded using microparticles. The main aim is to cut the blood supply to the tumour.
  - Transcatheter arterial chemoembolization (TACE): This procedure is similar to TAE but the embolic agent is loaded with chemotherapy (e.g. doxorubicine). The combination of ischaemia and chemotherapy increases the effect.
  - Transarterial radioembolization (TARE): This procedure is similar to TAE but completed with radioactive particles to provide a sort of local "brachytherapy". The treatment involves injecting tiny microspheres labelled with radioactive material into the arteries that supply the tumour so the spheres lodge in the small vessels of the tumour. The embolic effects of these small spheres are almost negligible, and the flow usually remains patent. Currently, Yttrium-90 or Holmium-166 labelled spheres are available.
  - Portal vein embolization (PVE) prior to therapeutic hepatectomy: PVE is performed if the expected remaining liver volume after resection is not large enough to ensure an adequate liver function. Typically, this is the case after right-sided hepatectomy. By blocking the portal vein branches on the side of the resection in order to force the blood supply of the liver to move to the smaller side, the so-called future liver remnant can be increased in size. Access to the portal vein is usually gained with percutaneous, US-guided, transhepatic puncture.

Clinical care and/or follow-up:

- In the first few weeks after the treatment, post-embolization syndrome (PES) may happen, which includes abdominal pain, elevated temperature, nausea, loss of appetite, and fatigue.
- Follow-up is done with cross-sectional imaging (e.g. CT or MRI) to assess efficiency and to rule out complications such as abscess formation.



5 Musculoskeletal Interventions

5.1 Vertebral Compression Fractures and Vertebral Augmentation

Clinical presentation including classification:

- Benign osteoporotic fractures result from bone weakness due to substantial loss of mineral density. This condition can be physiologic (e.g. in post-menopausal women), or iatrogenic (e.g. caused by: steroid use, chemotherapy, hormonal treatments for cancers, fractures subsequent to thermal ablation or radiation therapy, etc.). The weakened vertebral body may collapses even due to minimal compressive stresses thus resulting in a vertebral compression fracture (VCF). This causes the vertebral body to lose part or all of its height.
- Chronic unhealed VCFs result in a necrotic cavity filled with fluids and gases inside the vertebral body. This condition is known as Kummel's disease and is generally painful.
- A VCF may also occur as a result of high-energy trauma in healthy people, in such a case the Magerl's classification is used [25]. This classification distinguishes VCFs in 3 main groups according to the type of traumatic stress.
- Malignant vertebral body fractures are the consequence of tumoral bone destruction (including lytic metastases and multiple myeloma).

Imaging findings before intervention:

- X-ray is typically used to obtain an overview; however, before intervention, an MRI is commonly needed to assess the activity of a fracture. Healed fractures should not be treated.
- If MRI is contraindicated, single photon emission computed tomography (SPECT-CT) should be used.
- Pre-operative imaging should rule out the main contraindications to vertebral augmentation, including vertebral instability on the sagittal plane, spondylodiscitis and spondylarthrosis.

IR treatment options:

- Initially, conservative treatment with analgesics can be used, but intervention should be considered if pain persists or if the vertebral body collapses further.
- Standard vertebroplasty is performed by injecting an acrylic cement (i.e. polymethyl methacrylate (PMMA)) through uni- or bi-pedicular needles in the vertebral body.
- Vertebroplasty can be combined with radiation therapy or percutaneous ablation for lytic malignant lesions.
- Height restoration can be achieved through the use of balloons (i.e. kyphoplasty), or with stents (i.e. stentoplasty), especially in young patients presenting with traumatic fractures.

Clinical care and/or follow-up:

- Following vertebroplasty, patients are instructed to have bedrest for 4-6 hours. Thereafter, they may move without any significant restrictions.
- Clinical follow-up is recommended in osteoporotic patients as additional fractures due to the fragile bones are common so additional vertebroplasties may be needed.
  To prevent the occurrence of new fractures in heavily osteoporotic patients, dedicated medications (vitamin D and calcium, bisphosphonates, or similar) should be prescribed to slow down the osteoporotic disease.

5.2 Low Back Pain

Clinical presentation including classification:

- Low back pain is very common and presents as acute or chronic pain of the lumbar region, with or without irradiation to the lower limbs.
- Low back pain has many causes including disc tears in the annulus, disc herniation, degenerative or inflammatory changes of facet joints, and spinal canal stenosis.

Imaging findings before intervention:

- Unenhanced lumbar MRI is the preferred imaging modality used to postulate the possible cause of pain.
- MRI findings should be combined with the patient's history and a physical examination.

IR treatment options:

- Initially, conservative treatment with analgesics and physiotherapy is preferred.
- If conservative therapy is not successful, spinal injections can be performed under image-guidance (e.g. fluoroscopy or CT) to deliver anaesthetics and/or long-lasting anti-inflammatory steroids in the area where the pain is supposed to originate.
- If back pain originates from the facet joints and recurs after the injection, a focal thermocoagulation can be considered following an intra-articular injection of anaesthetics/steroids to provide relief.

Clinical care and/or follow-up:

- A pain questionnaire (e.g. a visual analogue scale) is typically filled out 30 minutes after the injection in order to assess the immediate effect.
- If the pain reoccurs, the injection can be repeated. If the pain free interval is short, surgical therapy can be considered, the response to the injection should reveal the source of pain.

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