MODERN RADIOLOGY eBook

Interventional Radiology

EUROPEAN SOCIETY OF RADIOLOGY

Preface

Modern Radiology is a free educational resource for radiology published online by the European Society of Radiology (ESR). The title of this second, rebranded version reflects the novel didactic concept of the *ESR eBook* with its unique blend of text, images, and schematics in the form of succinct pages, supplemented by clinical imaging cases, Q&A sections and hyperlinks allowing to switch quickly between the different sections of organ-based and more technical chapters, summaries and references.

Its chapters are based on the contributions of over 100 recognised European experts, referring to both general technical and organ-based clinical imaging topics. The new graphical look showing Asklepios with fashionable glasses, symbolises the combination of classical medical teaching with contemporary style education.

Although the initial version of the *ESR eBook* was created to provide basic knowledge for medical students and teachers of undergraduate courses, it has gradually expanded its scope to include more advanced knowledge for readers who wish to 'dig deeper'. As a result, *Modern Radiology* covers also topics of the postgraduate levels of the *European Training Curriculum for Radiology*, thus addressing postgraduate educational needs of residents. In addition, it reflects feedback from medical professionals worldwide who wish to update their knowledge in specific areas of medical imaging and who have already appreciated the depth and clarity of the *ESR eBook* across the basic and more advanced educational levels.

I would like to express my heartfelt thanks to all authors who contributed their time and expertise to this voluntary, non-profit endeavour as well as Carlo Catalano, Andrea Laghi and András Palkó, who had the initial idea to create an *ESR eBook*, and - finally - to the ESR Office for their technical and administrative support.

Modern Radiology embodies a collaborative spirit and unwavering commitment to this fascinating medical discipline which is indispensable for modern patient care. I hope that this *educational* tool may encourage curiosity and critical thinking, contributing to the appreciation of the art and science of radiology across Europe and beyond.

Minerva Becker, Editor
Professor of Radiology, University of Geneva, Switzerland

Interventional Radiology

CHAPTER OUTLINE:

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CHAPTER OUTLINE:

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Interventional Radiology

CHAPTER OUTLINE:

MODERN RADIOLOGY eBook

Based on the ESR Curriculum for Radiological Education

Interventional Radiology

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Interventional Radiology

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Introduction

CHAPTER OUTLINE:

/ What Is Interventional Radiology?

Interventional Radiology (IR) is a clinical subspecialty within radiology which specialises in the diagnosis and treatment of disease using image-guided techniques. Its common characteristics is a minimal invasive approach. Simplified, interventional radiologists are using needles, not knifes/scalpels.

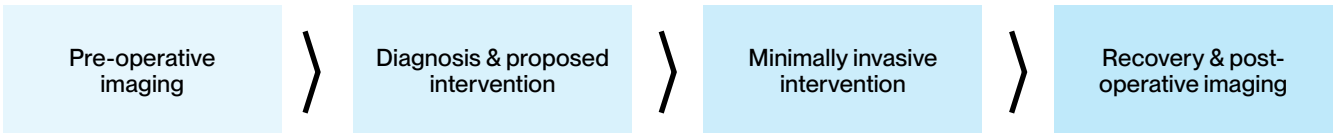
Interventional radiologists are trained both at diagnostic and therapeutic approaches enabling them to use existing and real-time imaging to diagnose, propose and execute treatment plans.

The applications of IR include four overarching and often overlapping categories:

- Vascular IR ("classical" IR)
- General body IR (vascular and non-vascular applications)
- Neuro IR (vascular and non-vascular)
- Interventional Oncology (IO)
- Emergency IR

Every patient referred to and treated by the IR team in any hospital, will have gone through four critical steps which are also considered fundamental pillars for the specialty. These are shown on the next page.

Interventional Radiology



Patient's interests are at the heart of this journey and this is reflected in the multitude of benefits that are often conferred by the very nature of these interventions.

<!> ATTENTION

IR procedures carry a smaller risk of complications, are less costly and are associated with shorter hospital stays than invasive procedures.

In emergency situations, IR techniques offer significant time saving.

Their minimally invasive nature lends itself for the increasingly comorbid, high-risk population that is often a poor candidate for surgical alternatives.

CHAPTER OUTLINE:

/ Basic Principles of Image Guided Intervention

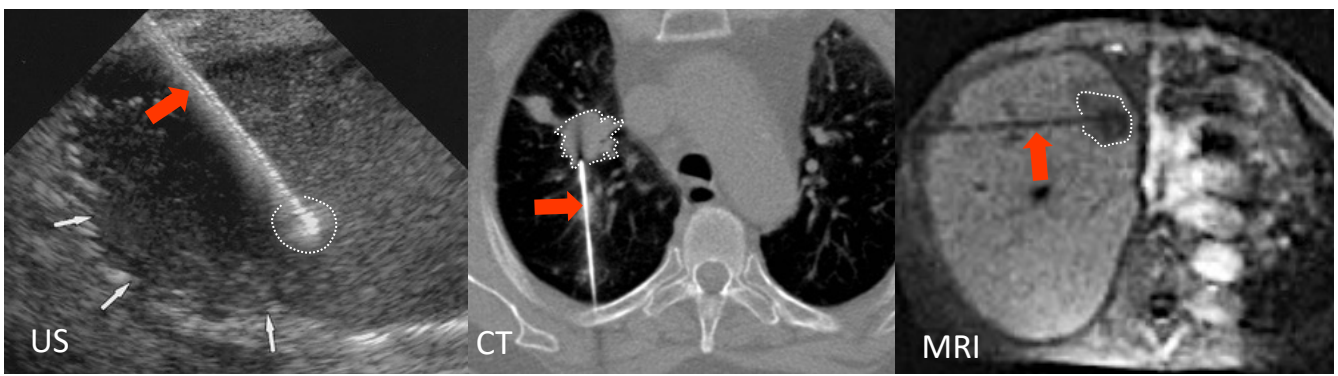
A series of steps are required for an IR procedure to be performed safely and competently. These include:

(1) Image acquisition for procedural guidance

- / It can be performed with real-time ultrasound (US), fluoroscopy, computed tomography (CT) or magnetic resonance imaging (MRI).
- / Different modalities are used for different image-guided IR techniques depending on the procedure being performed. Radiographer presence and support is needed for certain types of image acquisition and post-processing, e.g., in digital-subtraction angiography (DSA) which involves the subtraction of pre-contrast (i.e., mask) image from the post-contrast (live) image.

<∞> REFERENCE

> see eBook chapter on Vascular Imaging



Needle placement (red arrows) into different target lesions (contoured by dashed lines) under US, CT and MRI guidance.

(2) Precise needle placement

- Image-guided intervention aims to secure access into a vascular structure (vein or artery), an anatomical fluid cavity (e.g., pleural space or peritoneal space) or a pathological cavity (e.g., a drainable collection or abscess).
- Accurate and precise needle placement is a vital first step before access is further secured with guidewires and subsequent catheters and relevant devices.
- Needle placement is often performed under US-guidance, with some exceptions, such as in CT-guided biopsies or ablations where the target is often approached with placement of the needle followed by the relevant adjustment as deemed necessary from the successive CT image acquisition.

Needle placement (red arrow) into a large hepatic fluid collection (asterisk) under CT guidance. The patient is in a prone position on the CT table for facilitated access.

CHAPTER OUTLINE:

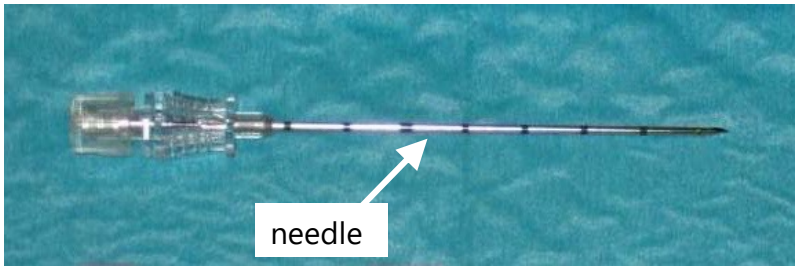
(3) Real-time imaging

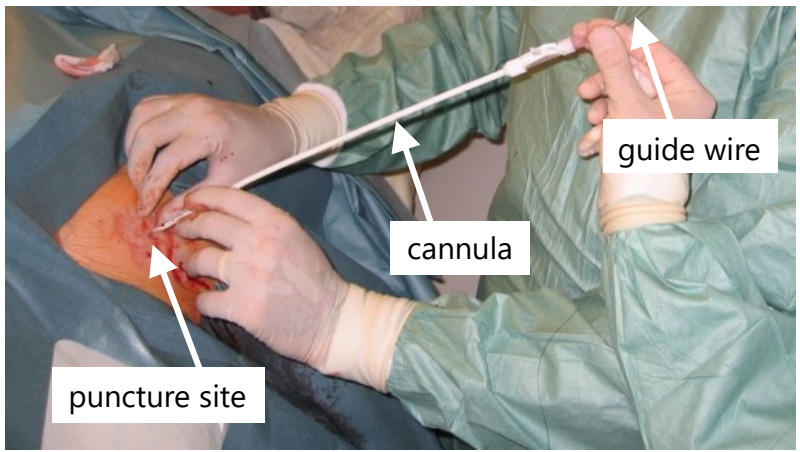
- Needles, wires, catheters, deployable devices or any kit employed during interventional procedures are visible through real-time imaging to guide manipulation. For example, fluoroscopic guidance of wires with subtraction techniques and intravenous contrast enable accurate placement of relevant catheters and devices.

(4) Minimally invasive approach

- Gaining access into the target is often achieved using thin needles which are hence minimally invasive with subsequent devices mounted on a 'railway' of equally thin guidewires.

Throughout these steps, patient monitoring is paramount as it determines success.





Abscess drainage using the Seldinger technique (see next page).

CHAPTER OUTLINE:

/ Seldinger Technique – Over the Wire

Principle: The guide wire is introduced via a needle. Trauma to the artery is thereby minimised (thin needle) and intraluminal position of guide wire is ensured.

Sven Ivar Seldinger (1921-1998) introduced this procedure in 1953.

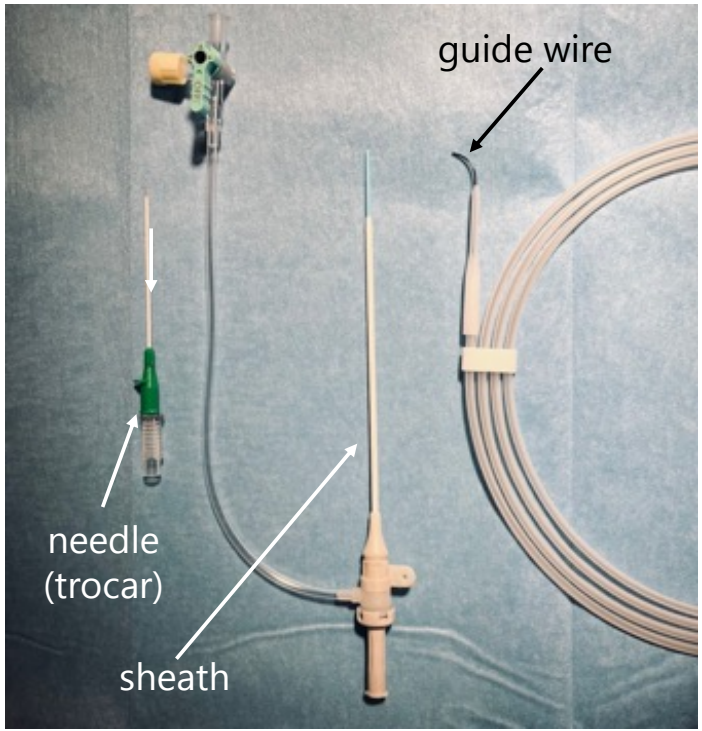
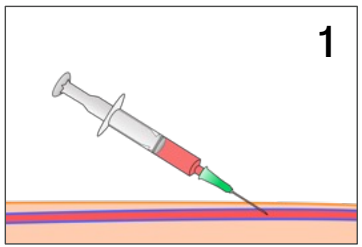


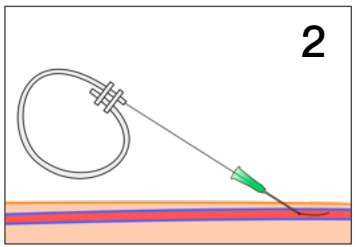
Illustration of the Seldinger technique material. Figure courtesy Dr. Matthieu Papillard, Unit of Abdominal and Interventional Radiology, Geneva University Hospitals, Geneva, Switzerland.

<=∞> REFERENCE

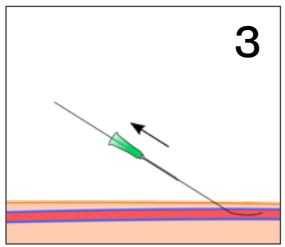
Seldinger, Sven Ivar (1953) 'Catheter Replacement of the Needle in Percutaneous Arteriography: A new technique', Acta Radiologica [Old Series], 39:5, 368 - 376



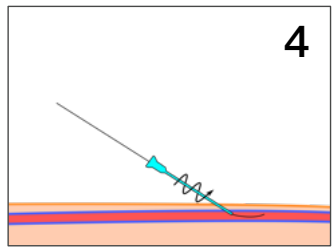
Punction with a sharp hollow needle called a trocar.



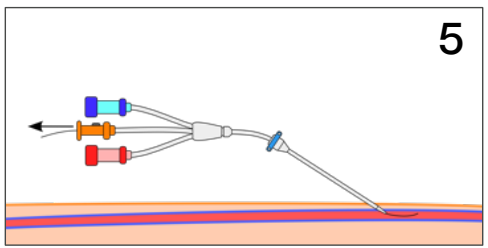
A round-tipped guidewire is advanced through the lumen of the trocar.



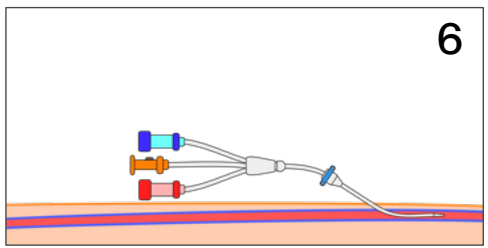
The trocar is withdrawn, guidewire is maintained.



Dilatator can be inserted in and out to enlarge the hole.



A "sheath" or blunt cannula can now be passed over the guidewire into the cavity or vessel. The guidewire is then withdrawn.



End of procedure.

Figure reproduced from: https://en.wikipedia.org/wiki/Seldinger_techniquegure

CHAPTER OUTLINE:

/ Seldinger Technique versus Trocar Technique

>|< COMPARE

Seldinger Technique

Procedure:

Step 1: A thin needle is inserted into the target area (blood vessel or body cavity), usually under imaging guidance.

Step 2: Once the needle is properly positioned, a flexible guidewire is passed through the needle.

Step 3: The needle is then removed, leaving the guidewire in place.

Step 4: A dilator or sheath is introduced over the guidewire to enlarge the opening.

Step 5: Finally, the catheter or tube is placed over the guidewire and the guidewire is removed.

Advantages:

Control:
Precise control and less traumatic to tissues, reducing the risk of complications.

Safety:
The step-by-step process, guided by imaging, minimises the risk of damaging surrounding structures.

Applications:
Widely used for vascular access, drainage of pleural effusion, ascites or abscesses and in other procedures requiring precise placement.

Trocar Technique

Procedure:

Step 1: A sharp, pointed instrument (trocar), often combined with a cannula, is inserted directly into the body cavity or space where the catheter needs to be placed.

Step 2: The trocar is used to pierce through the tissue, creating an entry point.

Step 3: Once the trocar is in place, the catheter is inserted through the cannula and the trocar is removed.

Advantages:

Speed:
Faster since it involves fewer steps than the Seldinger technique.

Simplicity:
The direct approach can be simpler in situations where quick access is needed.

Applications:

Commonly used when rapid access is necessary, such as in emergency settings or certain surgical procedures.

<!> ATTENTION

Each technique has its specific advantages depending on the clinical scenario, patient condition and the anatomical location where the procedure is performed.

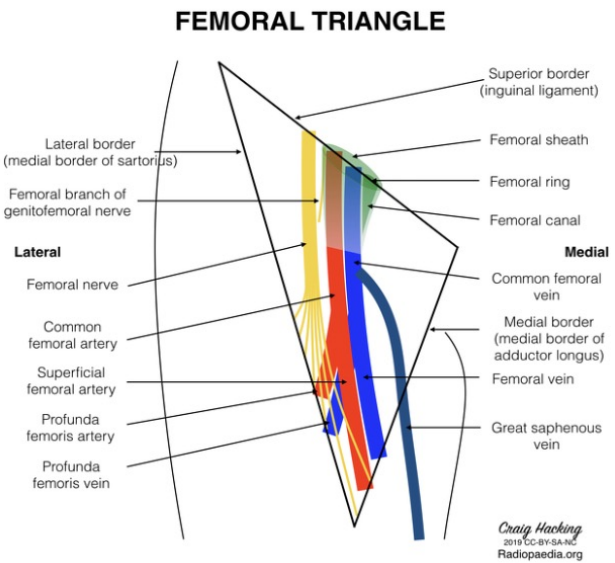
CHAPTER OUTLINE:

/ The Femoral Triangle

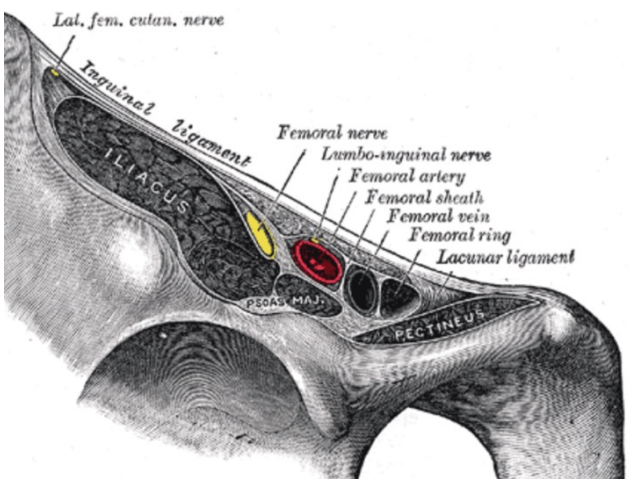
<!> ATTENTION

The **femoral triangle** is the preferred access site for femoral arterial and venous access.

The femoral triangle is a **subfascial space** bordered superiorly by the inguinal ligament, medially by the adductor longus muscle, laterally by the sartorius muscle, superficially by the skin, subcutaneous fat, superficial fascia and fascia lata and deeply by the muscular fascia of the iliacus, psoas and pectineus muscles.



From: Hacking C, Femoral triangle (diagram). Radiopaedia.org (Accessed on 20 Aug 2024) https://doi.org/10.53347/rID-70536



Anatomy of the femoral triangle. Inguinal ligament. From Gray's Anatomy plate 546. From Wikimedia Commons.

/ Interventional Radiology

CHAPTER OUTLINE:

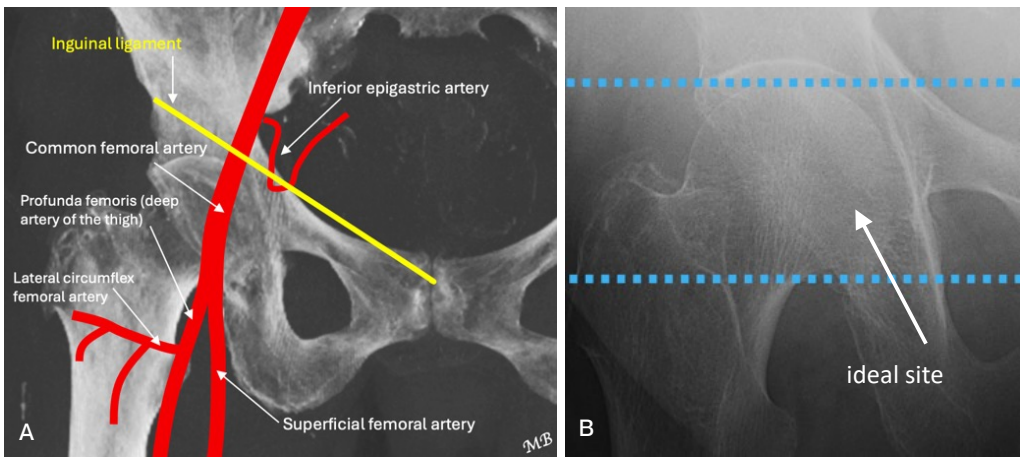
/ The Femoral Puncture

The common femoral artery (CFA) overlies the medial femoral head. When compressed against the underlying bone, the CFA is palpable in this area and this is also the site of the maximal femoral pulse.

<!> ATTENTION

Safest site for femoral puncture:

- / Landmark: femoral head
- / Originally recommended in case of a "missing femoral pulse", now routine use
- / Reduces the risk of vascular complications (i.e., retroperitoneal haemorrhage in puncture above the femoral head, increased risk of pseudoaneurysm in puncture below the femoral head)
- / Ideally: lower 2/3 of the femoral head



A. Schematic representation of the common femoral artery course in relationship to the femoral head and inguinal ligament. **B.** Safest site for femoral puncture.

Vascular Interventional Radiology (IR)

CHAPTER OUTLINE:

/ Aortic Disease

/ Acute Aortic Syndrome (AAS)

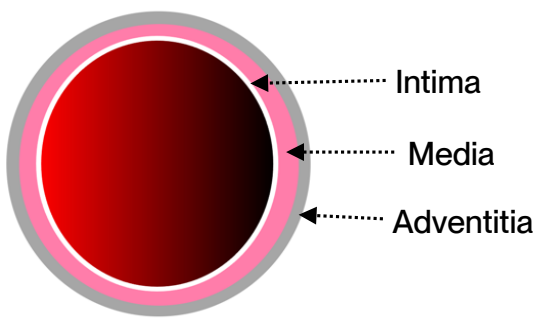
Aortic disease encompasses acute and chronic pathologies, often sharing epidemiological profiles and sometimes exhibiting overlapping and coexistent imaging features.

The **acute aortic syndrome (AAS)** is characterised by acute aortic pathology and typical “aortic” pain. It is associated with a high mortality risk, emphasising the urgency of early recognition, diagnosis and treatment.

Classically, AAS manifests as an abrupt onset of **typical “aortic” pain** which is described as sudden, severe, "tearing" chest or abdominal pain, usually located more dorsally, although presentations can manifest in more subtle forms.

The aortic wall is composed of 3 layers:

- **a thin inner intima:** mainly endothelial cells; it is the layer most susceptible to injury
- **a thicker central media:** smooth muscle cells and elastic fibres, accounts for 80% of the thickness of the aortic wall
- **a thin outer adventitia:** connective tissue/nerves/vasa vasorum (perfusing the outer aortic wall and a substantial portion of the media), high tensile strength



Schematic illustration of the aortic wall components as seen on a vessel cross-section.

Predisposing factors differ between patients above and below 70 years, with high epidemiological correlation between aging (wall alterations) and aortic diseases, such as aneurysms and dissection.

>|< COMPARE

The **older population** more commonly presents with hypertension, atherosclerosis and iatrogenic causes (e.g., cardiac catheterisation), while **younger patients** more likely suffer from congenital pathologies, including connective tissue disorders (e.g., Marfan syndrome), predisposing to aneurysm formation.

2.6-3.5 cases / 100.000

60% male; mean age: 63 years

Various pathological conditions affecting the media, trauma or infective processes can also contribute to the development of AAS.

CHAPTER OUTLINE:

Computed tomography (CT), magnetic resonance imaging (MRI), transthoracic echocardiography (TTE), transesophageal echocardiography (TEE) and abdominal aortic ultrasound (US) all have important roles for the diagnosis of acute aortic syndrome (AAS).

TTE is used for the **initial assessment** of the ascending thoracic aorta and detection of complications; it is preferred for certain cases where higher sensitivity and anatomic resolution are required.

Digital subtraction angiography (DSA) has long been considered the **gold standard for vascular imaging**; however, DSA is inadequate or even misleading for the preprocedural evaluation of aortic pathology and is only used during endovascular repair.

Non-invasive CT and MR angiography (CTA/MRA) allow superior visualisation of both lumen and aortic wall, evaluation of extraluminal soft tissues, detection of potential complications of end-organ ischaemia and impending or frank rupture [haemorrhagic periaortic / mediastinal / pleural / pericardial effusion with high risk for cardiac tamponade) / retroperitoneal haematoma, para-aortic fat stranding]. They are considered the gold standard imaging modalities for aortic disease evaluation. Electrocardiographic (ECG)-gated imaging decreases motion-pulsation artifacts of the aortic root and ascending aorta (that can mimic dissection), thus significantly increasing diagnostic confidence and precision and reproducibility of measurements.

The scope of imaging encompasses **4 fundamental pillars:**

- Detection of aortic pathology
- Potential monitoring for ongoing evaluation
- Preoperative planning
- Postoperative follow-up

For patients with a **high index of AAS suspicion**, a rapid, comprehensive diagnostic work-up is performed, including:

- **Clinical assessment**
- **Chest X-ray:** can help differentiate other possible causes for chest pain but can be misleading and while the widening of the aortic silhouette increases the likelihood of AAD, its absence does not reliably exclude the diagnosis.
- **D-Dimer and troponin:** no biomarkers are considered diagnostic and ruling out AAD on blood results is not advisable, given the almost ubiquitous access to cross-sectional imaging in modern practice
- **Electrocardiogram (ECG):** mandatory to rule out myocardial infarction (MI) but can be misleading as the presence of ECG findings consistent with MI occurs in 8% of AAD
- **ECG I-synchronised CT techniques**

Interventional Radiology

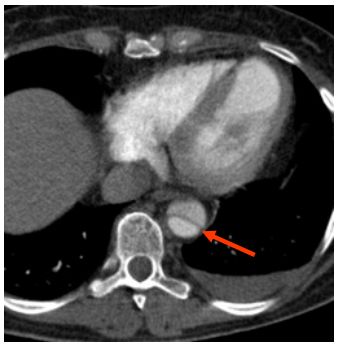
CHAPTER OUTLINE:

/ Acute Aortic Syndrome (AAS) Entities

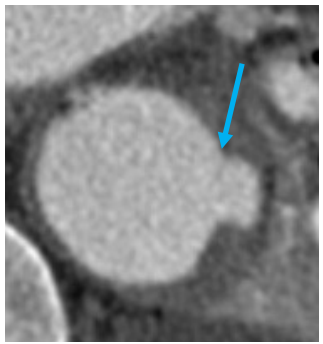
<!> ATTENTION

The entities encompassed under the umbrella term AAS include:

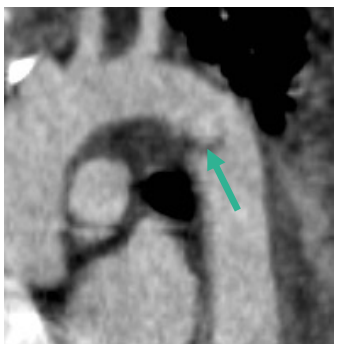
- / Classic acute aortic dissection (AAD)
- / Intramural haematoma (IMH)
- / Penetrating aortic ulcer (PAU)
- / Unstable (symptomatic/ ruptured) aortic aneurysm
- / Acute traumatic aortic injury



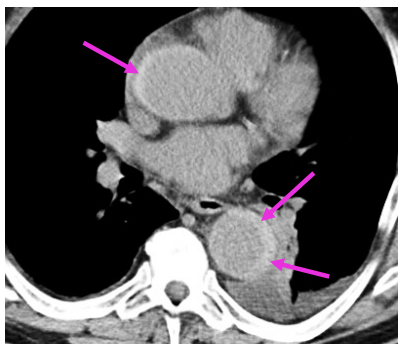
classic dissection with intimal flap



penetrating ulcer



traumatic dissection with irregular contour & intimal flap



intramural hematoma (crescent-like hyperdense areas)

/ Classic Acute Aortic Dissection (AAD)

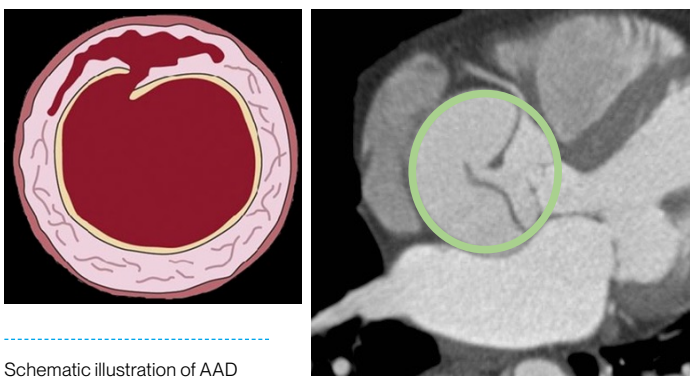
The **most common form of AAS** is caused by a **tear in the intima** and is commonly heralded by existing cystic media necrosis or media degeneration. Combined with continuous exposure to raised blood pressure and shearing forces, it can lead to a tear formation in the intimomedial layer, creating a **flap**. Blood entering under pressure into this false lumen, will cause **dissection of the intimomedial layer** from the outer wall of the aorta and may rupture back through the intima into the true lumen, creating a **re-entry tear**, a communicating passage between true and false lumens.

The dissection can progress **both proximally and distally** from the site of the initial tear leading to a number of life-threatening complications including acute aortic regurgitation (AR), myocardial ischaemia, cardiac tamponade, acute stroke or malperfusion syndromes.

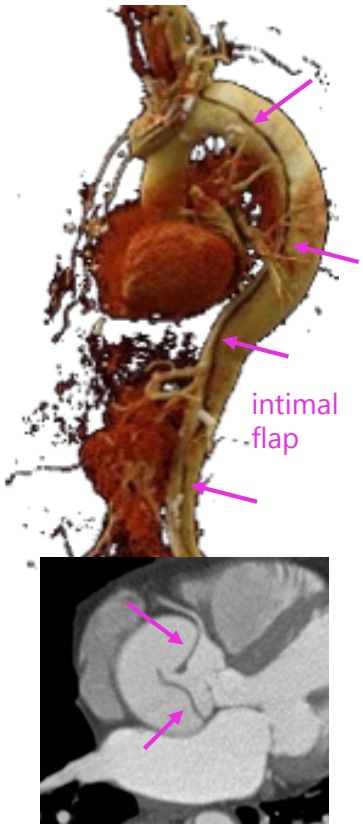
Should the blood within the false lumen penetrate the outer media and adventitia, **aortic rupture** will ensue.

Over time, blood flowing through a false lumen can contribute to the development of an **aneurysm with the potential for rupture**.

All subtypes of aortic dissection have at some point an intimal lesion in common!



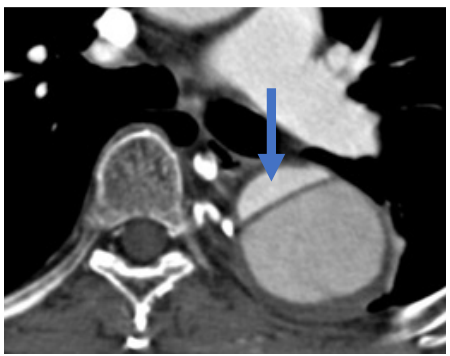
Schematic illustration of AAD



3D reconstruction and axial CT image of an aortic dissection.

“Classic” acute aortic dissection: initial intimal lesion (tear) leads to bleeding into the media and separation of true and false lumen (channel).

>|< COMPARE



true lumen:

more compressed,
contrast higher after iv. injection,
smaller diameter

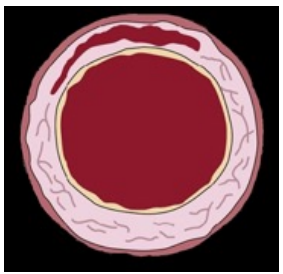
false lumen:

more expansive,
contrast lower after iv. injection,
larger diameter

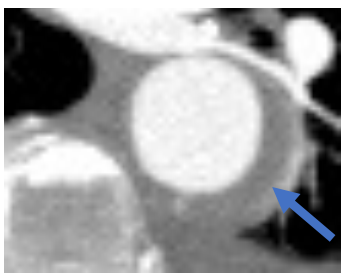
/ Intramural Haematoma (IMH)

Intramural haematoma (IMH) = contained haemorrhage in the aortic wall usually due to vasa vasorum bleeding or micro-intimal tears (not visualised on standard imaging examinations), with separation of parts of the aortic media. The micro-intimal tears would infer a possible common IMH and AAD pathophysiology, the difference being the absence of a large enough re-entrant tear to preserve the patency of the false lumen (thrombus formation due to stagnation leading to outward bulging of the outer aortic wall and a relatively normal appearing aortic lumen).

IMH is typically seen in elderly hypertensive patients and after blunt chest trauma. The natural history of IMH is variable. Less than 10% of IMH resolve spontaneously, whereas 16-47% progress to aortic dissection (AD) if the intimal layer ruptures and creates an entry tear.

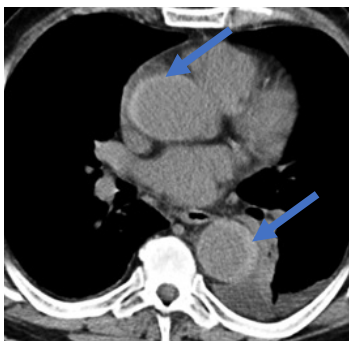


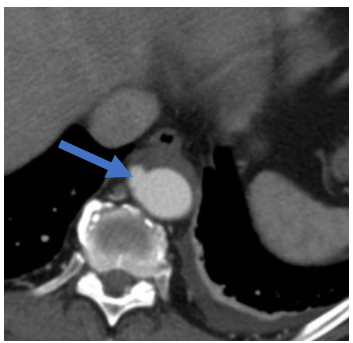
Schematic representation of IMH.



Wall haematoma density higher than lumen density (non-enhanced CT).

Wall haematoma on contrast-enhanced CT.



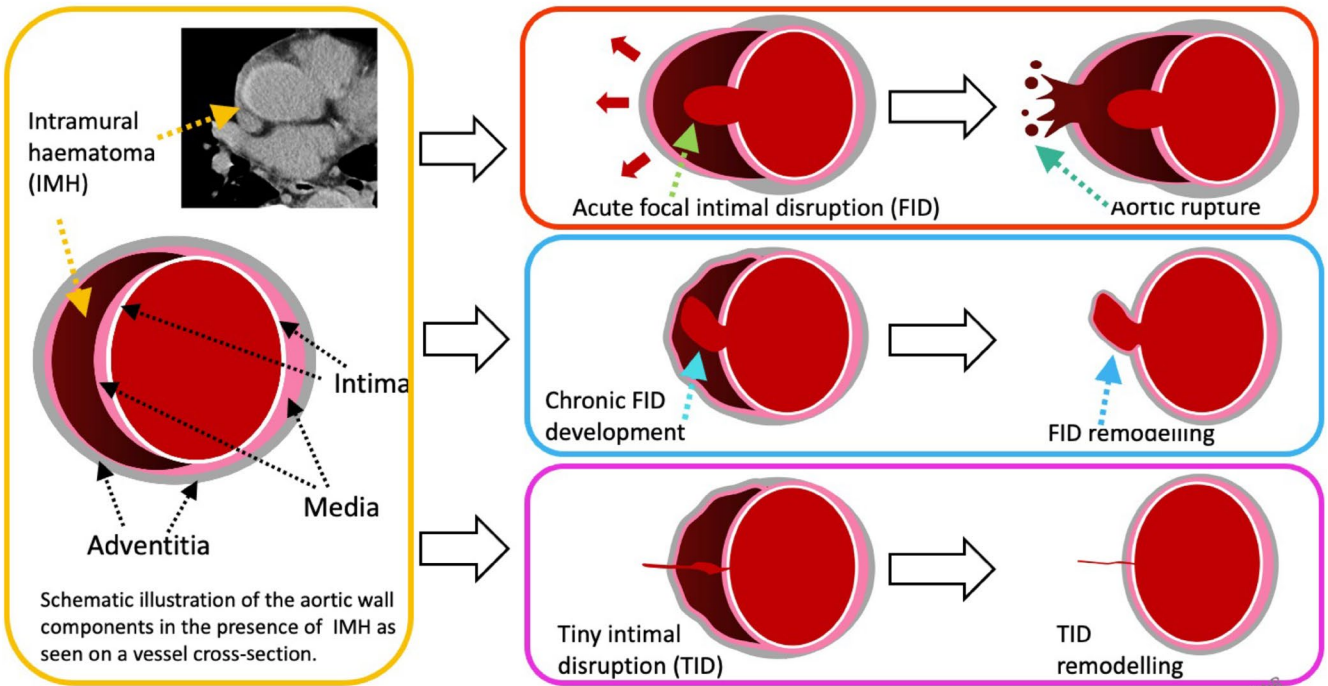


Can be caused by ulcer – Can cause secondary ulcer!

/ Interventional Radiology

CHAPTER OUTLINE:

/ IMH and Potential Complications



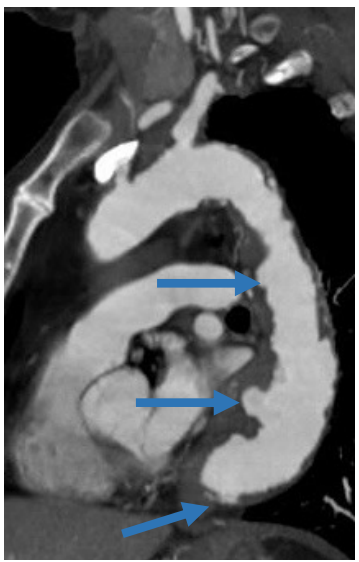
Schematic illustration of the aortic wall components in the presence of IMH as seen on a vessel cross-section.

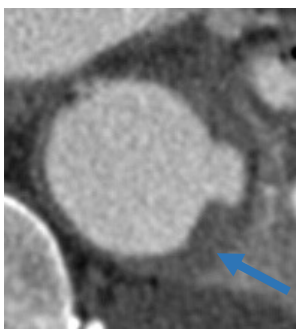
CHAPTER OUTLINE:

/ Penetrating Atherosclerotic Ulcer (PAU)

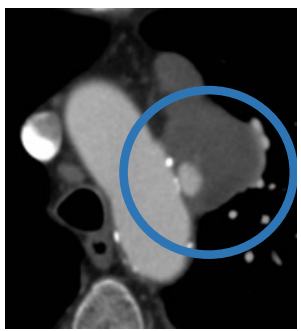
- / Penetrating atherosclerotic ulcer (PAU): penetration through intima and elastic lamina into media.
- / Predilection for the descending thoracic aorta.
- / Predisposing factors: hypertension, smoking, coronary artery disease.

Schematic representation of PAU





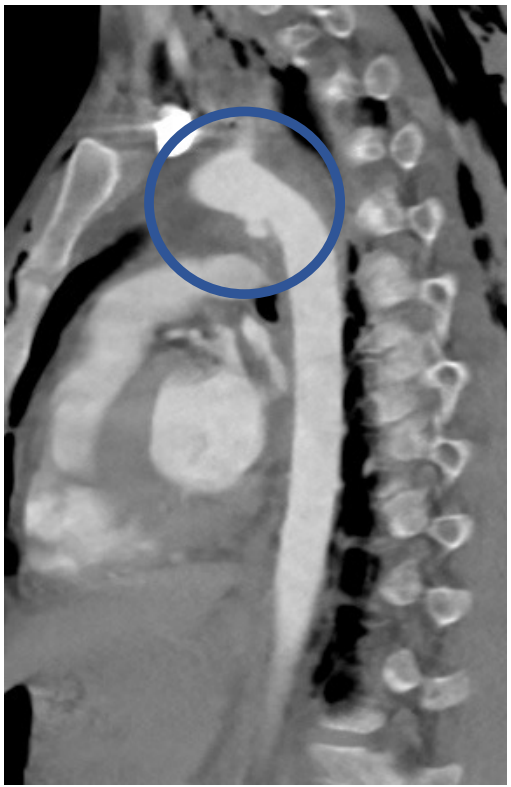
Can cause IMH



Can cause pseudoaneurysm

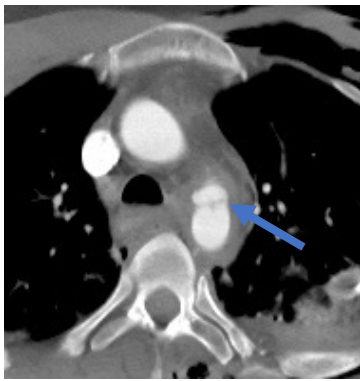
Can cause free rupture

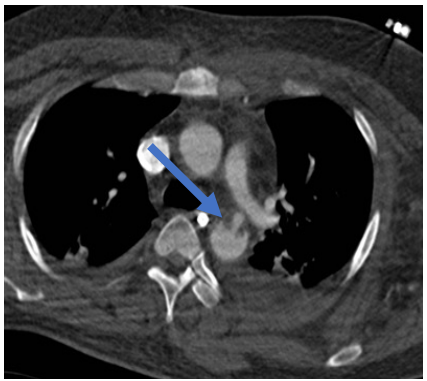
/ Iatrogenic / Traumatic Aortic Injury



Iatrogenic / traumatic aortic injury:

traumatic aortic injury = 2nd most common cause of death in patients with blunt trauma





<!> ATTENTION

- / typical localisation: insertion point of ligamentum arteriosum
- / high risk of rupture > life threatening condition!

/ Acute Aortic Dissection (AAD) Classification According to Localisation

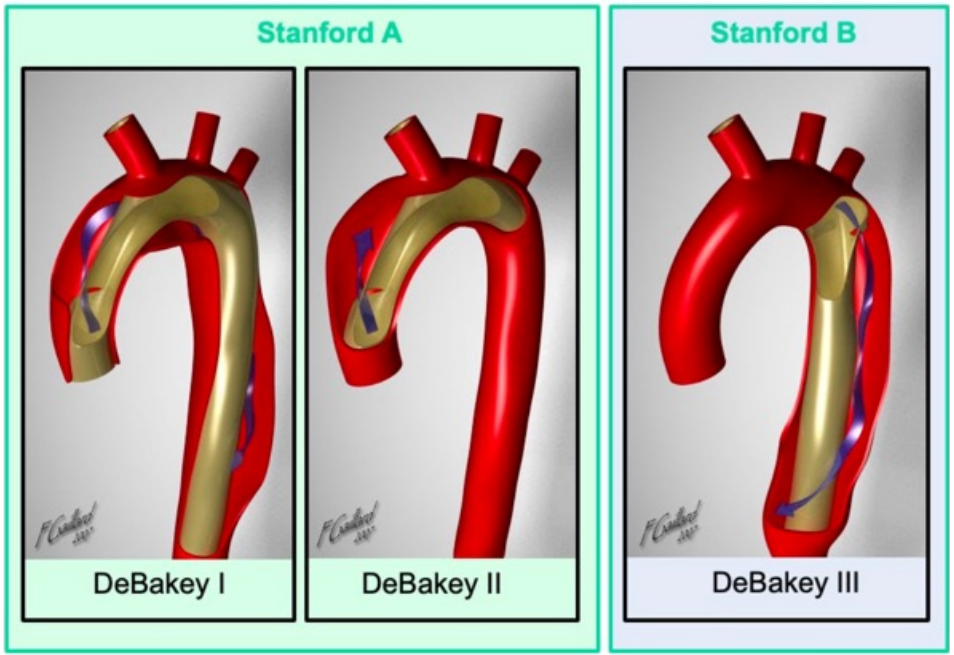
<!> ATTENTION

The most common aortic dissection classification systems are the Standford and the DeBakey classifications.

The **Stanford classification** is based on the **location of the intimal tear**:

/ **Type A:** involves any part of the aorta proximal to the origin of the left subclavian artery (ascending aorta ± descending aorta) **> any dissection involving the ascending aorta!**

/ **Type B:** dissection involving **only** the descending aorta (with proximal tear distal to the origin of left subclavian artery)



<∞> REFERENCE

> see eBook chapter on Vascular Imaging

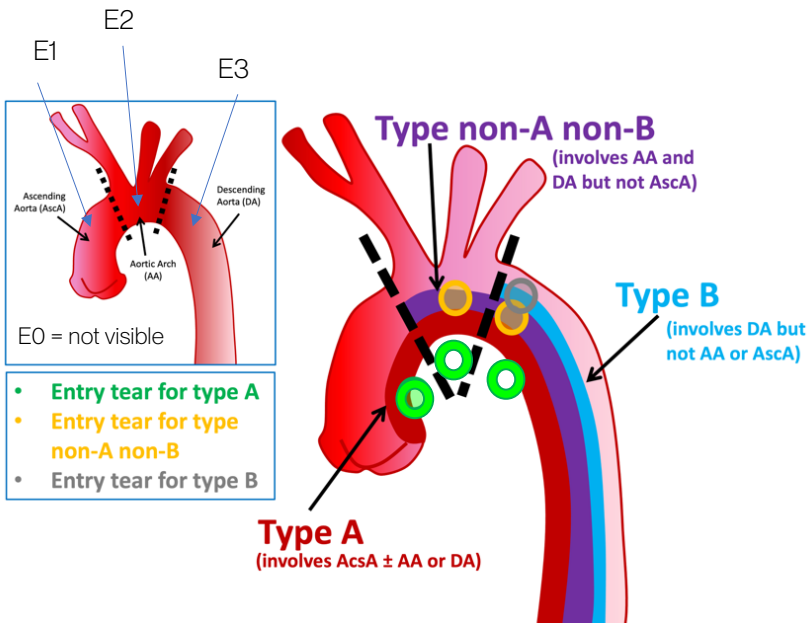
Case courtesy of Frank Gaillard, Radiopaedia.org, rID: 7640

/ Acute Aortic Dissection (AAD) Classification According to Localisation

<!> ATTENTION

Recently, the Stanford classification has been modified to integrate the localisation of the **most proximal entry tear** and the **secondary organ malperfusion** in the **TEM (Type, Entry tear, Malperfusion) classification**.

According to TEM, acute aortic dissection (AAD) is defined based on the localisation of the aortic dissection with the introduction of a new dissection type Stanford type non-A non-B when the dissection extends to the aortic arch but not to the ascending aorta. The entry site which is independent of the AAD type in the TEM classification is described by a number (E0 for no entry tear visible, E1, E2 or E3 according to its localisation). The malperfusion is noted as M0 (no malperfusion), M1 (coronary malperfusion), M2 (supraaortic malperfusion), M3 (visceral malperfusion) completed by the sign + or – if clinical symptoms are present.



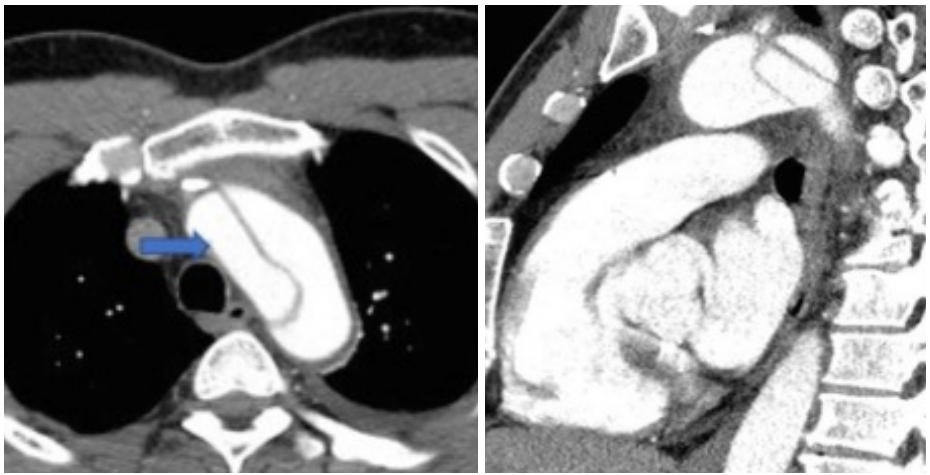
<∞> REFERENCE

Authors/Task Force Members; Czerny M, Grabenwöger M, Berger T, Aboyans V, Della Corte A, Chen EP, Desai ND, Dumfarth J, Elefteriades JA, Etz CD, Kim KM, Kreibich M, Lescan M, Di Marco L, Martens A, Mestres CA, Milojevic M, Nienaber CA, Piffaretti G, Preventza O, Quintana E, Rylski B, Schlett CL, Schoenhoff F, Trimarchi S, Tsagakis K; EACTS/STS Scientific Document Group; Siepe M, Estrera AL, Bavaria JE, Pacini D, Okita Y, Evangelista A, Harrington KB, Kachroo P, Hughes GC. EACTS/STS Guidelines for Diagnosing and Treating Acute and Chronic Syndromes of the Aortic Organ. Ann Thorac Surg. 2024 Jul;118(1):5-115. doi: 10.1016/j.athoracsur.2024.01.021. Epub 2024 Feb 26. PMID: 38416090.

/ Acute Aortic Dissection (AAD) Classification According to Localisation

<!> ATTENTION

According to the 2024 EACTS/STS Guidelines, type A AAD should be treated by surgery, most type B by optimal medical therapy (OMT) and type B with high risk features or type nonA-nonB by a combination of OMT, surgery or endovascular treatment according to the patient condition.



Pre-operative CT images of a non-A non-B aortic dissection case contained in the aortic arch, which was surgically managed. A: Axial view, blue arrow shows the true lumen; B: Sagittal view.

Figure from: Christodoulou KC, Karangelis D, Efenti GM, et al. Current knowledge and contemporary management of non-A non-B aortic dissections. World J Cardiol. 2023 May 26;15(5):244-252. doi: 10.4330/wjc.v15.i5.244.

<∞> REFERENCE

Authors/Task Force Members; Czerny M, Grabenwöger M, Berger T, Aboyans V, Della Corte A, Chen EP, Desai ND, Dumfarth J, Elefteriades JA, Etz CD, Kim KM, Kreibich M, Lescan M, Di Marco L, Martens A, Mestres CA, Milojevic M, Nienaber CA, Piffaretti G, Preventza O, Quintana E, Rylski B, Schlett CL, Schoenhoff F, Trimarchi S, Tsagakis K; EACTS/STS Scientific Document Group; Siepe M, Estrera AL, Bavaria JE, Pacini D, Okita Y, Evangelista A, Harrington KB, Kachroo P, Hughes GC. EACTS/STS Guidelines for Diagnosing and Treating Acute and Chronic Syndromes of the Aortic Organ. Ann Thorac Surg. 2024 Jul;118(1):5-115. doi: 10.1016/j.athoracsur.2024.01.021. Epub 2024 Feb 26. PMID: 38416090.

/ Acute Aortic Dissection (AAD) Treatment

Substantial advancements in endovascular technology (i.e., availability of percutaneous closure devices and lower-profile endovascular stent grafts), have rendered US-guided percutaneous access and closure more practicable.

These advancements have resulted in:

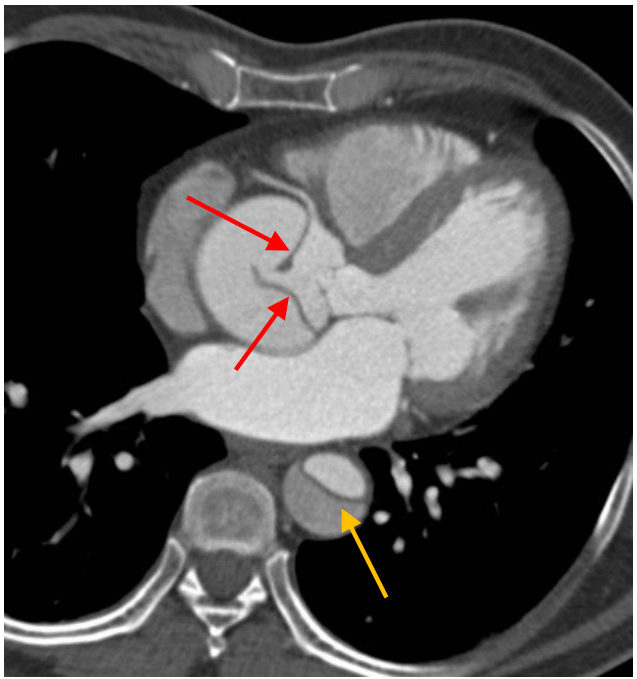
- / improved patient outcomes
- / reduced operative time
- / minimised blood loss
- / reduced pain and accelerated groin healing
- / and a transformative impact on treatment strategies employed by Interventional radiologists for patients with aortic diseases requiring intervention

<!> ATTENTION

The entry tear matters!

- / **Type A:** acute treatment mandatory!
  - / 5% mortality/h in the first 48 h
- / **Type B:** endovascular treatment in the subacute setting
- / The treatment aim in aortic dissection is always **closure of the primary entry tear** – therefore, identification and localisation of the entry tear is of outmost importance!

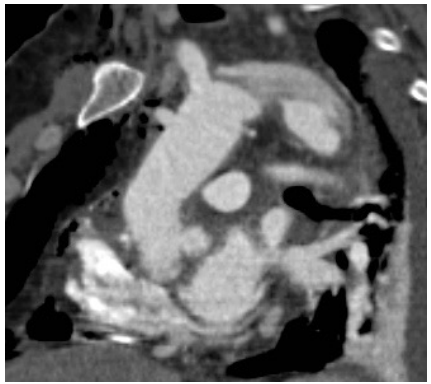
/ Acute Aortic Dissection (AAD) Treatment: Stanford Type A Dissection



Type A dissection with intimal flap in the ascending aorta (red arrows) & descending aorta (yellow arrow)

1

Standard procedure: replacement of the ascending aorta



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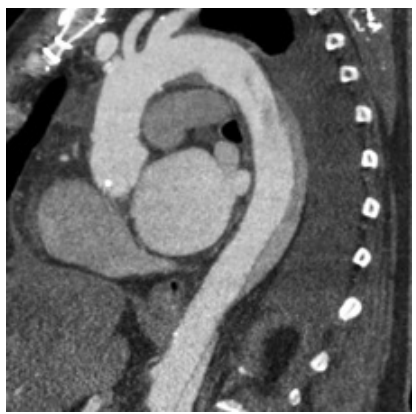


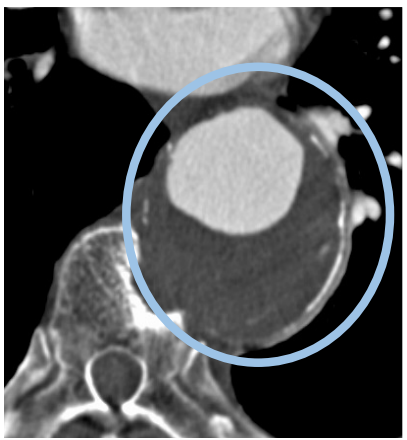
Typically remaining chronic type B dissection after treatment of type A

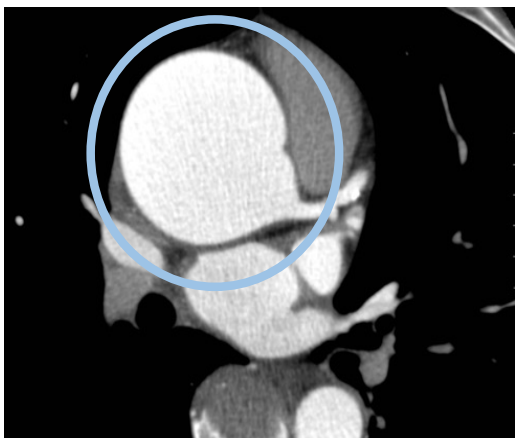
CHAPTER OUTLINE:

/ Aortic Aneurysm (AA) Incidence, Definition and Pathophysiology

Aortic aneurysm (AA)

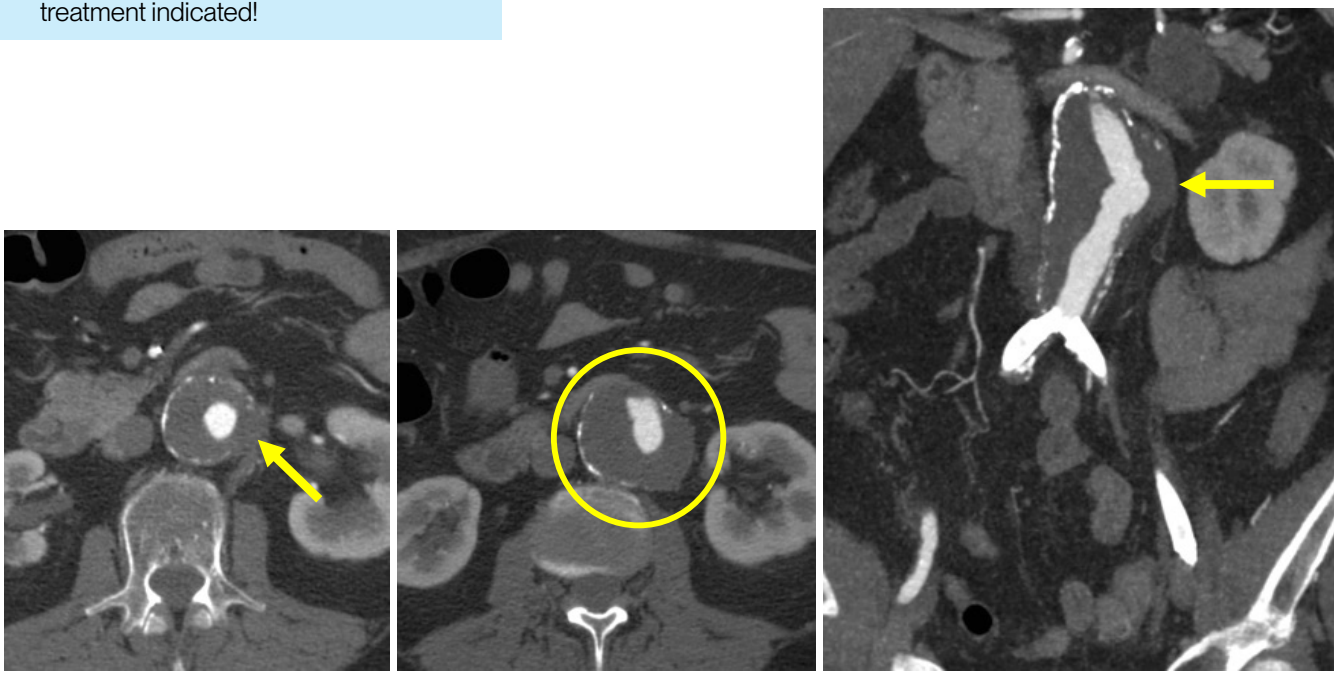
- = well-defined dilatation of the aorta involving all wall layers (different from pseudoaneurysm)
- dilatation for more than 1.5 times of nominal aortic diameter
  - thoracic aorta > diameter > 4 cm
  - abdominal aorta > diameter > 3.5 cm





Aortic aneurysm (AA) – pending rupture:

/ unsharp contour of the aneurysm, discontinuity in calcification – acute treatment indicated!



CHAPTER OUTLINE:

/ Aortic Aneurysm (AA) Treatment

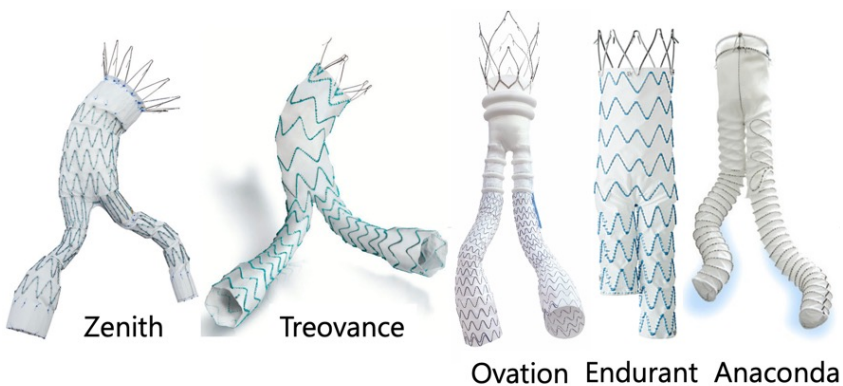
Endovascular treatment is widely used in the repair of aortic aneurysms, leveraging contiguous nonaneurysmal aortic or iliac segments for fixation of endovascular stent grafts to exclude blood flow from the aneurysmal sac.

One of the **limitations of endografting** is the occurrence of endoleaks resulting in blood flow persisting outside the graft and within the aneurysm sac, thus preventing its complete thrombosis. Patients with endovascular grafts necessitate lifelong surveillance imaging to proactively assess for the development of endoleaks or graft migration.

Stent grafts for the treatment of aneurysms have been approved for the ascending aorta, aortic arch and thoracoabdominal aorta having promising results especially in selected, high-risk patients.

<!> ATTENTION

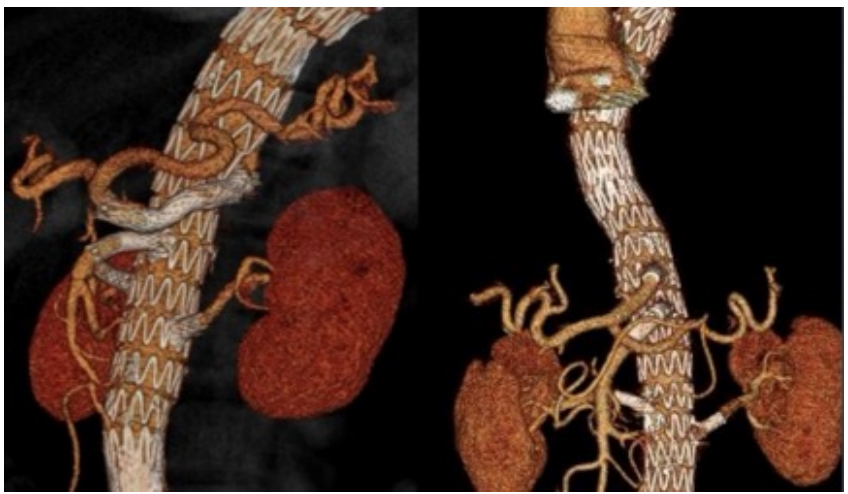
Stent grafts are used to treat aortic aneurysms. The stent graft is typically a tube made of leakproof polyester with a metal mesh underneath. Stent grafts are used in larger arteries, such as the aorta and provide a stable channel for the blood to flow through.



Many different endovascular devices (stentgrafts) are currently available.

Endovascular aneurysm repair (EVAR) has expanded treatment options for **Abdominal Aortic Aneurysms (AAA)**, especially for patients who are ineligible for open surgery due to cardiopulmonary or renal comorbidities.

- For ruptured AAAs with favourable anatomy, EVAR with "rupture protocols" (e.g., permissive hypotension, endovascular balloon occlusion) is preferred over open repair to reduce morbidity and mortality risks.
- EVAR is particularly advantageous for moderate- to high-risk surgical candidates, which have a high risk for Immediate postoperative complications (myocardial infarction, acute kidney injury and the need for dialysis).



Branched and fenestrated devices for arch ± thoraco-abdominal AA.

For patients with ruptured descending **thoracic aortic aneurysms (TAA)** who are anatomic candidates, **thoracic endovascular aortic repair (TEVAR)** is recommended over open repair due to lower perioperative mortality and morbidity.

- TEVAR may involve intentional coverage of the left subclavian artery, celiac artery or both to expand the landing zone, but this carries risks of stroke, spinal cord ischaemia and fatal visceral ischaemia.

CHAPTER OUTLINE:

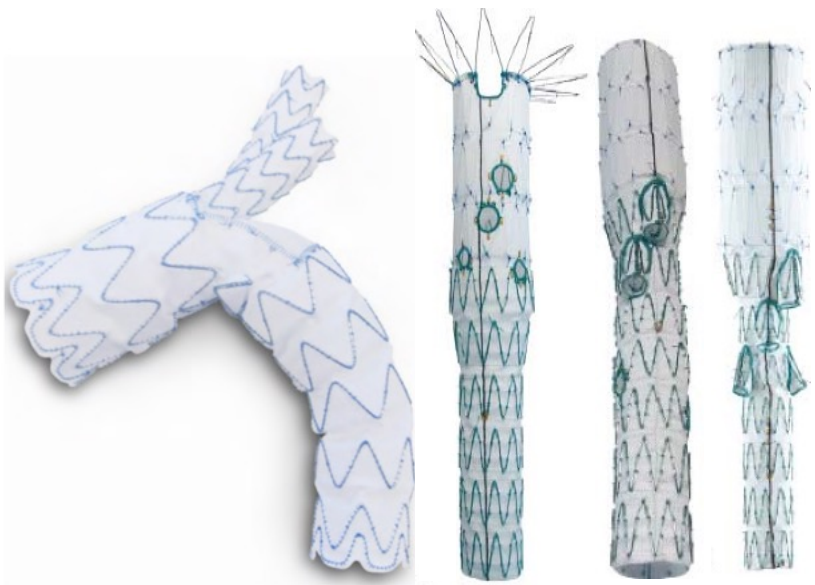
Thoracoabdominal aortic aneurysms (TAAAs) extend from the thoracic into the abdominal aorta. Endovascular repair with fenestrated or branched stent grafts is an option for stable patients in specialised centres, though manufacturing these grafts can take weeks.

Despite increasing use, long-term outcomes of endovascular repairs are limited and open repair remains preferred.

Both methods risk spinal cord ischaemia, causing paraparesis or paraplegia.

For patients with renal or visceral artery stenoses, perfusion can be improved through bypass, endarterectomy or angioplasty with stent placement.

Open repair is recommended for those with connective tissue disorders and intact TAAAs.



Branched and fenestrated devices for arch ± thoraco-abdominal AA.

/ Interventional Radiology

CHAPTER OUTLINE:

>|< COMPARE

ADVANTAGES:

+ Minimally invasive procedure
+ Minimised blood loss
+ Reduced procedure time
+ Lower perioperative morbidity and mortality rate
+ Shorter length of postoperative stay in hospital

DISADVANTAGES:

– Life-long imaging follow-up required
– Potential need for re-interventions
– Long-term durability of graft material not known yet

Conclusions

/ A decade ago, endoluminal therapy supplemented rather than replaced open repair of aortic pathologies due to limited device availability.
/ Since its introduction, TEVAR has seen widespread adoption, with EVAR surpassing open abdominal aorta repair in some centres.
/ Ascending aorta TEVAR is now a promising, life-saving option for select patients.
/ Advances in stent-graft design, enhanced vascular imaging technology and better operator training are expected to reduce re-interventions and improve long-term outcomes.

/ Chronic Peripheral Arterial (Occlusive) Disease (PAD)

/ Incidence, Definition and Pathophysiology

Peripheral arterial disease (PAD) = chronic arterial pathology causing reduced blood flow to the extremities (typically lower limbs).

- The main cause of PAD is atherosclerosis affecting the abdominal aorta, iliac, femoropopliteal and infrapopliteal arteries and this is why it usually affects persons over 40 years of age.
- Risk factors include diabetes mellitus (DM), smoking, hypercholesterolemia, chronic kidney disease, hypertension, increasing age and family history.
- Over 200 million people worldwide are affected by PAD and the incidence is 20% for those > 70 years.

Digital subtraction angiography (DSA) in 3 different patients with multiple stenoses and occlusions due to PAD.

PAD can be asymptomatic or present with symptoms like thigh or calf pain during walking (**intermittent claudication, IC**) and in advanced stages, ischaemic rest pain and tissue loss (**chronic limb-threatening ischaemia, CLTI**). CLTI progresses in about 1-2% of PAD patients and it is a serious condition requiring immediate revascularisation and wound care to prevent major amputations.

Treatment for IC includes medical therapy to reduce risk factors (e.g., smoking cessation, diabetes control, antihypertensives, statins) and supervised exercise, as well as revascularisation through endovascular or open surgical techniques. These treatments aim to lower cardiovascular risk and enhance walking capability.

The diagnosis of PAD involves patient history, physical exam, ankle-brachial index (ABI) tests and radiological imaging. Ischaemic wounds are inspected, with typical IC symptoms. Ischaemic rest pain is chronic, worsens at night and is unresponsive to standard pain medication. Peripheral pulses are diminished or absent and ABI is abnormal (< 90 mmHg).

<!> ATTENTION

Duplex ultrasound (DUS) is the first-line imaging tool, with CT- or MR-angiography used for confirmation and to determine revascularisation options.

Diabetic male smoker with severe PAD with dorsal foot ulceration chronically open since nearly 2 years.

Image reproduced from: https://en.wikipedia.org/wiki/Arterial_insufficiency_ulcer#/media/File:Arterial_ulcer_peripheral_vascular_disease.jpg

Patient with type 2 diabetes and heart failure. The second toe has a large ischaemic ulcer. The first toe has a small one.

Image reproduced from: https://en.wikipedia.org/wiki/Arterial_insufficiency_ulcer#/media/File:Two_ischaemic_ulcers_on_the_foot_of_an_individual_with_type_2_diabetes.jpg

Interventional Radiology

CHAPTER OUTLINE:

/ Endovascular Treatment Options

Angioplasty involves local anaesthesia, mild sedation and US-guidance to access the arterial system via the femoral, brachial or radial artery using small needles and sheaths (18-21G needles, 5-7Fr sheaths, < 2mm in diameter).

Plain balloon angioplasty (PBA) also called **plain old balloon angioplasty (POBA)**, which uses a balloon catheter over a guide-wire, is the gold standard for endovascular treatment in patients with IC, particularly for femoropopliteal and infrapopliteal stenosis.

However, POBA can result in suboptimal outcomes due to inadequate expansion, elastic recoil, flow-limiting dissection or mid-term restenosis caused by neointimal hyperplasia, leading to symptom relapse.

<∞> REFERENCE

> see also eBook chapter Vascular Imaging

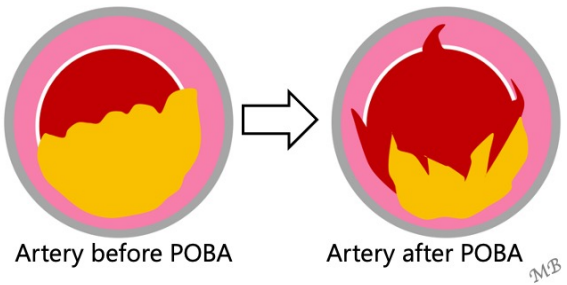


Figure courtesy: Dr. Matthieu Papillard, Unit of Abdominal and Interventional Radiology, Geneva University Hospitals, Geneva, Switzerland

CHAPTER OUTLINE:

Stent Placement is used to address issues of POBA failure, improving immediate angioplasty outcomes, patency and reducing reinterventions, especially in the iliac arteries (**Figure 1**).

Figure 2 illustrates how the procedure is carried out.

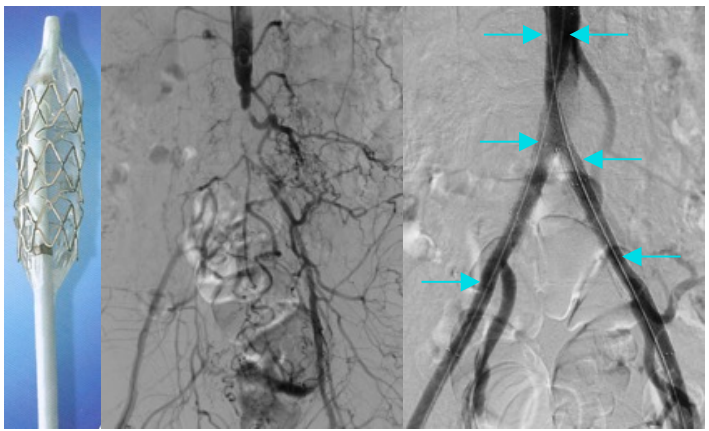


Figure 1. Iliac bilateral **"kissing" stenting** (blue arrows) for bilateral chronic common iliac artery occlusion. Note multiple arterial collaterals due to chronic PAD in the middle image.

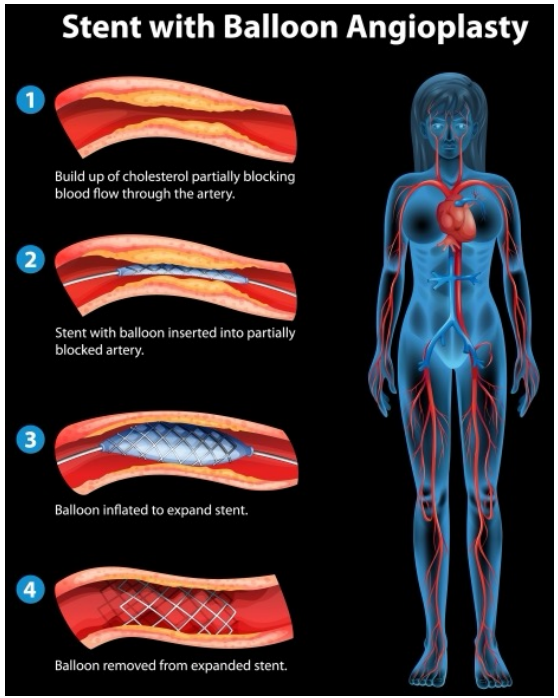


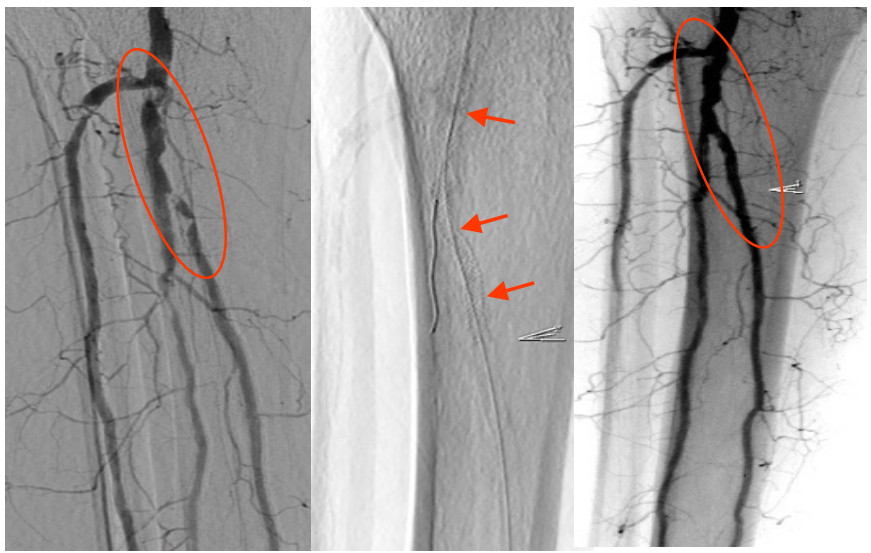
Figure 2. Schematic drawing illustrating the stent with PBA procedure.

Image reproduced from:Image by brgfx on Freepik

CHAPTER OUTLINE:

Drug-eluting stents (DES) and **drug-coated balloons (DCB)** are coated with anti-restenotic drugs like paclitaxel and sirolimus. These technologies inhibit neointimal hyperplasia, reducing the need for re-interventions. They have shown superior outcomes in treating both femoropopliteal and infrapopliteal lesions.

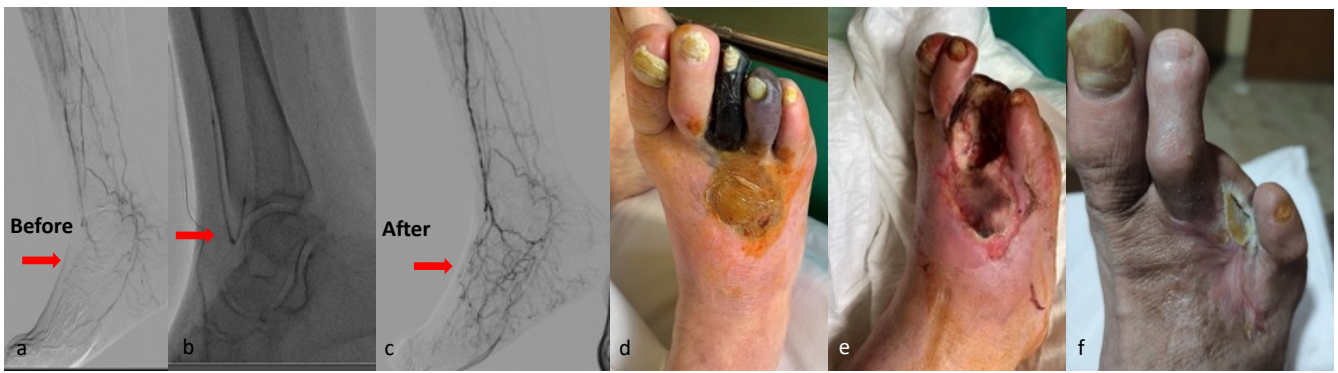
Percutaneous atherectomy involves percutaneous atherosclerotic plaque removal with endovascular devices like directional, rotational or orbital atherectomy. This method excises the plaque instead of just dilating it, being particularly effective in calcified lesions resistant to dilation. Despite lacking data on superior outcomes compared to POBA or stenting, percutaneous atherectomy is more aggressively used in CLTI patients to achieve optimal luminal gain and enhance foot blood perfusion even in small below-the-knee arteries.



Infrapopliteal bifurcation DES. A image before the procedure shows multiple stenoses. Image during the procedure shows the DES. Control DSA after the procedure with DES in place.

/ Interventional Radiology

Endovascular treatment options have similar technical (80-100%) and clinical success rates as open surgical procedures in appropriately selected patients.



67-year-old diabetic patient with infected wet gangrene of the left foot (3rd and 4rth toe and metatarsal). (**a**) Angiographic image demonstrating extensive disease of the anterior tibial artery (ATA), occlusion of the pedal artery and complete absence of the anterior pedal arch (arrow). (**b**) Balloon angioplasty of the ATA and the proximal pedal artery with retrograde angioplasty of the distal peroneal artery (arrow). (**c**) Final angiogram demonstrating the recanalisation of the ATA and the improvement of the perfusion of the anterior pedal arch (arrow). (**d**) Pre-angioplasty image of the foot, (**e**) minor amputation following revascularization and (**f**) complete wound healing at 3 months follow-up.

CHAPTER OUTLINE:

<!> ATTENTION

ADVANTAGES OF IR FOR PAD AND CLTI

+ Can be performed under local anaesthesia, using a small-diameter access, most cases as day cases.
+ Less morbidity and mortality compared to open surgery.
+ Can be repeated multiple times if needed and future open surgical procedures are not precluded if clinical relapse.
+ Revascularisation of multiple arteries and pedal arch treatment not amenable to open surgery
+ Offer technical (80-100%) and clinical success rates comparable to open surgery in appropriately selected patients.

Conclusions

/ Minimally invasive endovascular treatment options for PAD include mainly balloon angioplasty and stenting and provide satisfactory technical and clinical success rates, with reduced morbidity and mortality rates compared to standard open surgical procedures.

/ Clinical relapse and re-interventions can occur due to restenosis. Various devices such as DES, PCB and atherectomy are currently being investigated to improve long-term clinical outcomes.

/ Definition of the Clinical Problem and Imaging Assessment

Arterial occlusions pose a significant threat to vascular integrity by disrupting blood flow and leading to a cascade of debilitating consequences, thereby resulting in severe pain, tissue ischaemia and potentially leading to organ loss or death.

Causes include atherosclerosis, plaque rupture, thrombus formation (either in situ or as emboli) or arterial dissection.

The role of IR in treating acute arterial occlusions of the superior mesenteric artery (SMA) and limb perfusion is illustrated on the next pages.

<!> ATTENTION

Computed tomography (CT) and CT angiography (CTA) are the gold standard imaging techniques for evaluating suspected acute arterial occlusions.

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The **role of IR** in **acute arterial occlusions** continues to expand as new minimally invasive techniques and technologies are developed. From conventional balloon angioplasty and stenting to combined pharmaceutical and mechanical thrombus lysis-maceration-aspiration techniques, IR offers a valuable alternative to surgical interventions, providing patients with effective and less invasive treatment options for a broad spectrum of vascular conditions.

/ Superior Mesenteric Artery (SMA) Occlusion

Diagnosis

SMA occlusion may result from either **in-situ thrombosis** of the vessel due to underlying atherosclerotic disease or **embolic occlusion** from a distal source (e.g., atrial fibrillation). Less common causes include vasculitis or aortic dissection.

Thrombotic occlusions usually affect the more **proximal SMA** segments, leading to more extensive intestinal infarction, while embolic occlusions may lodge more distally, depending on the embolus's size. The **extent of intestinal injury** is directly correlated with the amount of affected small bowel, with more proximal occlusions resulting in more severe injury. Other factors, including the duration of ischaemia, hypotension and collateral circulation presence, also impact injury severity.

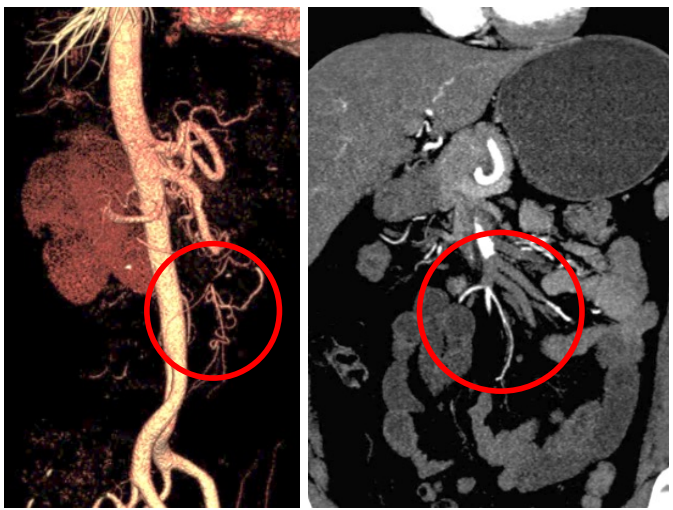
The most common **symptom** is moderate to severe, diffuse and constant abdominal pain, often disproportionate to physical exam findings. Other symptoms may include nausea, vomiting, diarrhoea and rectal bleeding.

Prompt diagnosis is critical due to the variability and non-specificity of clinical presentation. Rapid clinical deterioration is common and if peritoneal signs are present, bowel infarction should be presumed, necessitating emergency laparotomy for necrotic bowel resection.

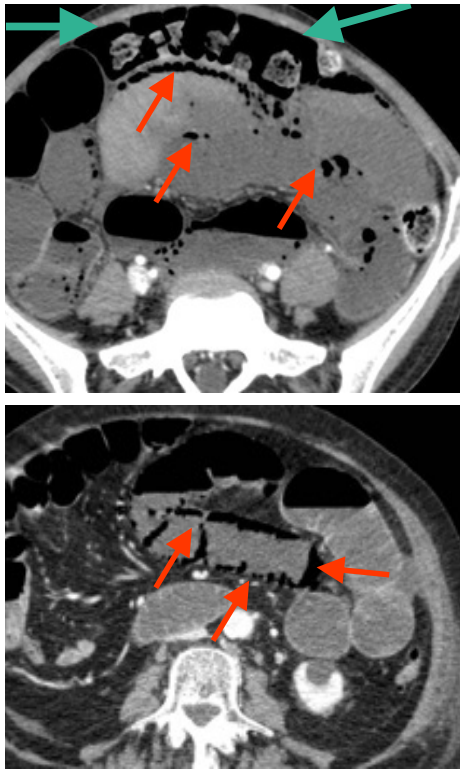
In **suspected acute bowel ischaemia** due to SMA occlusion, CT with CTA is the evaluation method of choice.

In **suspected acute bowel ischaemia** due to SMA occlusion, CTA enables rapid image acquisition, direct visualisation of arterial occlusion, detailed assessment of vascular anatomy and associated ischaemic damage of the affected bowel.

Key findings such as **pneumoperitoneum** (free air in the abdominal cavity), **pneumatosis** (air bubbles within the bowel wall), portal venous gas and bowel wall thickening are critical for guiding appropriate therapeutic interventions.



CTA (3D surface rendering, left and 2D coronal reconstruction, right) demonstrates acute occlusion of the SMA.



CT reveals acute bowel ischaemia leading to paralysis.

CHAPTER OUTLINE:

/ Management of Acute Arterial Occlusion

/ Acute Limb Ischaemia (ALI)

In suspected Acute Limb Ischaemia (ALI), evaluation begins with a bilateral pulse exam using manual palpation.

If a deficient pulse is detected, a continuous wave Doppler probe can be used to assess arterial flow presence and character, which helps determine the level of arterial occlusion.

A normal arterial flow is indicated by a **triphasic flow** pattern, while pre-occlusive flow shows an **attenuated systolic peak and absent diastolic flow. No flow** is typically found distal to an arterial occlusion and **continuous systolic-diastolic flow** usually indicates an older occlusion compensated through collateral circulation.

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Duplex Ultrasound (DUS) is the **primary imaging method for ALI** due to its wide availability, non-invasive nature, lack of radiation, relative affordability and quick performance.

DUS can accurately determine the **anatomic location and severity of obstruction**, providing essential haemodynamic information and aiding in monitoring revascularisation outcomes.

When an occlusion is detected, **confirmation with CT angiography (CTA)** is usually performed as it is faster and more accessible.

/ Endovascular Treatment of Acute SMA Occlusion

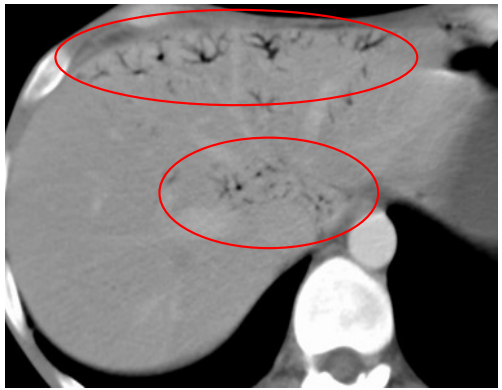
For patients with documented mesenteric thrombosis without peritoneal signs, minimally invasive treatments may be considered.

Catheter-directed thrombolytic infusion involves placing an infusion catheter into the thrombosed SMA segment and infusing tissue plasminogen activator (tPA) over 12-24 hours to dissolve the clot. This method requires weighing the benefits of revascularisation against the time required for therapy.

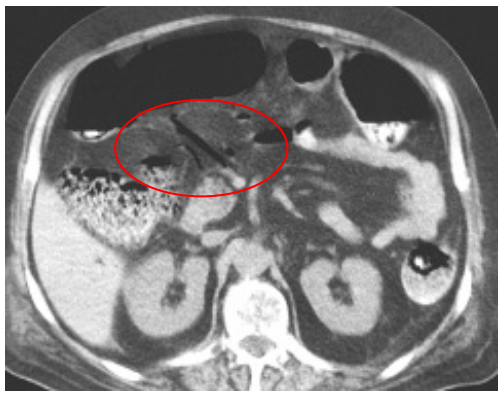
Catheter-directed thrombectomy using small intravascular thrombectomy devices along with tPA offers a shorter treatment duration.

Stent placement is also a viable option, while **intraluminal vasodilators and papaverine** can be administered to manage vasospasm, which often accompanies thrombotic events.

Despite these treatments, acute SMA occlusion remains a severe condition with high mortality.



Gas within the portal veins



Gas within the mesenteric veins

Acute Limb Ischaemia (ALI) is a vascular emergency with **high mortality and amputation rates**, characterised by a sudden decrease in limb perfusion within two weeks after an inciting event, threatening limb viability.

Unlike **critical limb ischaemia (CLI)**, where collateral blood supply is often present, ALI presents an abrupt onset with severe symptoms, as there is insufficient time for new blood vessel growth to compensate for the lost perfusion.

Patients with a history of PAD may have established collateral circulation, resulting in variable symptom presentation and severity.

ALI can affect any peripheral artery, but non-traumatic ischaemia of the lower extremities is more common. The **distal superficial femoral artery** is the typical area affected, leading to claudication and ischaemia in the calf muscle area. The sudden onset of ischaemia severely impacts all metabolically active tissues within the limb, including skin, muscles and nerves. **Symptoms** range from new or worsening intermittent claudication (pain in the involved muscle group which aggravates on exertion) to severe rest pain, paresthesia, muscle weakness, paralysis and even gangrene.

Prompt diagnosis and treatment are crucial to prevent irreversible damage and improve patient outcomes.

<!> ATTENTION

The classical presentation of ALI includes the “6 Ps”: pallor, pain, paresthesia, paralysis, pulse deficit and poikilothermia.

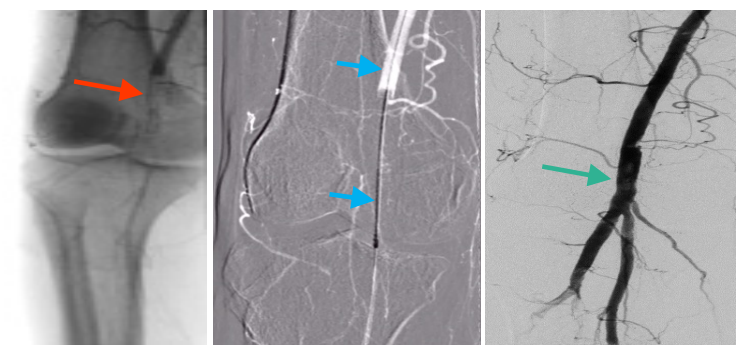
/ Interventional Radiology

CHAPTER OUTLINE:

Current endovascular treatments for ALI include catheter-directed thrombolysis (CDT), percutaneous mechanical/pharmacomechanical thrombectomy (MT/PMT) and vacuum-assisted thrombectomy or percutaneous thromboaspiration (VAT or PAT). Thrombolytic agents are directly infused into the thrombus through a catheter with multiple side-holes, ensuring concentrated delivery and reducing systemic drug exposure. Once flow is restored, underlying lesions are addressed through interventional or surgical methods.

Percutaneous thrombus removal is often the first-line therapy for ALI, used either as an adjunct or stand-alone option to minimise or eliminate the need for intra-arterial thrombolytics. In PMT, thrombolytics are administered via pulse-spray combined with mechanical thrombectomy to break up and remove the clot. VAT employs continuous vacuum suction to aspirate the clot, while percutaneous thromboaspiration uses large lumen catheters connected to a syringe for manual aspiration, offering a lower-cost, rapid technique.

A newer technique, **US-accelerated thrombolysis (USAT)**, uses low-frequency sound waves to accelerate thrombolysis by mechanically fragmenting clots and enhancing enzymatic fibrinolysis. However, well-organised thrombi remain challenging for most percutaneous thrombectomy devices. Therefore, devices combining fragment aspiration with pulse spray thrombolysis using a high-pressure jet of saline are preferred, as they simultaneously aspirate the thrombus and administer thrombolytic agents.



Mechanical Aspiration Thrombectomy System (middle image) in ALI case with popliteal thrombus aspiration (left image) and blood flow restoration (right image).

A significant concern associated with PTDs is the risk of distal emboli, which can potentially lead to limb loss.

Combination of endo-techniques (including stenting) is frequently required.

Patients exhibiting paralysis, absent pain and inaudible arterial and venous pulses, are considered to have sustained irreversible limb damage, necessitating surgical intervention (amputation).

Complications rates among ALI patients are high, despite early revascularisation. After target vessel re-opening, especially in advanced stages of ischaemia, sudden tissue reperfusion can lead to the development of compartment syndrome*, to a systemic acid–base disorder and impaired cardiopulmonary function.

Reperfusion injury makes prompt recognition and treatment just as important as the initial diagnosis of acute arterial occlusion.

*absolute contraindication to thrombolysis and other revascularisation techniques should be applied

Conclusions

- Arterial acute occlusions represent a significant medical challenge, with the potential to cause severe complications, including acute kidney injury, bowel as well as limb ischaemia.
- Surgical interventions have been the mainstay of treatment for arterial occlusions. However, IR has emerged as a minimally invasive and increasingly preferred approach for managing these conditions.

/ Venous Interventions

/ Venous Interventions for Acute and Chronic Occlusions

Venous thrombosis, whether acute or chronic, occurs due to **Virchow's triad**: venous stasis, endothelial injury and hypercoagulable states. Hospitalised patients are at higher risk for acute venous occlusions due to factors such as immobility, surgery, trauma or malignancy. Chronic **venous occlusion**, resulting from unresolved acute thrombosis, leads to long-term impaired venous circulation and forms a separate disease entity.

The role of interventional radiology (IR) in diagnosing and managing occlusive venous disease is critical.

Deep Vein Thrombosis (DVT) typically presents with localised pain, swelling and sometimes erythema. DVT complications can include pulmonary emboli.

Timely recognition and prompt diagnosis of DVT with imaging improves prognosis and patient outcomes.

<!> ATTENTION

Duplex US with high sensitivity (100%) and specificity (98%), is the first-line diagnostic tool.

Computed tomography venography (CTV) and magnetic resonance venography (MRV) are used when duplex findings are unclear or when detailed venous anatomical mapping is necessary for further treatment planning.

CHAPTER OUTLINE:

The role of IR in managing DVT is pivotal, especially in complex or refractory cases where standard anticoagulation is insufficient. IR provides advanced treatment options such as catheter-directed thrombolysis, mechanical thrombectomy and the placement of inferior vena cava (IVC) filters, each with specific indications.

Catheter-Directed Thrombolysis: Thrombolysis aims at dissolving clots to restore blood flow. While traditionally administered systemically, it can also be targeted using catheter-directed techniques. This approach involves the precise delivery of thrombolytic agents directly to the clot through a catheter, often in acute cases but also applicable to chronic occlusions. It is frequently combined with mechanical thrombectomy for enhanced efficacy.

Mechanical Thrombectomy: This technique involves the physical removal of clots using specialised devices introduced through percutaneous access. Thrombectomy devices vary widely but generally use two main technologies: rheolytic systems and fragmentation baskets. Rheolytic devices create a high-pressure jet and vortex to dislodge and remove clots, while fragmentation baskets mechanically break up the clot. The primary goal of thrombectomy is to create channels within chronic occlusions, facilitating subsequent angioplasty and stenting procedures.

By employing these advanced IR techniques, radiologists can offer effective alternatives for managing DVT, particularly in patients who do not respond to conventional treatments.

Inferior Vena Cava (IVC) Filter

For **chronic venous occlusions** in the iliofemoral region or distal IVC or when anticoagulation is contraindicated for pulmonary emboli, placement of an IVC filter is an alternative approach to 'catch' any venous clots, prevent proximal migration into the central venous system and reduce the likelihood of recurrent emboli formation in the pulmonary or arterial circulation (in the presence of shunting).

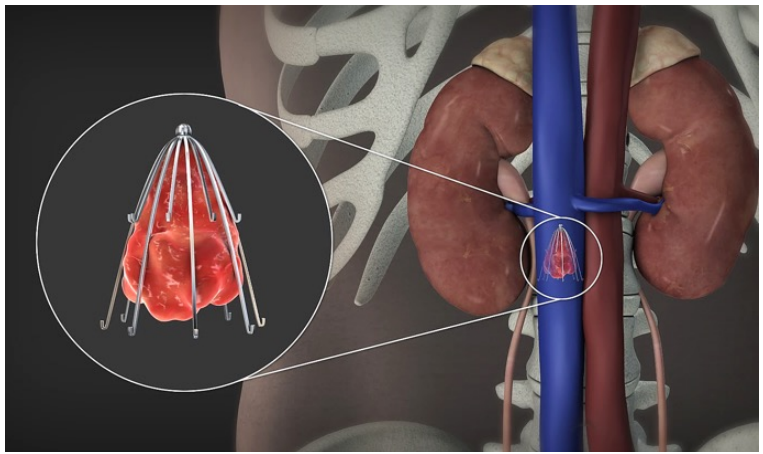
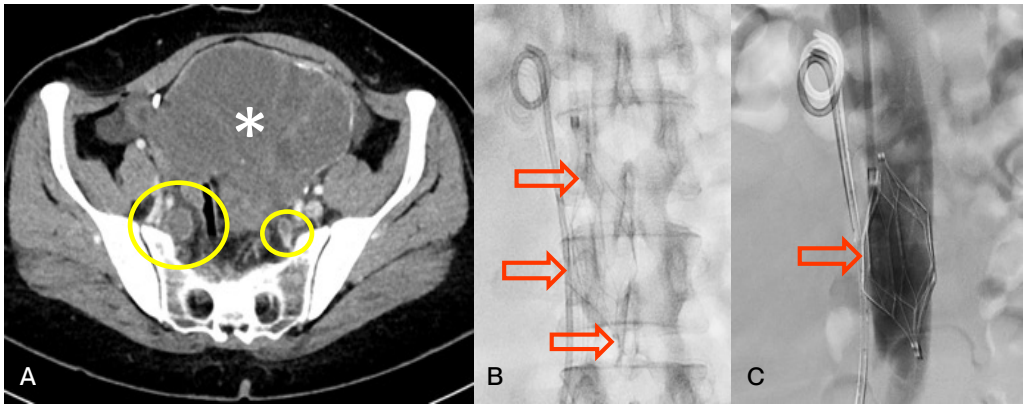


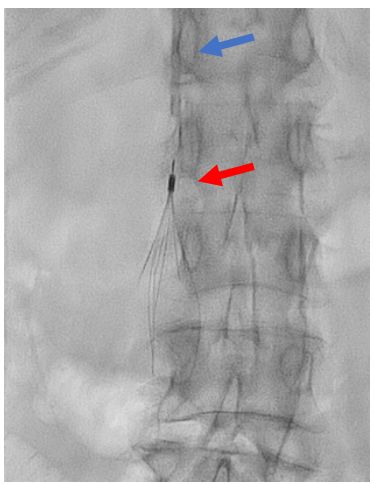
Image above: Illustration of the principle of IVC filters. Reproduced from: https://upload.wikimedia.org/wikipedia/commons/4/42/3D_Medical_Animation_Inferior_Vena_Filter.jpg https://www.scientificanimations.com, CC BY-SA 4.0, via Wikimedia Commons

<!> ATTENTION

Both permanent and retrievable filters carry a significant risk of thrombosis with longer dwell times, therefore retrieval is advised sooner than later.



Deployment of an IVC filter in a patient with a large tumour mass (*) and associated thrombosis (circles) of the iliac veins (**A**). Images **B** and **C** show successful implantation of the IVC filter (block arrows).

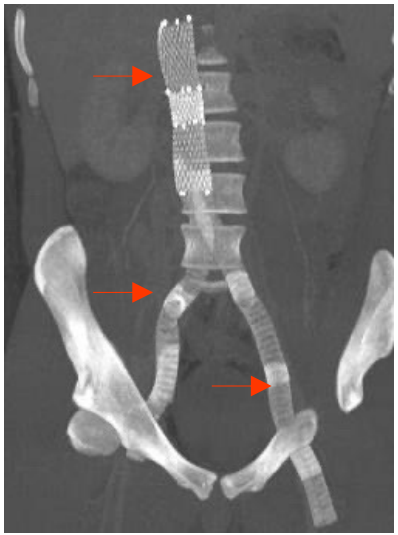


Deployment of an IVC filter (red arrow) via a jugular approach in a patient with pulmonary embolism. Once deployed the catheter (blue arrow) is removed under fluoroscopy.

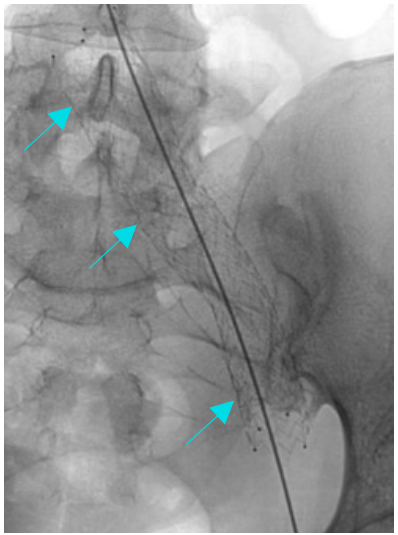
CHAPTER OUTLINE:

Venoplasty and Stenting

As discussed earlier, thrombolysis and mechanical thrombectomy are used to achieve debulking and make the lesion more amenable to stenting. As a general rule, **venoplasty** is used for benign disease or stenoses whilst **stenting** is reserved for malignant disease, however this is a rapidly developing field with the indications for each constantly changing.



3D CT reconstruction of an iliocaval stent.



Example of a venous stent.

Common indications for venoplasty and stenting are superior vena cava obstruction (SVCO) which is often a complication of malignancy or IVC obstruction from expanding thrombi in benign chronic iliofemoral venous occlusions as part of post-thrombotic syndrome.

The medical device industry is constantly developing new stent technologies which are subject of ongoing clinical trials, the efficacy of each varying depending on the treated venous segments. Nevertheless, it is important to distinguish between venoplasty, which is the use of inflatable balloons to widen the lumen of stenosed veins and stenting which is the deployment of mesh-like devices to maintain the patency of the diseased segment and provide structural support.

/ Pulmonary Embolism (PE)

/ Pulmonary Embolism Severity Index

Pulmonary embolism (PE) obstructs blood flow through the pulmonary arteries interfering with cardiopulmonary circulation and gas exchange. The clinical severity of PE depends on factors such as a patient's cardiopulmonary reserve as well as the burden of clot.

In cases of confirmed PE, haemodynamic parameters, cardiac biomarkers, ECG and cardiac echo are used to stratify patients into high, intermediate and low risk groups for early mortality, which determines management:

Low risk PE

- / Haemodynamically stable
- / No evidence of right heart strain
- / PESI* < Class III
- / Negative cardiac troponin (assessment optional)

Intermediate risk PE

- / Haemodynamically stable
- / Evidence of right heart strain
- / PESI* Class III - V
- / Positive cardiac troponin

High risk PE

- / Haemodynamic instability
- / Evidence of right heart strain
- / PESI* Class III - V
- / Positive cardiac troponin

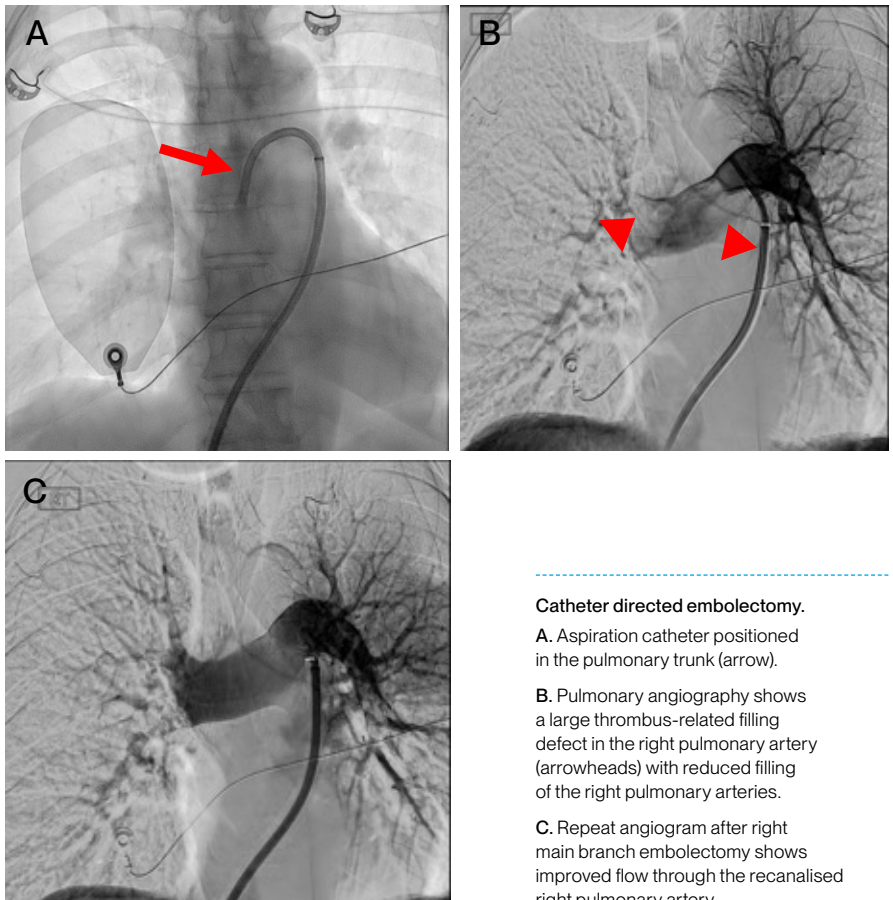
Criteria determining risk of in-hospital or 30-day mortality from acute PE.

* PESI = Pulmonary Embolism Severity Index. It is a risk stratification tool to determine the mortality of patients with newly diagnosed.

/ Endovascular Treatment for Pulmonary Embolism (PE)

While anticoagulation remains the cornerstone of therapy, several minimally invasive procedures are used to manage select PE cases including:

- **Catheter-Directed Therapy:** Percutaneous transcatheter procedures performed through the femoral or jugular vein in patients with intermediate - high risk PE
- **Embolectomy:** Emboli are directly aspirated from the pulmonary arteries using an aspiration catheter under fluoroscopic guidance (see example next page)
- **Catheter directed thrombolysis:** A pigtail catheter advanced into the pulmonary trunk allows continuous infusion of thrombolysis medication directly into thrombus. This results in more efficient thrombolysis, reduction in total dose and reduced “non target” systemic thrombolysis
- **Inferior Vena Cava (IVC) Filter:** in patients with DVT or PE in whom anticoagulation is contraindicated (see previous pages)
- **Pulmonary angioplasty:** Performed for sequelae of chronic PE. Chronic PE can cause pulmonary arterial webs or stenoses that alter haemodynamics resulting in pulmonary hypertension. Balloon angioplasty can be performed to break up webs and recanalise stenosis improving pulmonary circulation



Catheter directed embolectomy.

A. Aspiration catheter positioned in the pulmonary trunk (arrow).

B. Pulmonary angiography shows a large thrombus-related filling defect in the right pulmonary artery (arrowheads) with reduced filling of the right pulmonary arteries.

C. Repeat angiogram after right main branch embolectomy shows improved flow through the recanalised right pulmonary artery.

Conclusions

IR can offer a selection of minimally invasive, relatively quick procedures for a subset of patients with PE and DVT.

These procedures have short recovery times and may be performed with local anaesthetic and light sedation, which is beneficial in unstable patients.

IR offers a vital alternative treatment approach in patients with contraindications to conventional treatment with anticoagulation or thrombolysis.

CHAPTER OUTLINE:

Interventional Oncology (IO)

CHAPTER OUTLINE:

/ Definition

Interventional Oncology (IO) in conjunction with surgical, medical and radiation oncology, forms the cornerstone of cancer management, constituting the 4th pillar of oncological care.

IO is dedicated to the diagnosis, treatment and palliation of cancer and cancer-related problems using minimally invasive procedures performed under image guidance.

IO procedures can achieve excellent results for the right patients and often involve fewer complications and shorter hospital stay while being more cost-effective than the alternative treatments.

Interventional Oncology

- / Image guided percutaneous biopsy/cytology
- / Percutaneous oncological treatments
- / Palliative oncological treatment

/ Image Guided Percutaneous Biopsy/Cytology

/ Indications

Image-guided percutaneous biopsy and cytology are indicated in various clinical scenarios, including suspicious masses or tumours, infectious processes and fluid collections.

Biopsies are essential for cellular, molecular and genetic tissues characterisation, which is crucial for diagnosis and treatment planning.

Procedure

Biopsies are performed under imaging guidance by utilising US, CT and less frequently MRI. Fluoroscopy is mainly used in bone biopsies (usually spine).

Two available techniques:

Fine-needle aspiration biopsy (FNAB):

- 21- to 25-G needles
- Repeatedly move back and forth numerous times to gather samples

Core needle biopsy (CNB)

- 12- to 20-G needles
- Acquires tissue cores suitable for pathological analysis

Relative contraindications

- Uncorrected coagulopathy
- Haemodynamic unstable patients
- Patients unable to provide consent
- Technically unsafe to perform

>|< COMPARE

ADVANTAGES:

Minimally invasive

+ Small incision(s) and needle insertions compared to traditional open surgical biopsies, therefore, less tissue damage, reduced pain and faster patient recovery.

Accurate real time targeting

+ Precise targeting significantly reduces the likelihood of sampling errors, the risk of damaging surrounding tissues and procedural time.

Rapid results

+ As a minimally invasive procedure, short duration, fast patient recovery and improved accuracy in obtaining samples, reduced waiting times for obtaining results.

Cost effective:

+ More cost-effective compared to surgical techniques.

DISADVANTAGES:

Risk of general complications (can happen in any biopsy)

– Haemorrhage (incidence of major haemorrhage = 0.1 to 8.3%)

– Infection

– Perforation or damage of an adjacent organ

Organ-specific complications (depend on the targeted organ)

– Pneumothorax and hemoptysis in lung biopsy

– Urinoma in renal biopsy

– Hematuria in renal & prostate biopsy

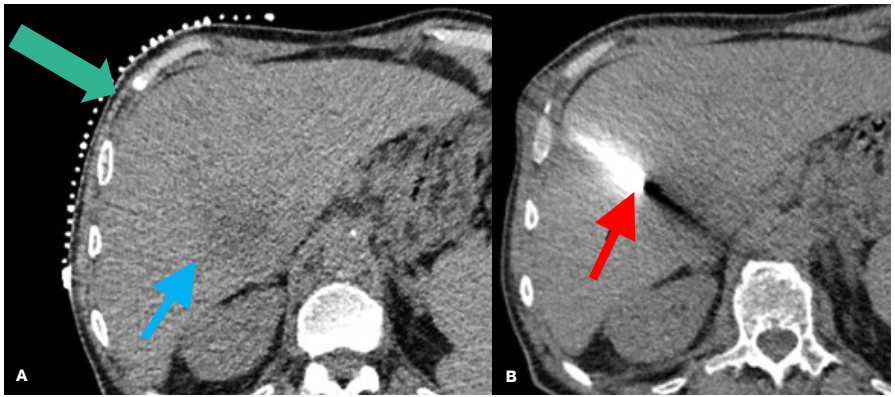
Inadequate sampling

– = biopsy procedure fails to collect a sufficient or representative tissue sample for accurate diagnosis/analysis.

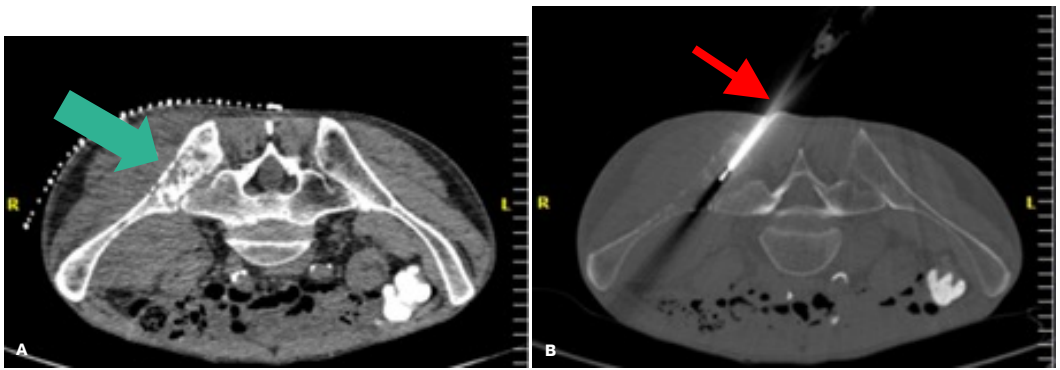
False negative results

– Biopsies may occasionally yield samples that do not accurately represent the underlying pathology.

/ Examples of Core Needle Biopsy (CNB) under CT Guidance



Example of a **CNB of a liver lesion under CT guidance.** 65-year-old patient with a large lesion of unknown histology in the right liver lobe. To begin with, a CT scan without contrast injection is performed to locate the lesion and to plan the optimal biopsy pathway. Image **A** illustrates the hypodense lesion in the right liver lobe (blue arrow). Planning of the needle path is performed before the biopsy (green arrow). Image **B** illustrates the position of the biopsy needle (red arrow). A post procedural scan is always performed following the procedure to check for any complications.

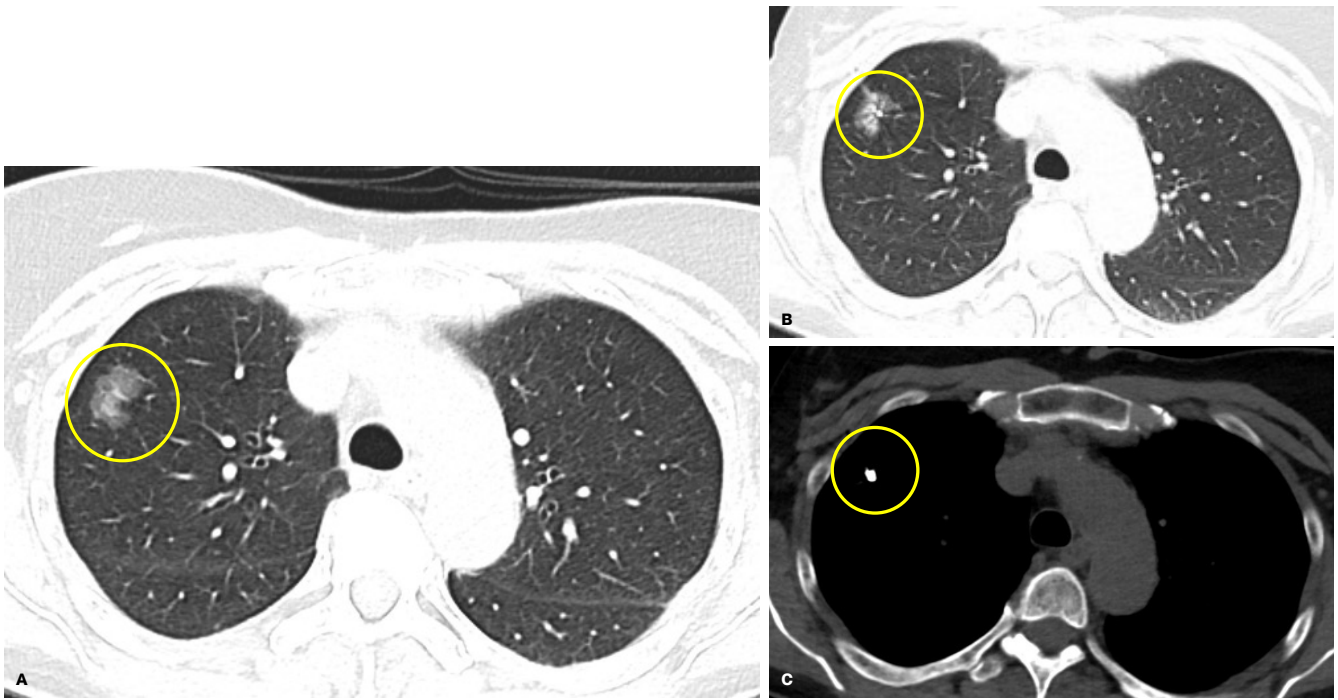


Example of a **CNB of a bone lesion under CT guidance**. 70-year-old patient with a lesion in the right iliac bone (green arrow in **A**). The patient was placed in a prone position. The biopsy needle (red arrow in **B**) is placed inside the bone lesion.

/ Interventional Radiology

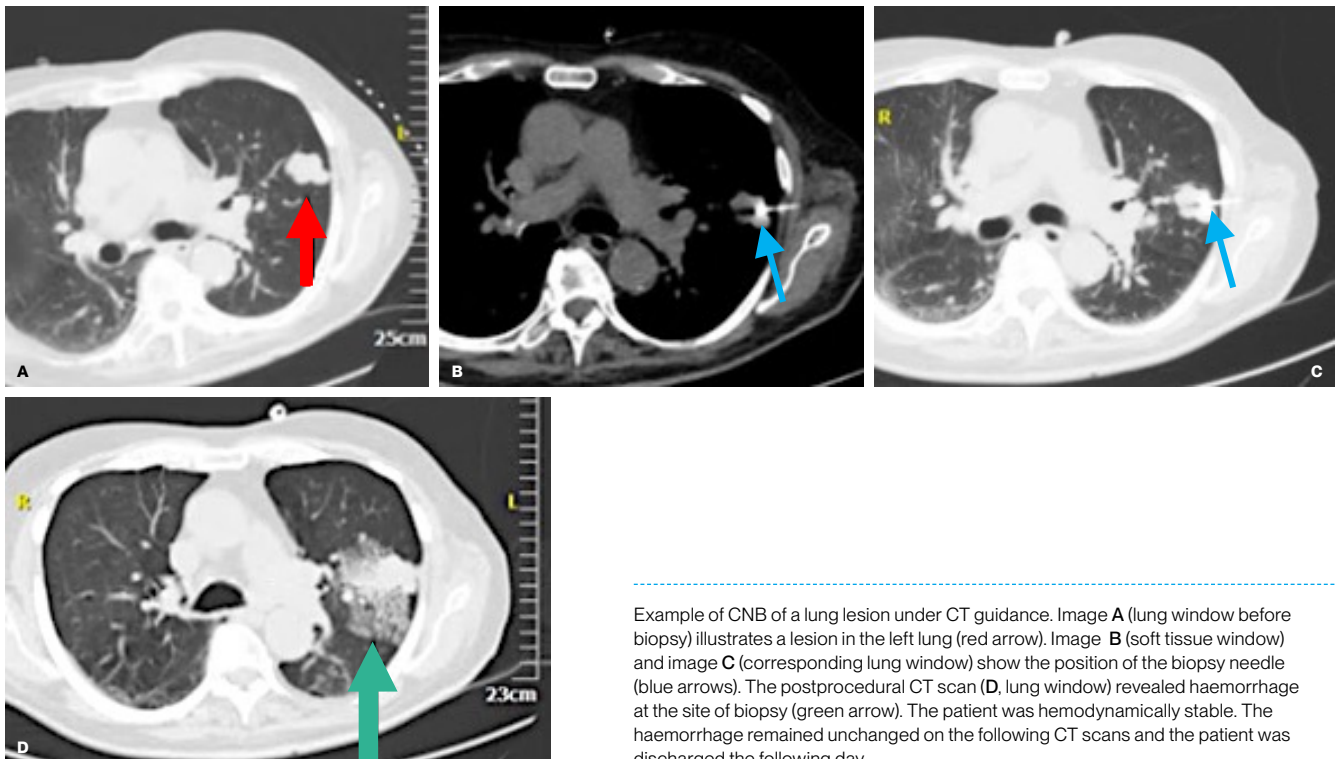
CHAPTER OUTLINE:

/ Example of Presurgical Marking



Example of a **CT guided presurgical marking of a non-solid pulmonary lesion**. **A**. Lung window setting showing an Ill-defined, non-solid pulmonary lesion in the right upper lobe (yellow circle). Lung window (**B**) + soft tissue window (**C**) after lesion marking using an endovascular coil. During atypical resection, the surgeon could easily find the lesion under fluoroscopic guidance and, therefore, minimise tissue loss.

/ Example of a Postprocedural Complication after CNB



Example of CNB of a lung lesion under CT guidance. Image **A** (lung window before biopsy) illustrates a lesion in the left lung (red arrow). Image **B** (soft tissue window) and image **C** (corresponding lung window) show the position of the biopsy needle (blue arrows). The postprocedural CT scan (**D**, lung window) revealed haemorrhage at the site of biopsy (green arrow). The patient was hemodynamically stable. The haemorrhage remained unchanged on the following CT scans and the patient was discharged the following day.

/ Endovascular Interventional Treatments

<!> ATTENTION

Definition

Locoregional intra-arterial treatments encompass various therapeutic approaches, including the following embolisation techniques:

- / Conventional trans-arterial chemoembolisation (cTACE)
- / Drug-eluting microparticle trans-arterial chemoembolisation (DEM-TACE)
- / Selective internal radiation therapy (SIRT)

They all take place in specialised angiography suites.

Procedure

The decision to perform a procedure is based on a **multidisciplinary meeting** taking into account various factors, e.g., tumour histology and grading, patients' comorbidities, baseline imaging and patient's preference.

Procedures are usually performed under local anaesthesia and mild sedation, via puncture of the common femoral or radial arteries. The commonest vessels targeted in abdominal endovascular treatments are the hepatic artery (HA) followed by gastric (GA) and superior mesenteric artery (SMA).

Advantages of endovascular transarterial oncologic treatments

Tumour control

+ Precise occlusion or decrease of tumour blood supply deprive tumours of essential nutrients and oxygen resulting in tumour regression and, in certain instances, complete eradication. Embolisation can be used as a stand-alone treatment or ± surgery or radiation.

Preservation of normal tissue

+ Damage to surrounding healthy tissue is minimised. This focused approach reduces the risk of complications associated with collateral tissue injury and preserves the function of the healthy tissue, contributing to a quicker post-procedural recovery.

Palliation of symptoms

+ By selectively blocking or reducing the blood supply to tumours or abnormal growths, embolisation can effectively reduce their size and relieve associated symptoms such as pain and bleeding.

/ Transarterial Chemoembolisation (TACE)

Definition

Transarterial Chemoembolisation (TACE) involves the simultaneous administration of both embolic materials and chemotherapeutic agents directly into the tumour through its arterial blood supply. The fundamental principle behind TACE is that liver tumours receive their blood supply primarily from the hepatic arteries, whereas the majority (approximately 80%) of the healthy liver's blood flow is sustained through the portal vein.

TACE is classified into two major categories based on the agents utilised for delivery, the cTACE, where the chemotherapeutic agent is mixed with Lipiodol and DEM-TACE, where the agent is loaded onto drug-eluting microparticles. The chemotherapeutic agents used include Doxorubicin and Idarubicin.

Indications

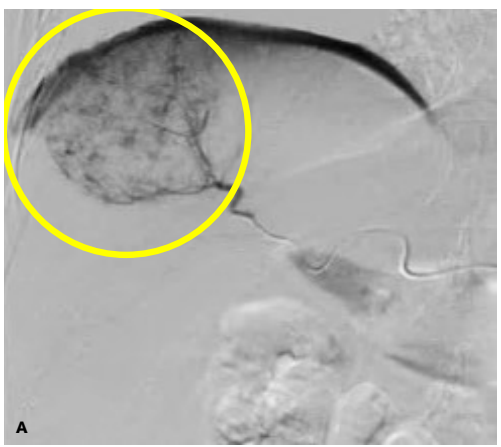
- early stages 0-A hepatocellular carcinoma (HCC) when ablation and resection are not indicated (recommendation class IB) and intermediate-stage stage B in the transplant setting (recommendation class IA), aiming in reducing/down-staging (according to Barcelona Clinic Liver Cancer –BCLC recommendations*).
- surgically unresectable or inoperable liver-only or liver-dominant disease.
- in colorectal metastatic disease, in patients with only liver disease when chemotherapy fails.
- metastatic disease in neuroendocrine tumours (NET) limited to the liver, when systemic therapy fails.
- selected cases of non-colorectal, non-NET liver metastasis.

* BCLC staging system: stage 0 (very early stage), stage A (early stage), stage B (intermediate stage), stage C (advanced stage)

ADVANTAGES OF TACE

+ **Targeted drug delivery** within the tumour enhances treatment efficacy while reducing the risk of systemic side effects commonly associated with traditional chemotherapy. By sparing healthy tissues from the cytotoxic effects of chemotherapy, TACE optimises treatment outcomes and improves therapy tolerance.

+ An **enhanced antitumour effect** is obtained by combining the embolisation of tumour-feeding blood vessels with targeted delivery of chemotherapeutic agents. TACE induces ischaemia and ensures high concentration of cytotoxic agents, which accelerates cell death. Moreover, TACE offers the advantage of sustained chemotherapy release within the tumour bed, prolonging its antitumour effects over time.



80-year-old patient with HCC in the right liver lobe treated with TACE. **A**. Selective arteriogram of the anterior subsegmental artery of the right hepatic artery shows the tumour stain (circle). **B**. Angiography after TACE does not show any tumour hypervascularity.

/ Selective Internal Radiation Therapy (SIRT)

Definition

This approach, also known as **radioembolisation (RE)**, employs tiny embolic particles delivered selectively to the tumour. The particles act as carriers for a radioisotope, which emits radiation. SIRT thus enables precise and selective delivery of high doses of radiation directly to hepatic tumours while sparing the surrounding healthy liver tissue; this results in a highly targeted and effective treatment approach. Yttrium 90 (Y-90) is one of the frequently utilised agents in SIRT.

Procedure

- Unresectable primary liver cancer (HCC or cholangiocarcinoma).
- All stages of HCC (curative setting in BCLC stage A, for downstaging and bridging in the transplant patient and for palliation in BCLC stages B and C).
- Colorectal metastasis (CRM), when systemic therapy fails.
- Metastasis from NET tumours.

ADVANTAGES

Localised Radiation

+ Unlike external beam radiation therapy (RT), RE minimises the collateral damage to normal structures. This precision allows administration of significantly higher radiation doses within the tumour, optimising cytotoxic effects.

Prolonged Effect

+ RE offers a continuous release of radiation, ensuring that cancer cells are exposed to therapeutic doses for an extended duration. This prolonged effect increases the likelihood of damaging/killing cancerous cells, making it particularly effective in controlling tumour growth and achieving durable responses. The gradual radiation release also minimises the risk of acute toxicity to surrounding healthy tissues.

/ Percutaneous Oncological Treatments

/ Percutaneous Tumour Treatments (Ablative Techniques)

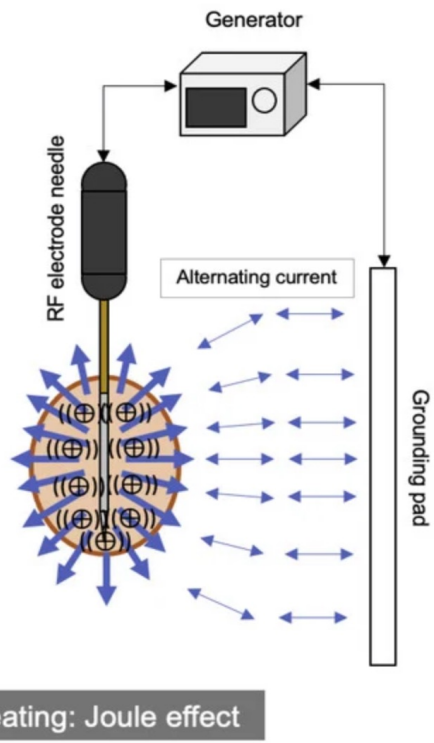
Definition

Imaging-guided tumour ablation encompasses the utilisation of energy (thermal and non-thermal) and non-energy based methods (e.g., chemical ablation), all performed under the guidance of imaging techniques (US, CT, MRI or fluoroscopy) to treat malignancies. **Thermal ablation** includes **radiofrequency ablation (RFA)**, **microwave ablation (MWA)**, **cryoablation** and **laser ablation**. High-intensity focused ultrasound (HIFU) and histotripsy are **non-thermal methods using external energy delivery**.

Indications

RFA procedures are based on a generator which generates alternating current, between 200 to 1,200 Hz. This alternating current induces agitation of ions within the surrounding tissue, leading to a rise in tissue temperature, typically between 60 to 100°C, which leads to coagulative necrosis of tumour cells.

Image reproduced from: Minami Y, Aoki T, Hagiwara S, Kudo M. Tips for Preparing and Practicing Thermal Ablation Therapy of Hepatocellular Carcinoma. Cancers. 2023; 15(19):4763. https://doi.org/10.3390/cancers15194763



/ **Interventional** Radiology

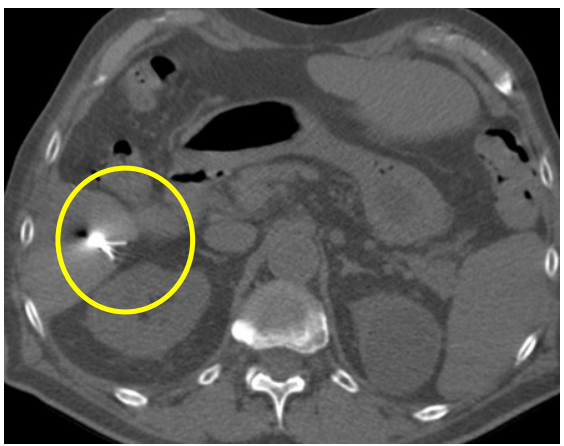
CHAPTER OUTLINE:

/ Radiofrequency Ablation (RFA)

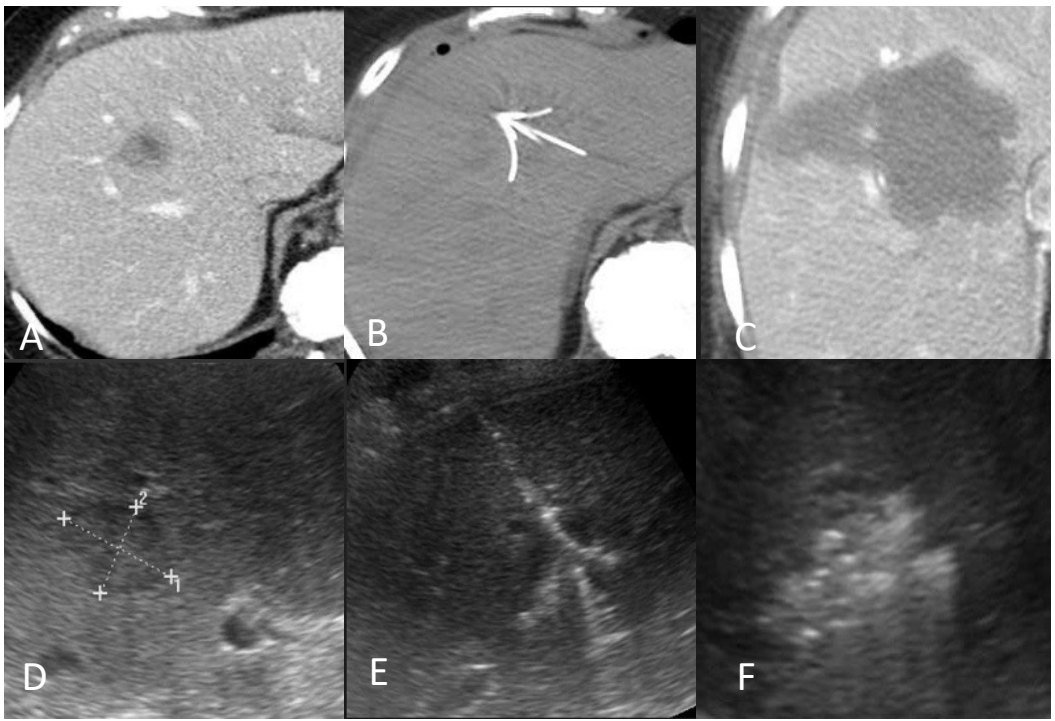
ADVANTAGES OF RFA

+ **Targeted destruction of tumour tissue** through a small skin incision. This minimally invasive approach significantly reduces trauma to surrounding healthy tissues, resulting in less post-procedural pain and shorter recovery times compared to open surgery.
+ **Preservation of normal tissue** thus reducing the risk of collateral damage often encountered in more aggressive treatments. This advantage enhances patient safety and fosters quicker post-procedural recovery and reduced incidence of complications.
+ **Applicability to various primary and secondary liver tumours**:
  + liver cancer stage 0 and stage A
  + patients anticipating liver transplantation
  + oligometastatic liver disease
  + small renal cell carcinomas (T1 stage)
  + some lung cancers

Typical “sunburst” RFA needle



CT-guided RFA of a liver tumour



Two examples of RFA: **A** and **B**: CT guided procedure; C: control after RFA. **D** and **E**: US-guided procedure; **F**: control after RF. The RFA electrode is open after proper placement within the tumour like an umbrella.

/ Interventional Radiology

CHAPTER OUTLINE:

/ Microwave Ablation (MWA)

Definition

Microwave ablation (MWA) utilises electromagnetic energy, typically operating at either 915 MHz or 2.45 GHz frequencies, to generate frictional heat within tissues, resulting in temperatures ranging from 60 to 100°C. This heat leads to subsequent protein denaturation and coagulation necrosis.

Indications

Tumours with a maximal diameter of 3 cm (in case of a multiple-needle approach, larger tumours can be approached as well).

Can be performed percutaneously or even during surgical procedures.

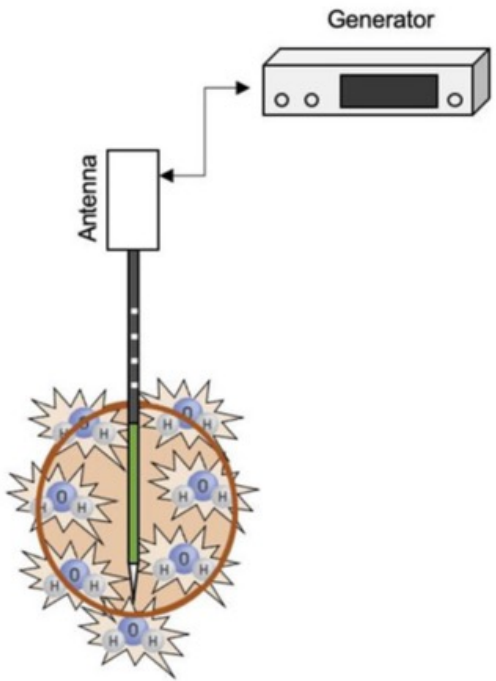


Image reproduced from: Minami Y, Aoki T, Hagiwara S, Kudo M. Tips for Preparing and Practicing Thermal Ablation Therapy of Hepatocellular Carcinoma. Cancers. 2023; 15(19):4763. https://doi.org/10.3390/cancers15194763

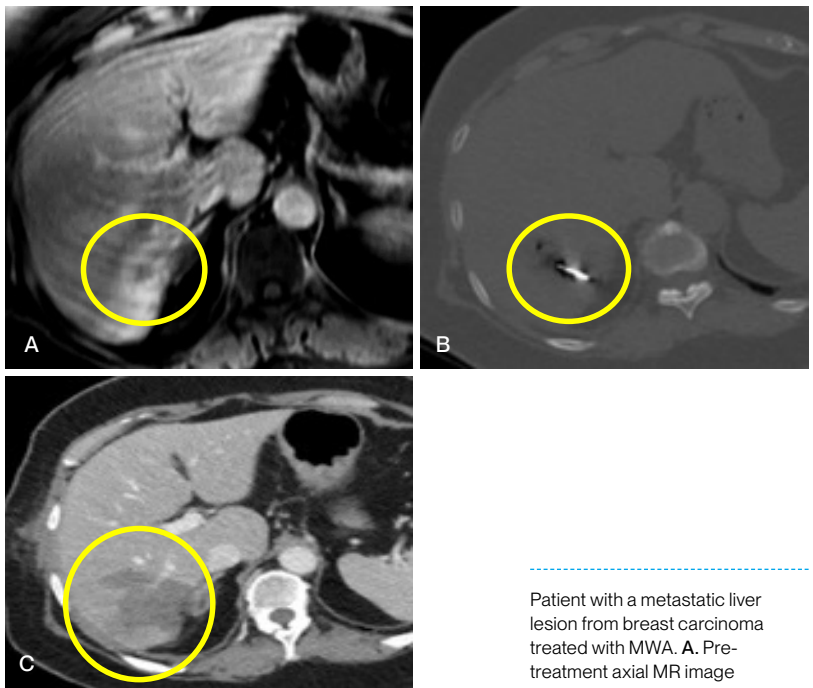
ADVANTAGES OF MWA

Larger Ablation Zone

+ An advantageous aspect of MWA is its **reduced susceptibility to the heat-sink effect**, making it an appealing option for the treatment of **highly vascular** lesions. The heat-sink effect occurs when the target lesion is in close proximity (within 1 cm) to a large blood vessel (≥ 3 mm in diameter), where blood circulation has a cooling effect, limiting the extent of the ablation zone and, consequently, the effectiveness of the treatment > **see next page**.

Efficient and Faster Ablation

+ **More homogeneous tissue coagulation** compared to RFA, the absence of the need for ground pads and the ability to operate multiple antennas simultaneously.

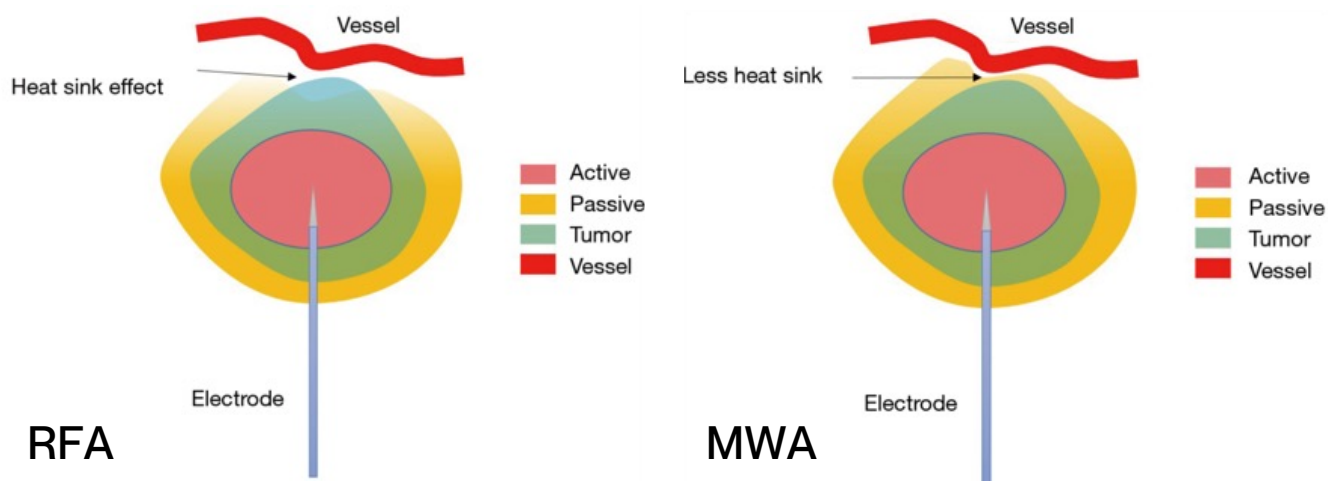


Patient with a metastatic liver lesion from breast carcinoma treated with MWA. **A.** Pre-treatment axial MR image shows a lesion in segment VI of the liver (circle). **B.** CT imaging during ablation after MWA probe placement. **C.** Post-contrast axial CT image obtained immediately post-ablation shows a satisfactory ablation zone (circle).

CHAPTER OUTLINE:

Heat sink effect > Large vascular structures adjacent to the target lesions decrease the effective thermal energy delivered during treatment because of continuous blood flow.

>|< COMPARE



/ Interventional Radiology

CHAPTER OUTLINE:

/ Cryoablation

Definition

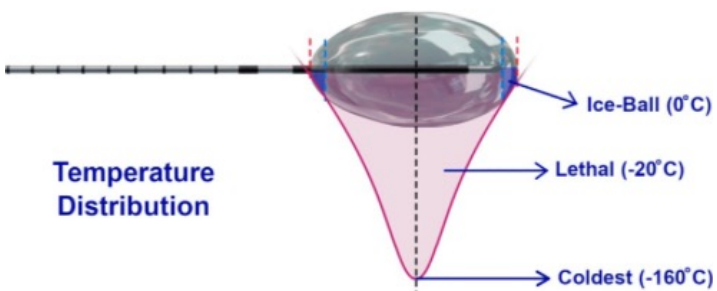
Cryoablation (CA) employs specialised cryoprobes to introduce room-temperature, pressurised argon gas, rapidly cooling the target tissue to extremely low temperatures (reaching as low as -100°C) within a matter of seconds. This cooling phase is alternated with the delivery of helium gas, facilitating active thawing of the tissue. Cell death results from this sequence of freezing and thawing cycles.

Indications

Mainly applied for lung, renal and adrenal tumours and sometimes for breast tumours.

ADVANTAGES

+ Low peri- and post-procedural pain.
+ Controlled Destruction: Cryoablation offers the advantage of the ability to visually monitor the formation of the ice ball during the procedure. By controlling the extent and depth of tissue destruction, cryoablation minimises collateral damage and reduces the risk of complications.
+ Applicability to various tumours, including primary and metastatic lung carcinomas and renal cell carcinomas. ..



Schematic presentation of cryoablation. (**A**) Design of a cryoprobe, whereby a cryogen circulates to rapidly cool the cryoprobe to -160 °C, resulting in an ice ball around the cryoprobe of varying temperatures, of which -20 °C is lethal. Image reproduced from: Mansur A, Garg T, Shrigiriwar A, Etezadi V, Georgiades C, Habibollahi P, Huber TC, Camacho JC, Nour SG, Sag AA, Prologo JD, Nezami N. Image-Guided Percutaneous Ablation for Primary and Metastatic Tumors. Diagnostics (Basel). 2022 May 24;12(6):1300. doi: 10.3390/diagnostics12061300.

/ Symptomatic Palliative Oncological Treatment

Definition

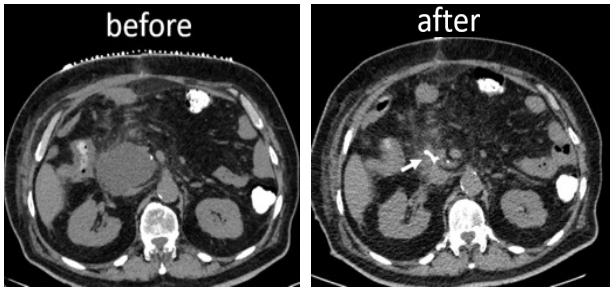
Palliative oncological treatment aims to improve the quality of life of patients with advanced cancer. As a multidisciplinary approach, it employs minimally invasive techniques to manage symptoms, control tumour-related complications and mitigate the adverse effects of cancer and its treatments.

Drainage

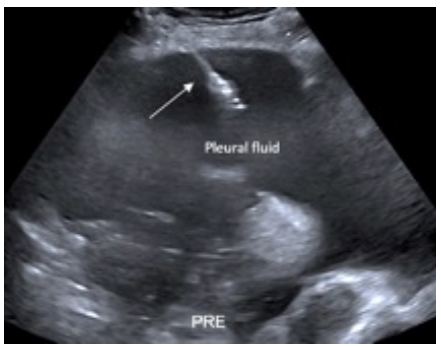
Pleural effusion and ascites are common complications in cancer patients. Drainage of these fluids is typically done using US or CT guidance, often with non-tunneled pigtail catheters via Seldinger or trocar techniques.

While there are no absolute contraindications, **relative contraindications** include uncorrected coagulopathy, high procedural risk and patient inability to cooperate or consent.

Serious complications are uncommon (0-15% of cases) and include infection, bowel perforation, pneumothorax, haemothorax and damage to nearby organs. As cancer patients frequently develop abscesses, these are effectively treated with percutaneous drainage under CT guidance.



54-year-old patient with a peripancreatic fluid collection after an episode of pancreatitis treated with percutaneous drainage under CT guidance. Image prior to procedure illustrating the peripancreatic fluid collection (asterisk). Image taken post procedure shows the tip of the catheter (white arrow) inside the collection from breast carcinoma.



Patient with shortness of breath due to a large pleural fluid collection. He was treated with percutaneous drainage under ultrasound guidance. White arrow shows the tip of the catheter during insertion.

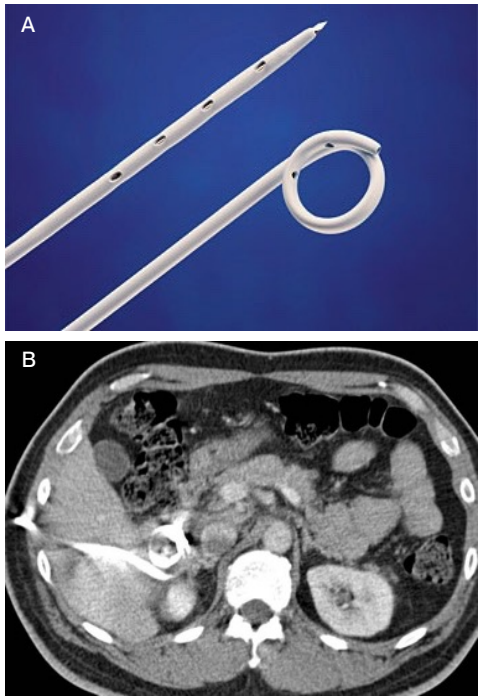
CHAPTER OUTLINE:

/ Biliary Duct Drainage / Stent Implantation

Malignant biliary obstruction is a common issue in cancer patients, leading to impaired liver function and sepsis if untreated.

IR management involves **percutaneous transhepatic cholangiography (PTC)** followed by biliary drainage and stent placement, typically under ultrasound and fluoroscopic guidance.

The procedure has a complication rate of 4-12%, with potential risks including haemobilia, infection, sepsis, pneumothorax and peritonitis. Proper management of this condition is crucial to prevent severe complications.



Typical "pigtail" configuration of a drainage catheter (A). Transhepatic drainage of a perihepatic abscess (B).

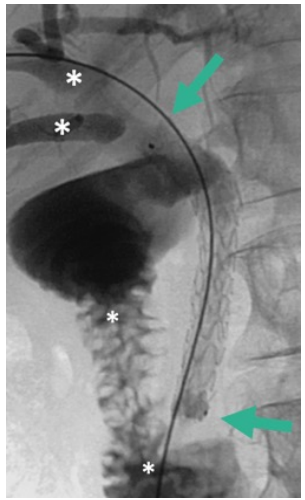


Image above: PTC depicting a malignant stricture treated by a permanent metallic stent. Upper arrow points at the transhepatic biliary guide wire used to deploy the stent in the common bile duct (CBD), lower arrow points at the distal stent extremity. Dilated contrast-filled biliary ducts (large *). Duodenum outlined by contrast material from the CBD (small *). Image reproduced from the ebook chapter on bile ducts. European Society of Radiology, Pedro Gil Oliveira, Filipe Caseiro-Alves (2022) eBook for Undergraduate Education in Radiology: Bile Ducts. DOI 10.26044/esr-undergraduate-ebook-01

/ Interventional Radiology

CHAPTER OUTLINE:

/ Oesophageal Stenting

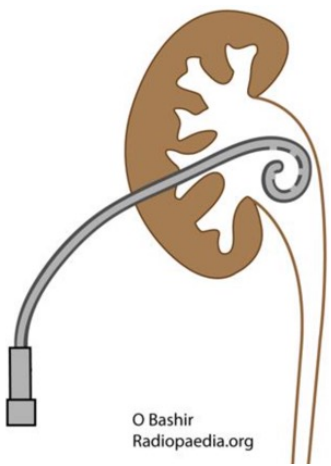
Oesophageal stenting, involving the placement of self-expanding metal stents (SEMS), is essential in palliative care for patients with advanced oesophageal cancer or other obstructive malignancies.

This minimally invasive procedure restores the oesophagus's patency, enabling the passage of food and liquids. In palliative settings, oesophageal stents significantly alleviate dysphagia, reduce symptoms and minimise the risks of complications such as aspiration, pneumonia and malnutrition, which are common in oesophageal obstruction. This intervention plays a crucial role in improving the quality of life for patients with obstructive oesophageal conditions.

/ Nephrostomy

Nephrostomies are crucial in palliative care for patients with advanced urinary tract cancers or related complications.

These minimally invasive procedures involve placing a catheter directly into the renal pelvis to drain urine when the urinary system is obstructed or severely dysfunctional. In palliative care, nephrostomies alleviate urinary tract obstructions caused by tumours or metastases, reducing pain, discomfort and the risk of hydronephrosis, which can lead to kidney damage. Additionally, they divert urine away from the obstructed areas, decreasing the risk of infections and complications. By addressing urinary symptoms, nephrostomies significantly enhance patient comfort, improve hydration and maintain overall well-being, thereby improving the quality of life.



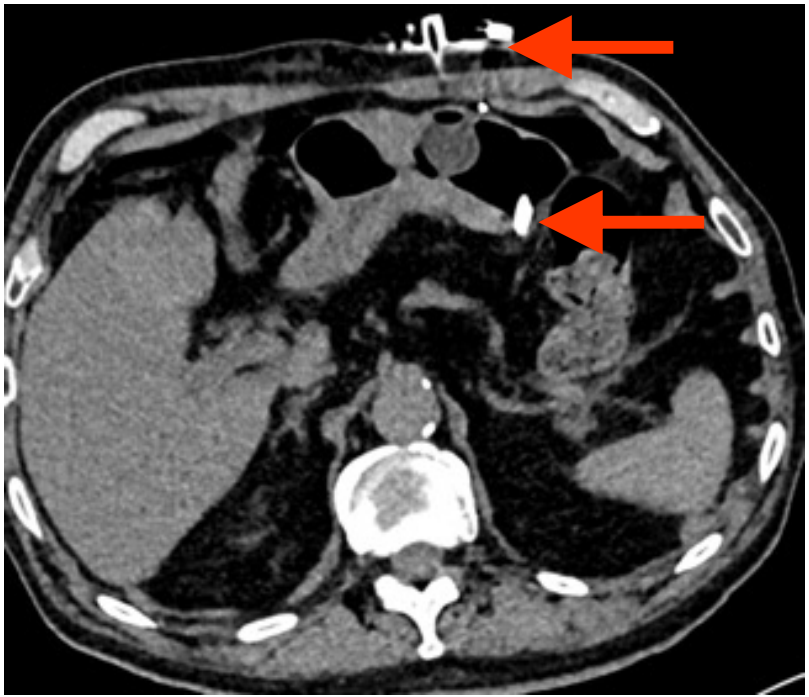
Reproduced from: Bashir O, Percutaneous nephrostomy diagram. Case study, Radiopaedia.org (Accessed on 11 Aug 2024)
https://doi.org/10.53347/rID-17826om

CHAPTER OUTLINE:

/ Feeding Tube Placement

The placement of enteral feeding tubes, including percutaneous endoscopic gastrostomy (PEG) and radiologically inserted gastrostomy (RIG) tubes, is crucial in palliative oncological care.

These tubes are inserted directly into the stomach or small intestine via the abdominal wall, providing essential enteral nutrition when oral intake is not possible due to advanced cancer or related complications. Feeding tubes ensure adequate nutrition and hydration, manage symptoms like dysphagia, odynophagia or aspiration and serve as a means for administering medications, including analgesics and other palliative treatments, thereby enhancing patient comfort and quality of life.

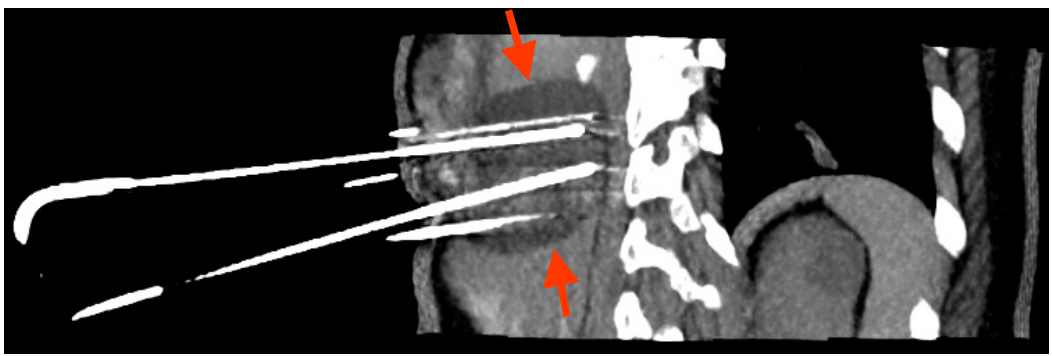


CT-guided placement of a percutaneous endoscopic gastrostomy (PEG, arrows).

/ Pain Treatment

/ Pain affects up to 70% of oncologic patients and - often being undertreated - leads to poor quality of life. Cancer pain is categorised into somatic, visceral, neuropathic or mixed types. Somatic pain, the most common, arises from tumour invasion in bones, muscles and connective tissues. Visceral pain results from inflammation, compression, distention or ischaemia of internal organs, mediated by nociceptors leading to the spinal cord.

/ **Neurolysis procedures**, proven safe and effective, target pain from peripheral, cranial, splanchnic and intercostal nerves, as well as nerve ganglia and plexuses. It can be done chemically, using substances like alcohol or phenol or thermally through RFA, MWA, cryoablation and HIFU under CT guidance. Additionally, augmentation techniques for skeletal malignancies, applied to the spine and peripheral skeleton, are crucial for pain relief and reinforcing bone integrity. These methods significantly improve the management of cancer-related pain and patient quality of life.



A 64-year-old female patient with an unresectable left kidney sarcoma who presents with a PAINFUL soft tissue metastasis (arrows) of left paraspinal muscles. Since this lesion caused excruciating pain, it was decided to proceed with **percutaneous cryoablation** to reduce pain.

Emergency Interventional Radiology (IR)

CHAPTER OUTLINE:

/ Management of Arterial Trauma

IR is a crucial part of trauma teams in hospitals, often being the first to respond to patients with severe injuries, such as penetrating wounds (e.g., stabbings, gunshots) or significant blunt trauma. Accurate imaging upon arrival is essential for quick diagnosis and effective triage. For stable patients, CT is the imaging modality of choice. Regardless of imaging protocol, the goal is to detect vascular injuries like aortic dissection, hepatic or splenic bleeding or peripheral arterial injury. Haemorrhage control, especially through embolisation, is the most common acute procedure performed by IR.

Embolisation

Embolisation is a medical procedure that blocks blood vessels to stop bleeding, either as a pre-surgical damage control method or as a standalone treatment when surgery isn't needed. It involves using guidewires and catheters to reach the bleeding site, guided by a CT angiogram. Various embolic agents, like liquids, coils and foam, are used based on the patient's condition and the bleeding location.

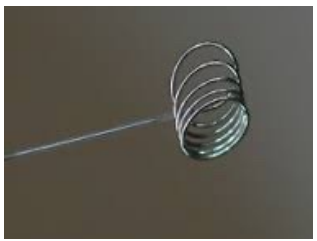
Embolic agents include **particulate agents** (e.g., polyvinyl alcohol particles), **liquid agents** (e.g., sclerosants) and occlusion **devices** (e.g., coils and plugs). The choice of agent depends on different factors (e.g., **temporary versus permanent blockage or selective versus non-selective treatment**).

Temporary blockage is useful in non-major vessel injuries to allow healing and later reassessment. **Temporary embolic materials** include gelatin sponge (e.g., Gelfoam) or polyvinyl alcohol (PVA) particles. The decision between selective (targeting single vessels) and non-selective (treating entire vascular beds) treatment depends on the clinical scenario, with bleeding often favouring selective treatment.

Coils are suitable for larger vessels, while liquid agents are used for distal arterioles or non-specific bleeders.

/ Embolisation → Large Choice of Embolic Agents

>|< COMPARE



Coils and microcoils (made of metal) are used to induce clot formation within a vessel leading to permanent vessel occlusion.

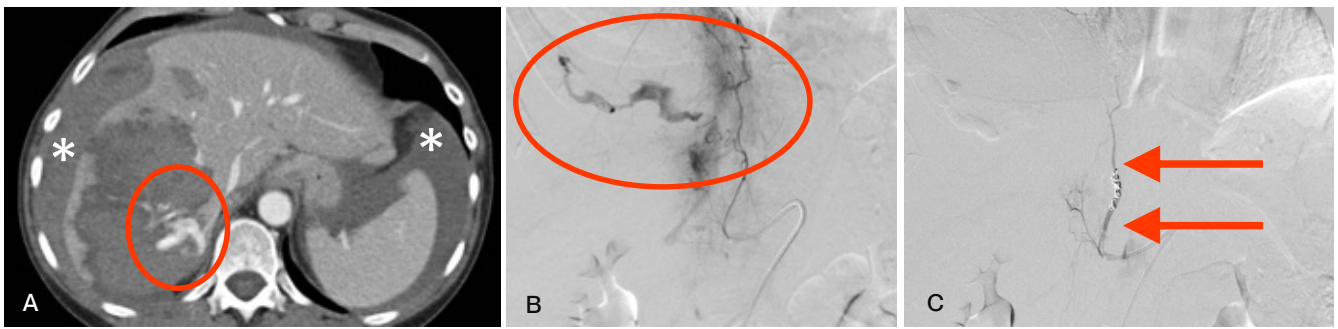
ADVANTAGES:

+ wide range of sizes and models
+ to be set down very precisely
+ super-selective embolisation possible

DISADVANTAGES:

– clotting only with regular coagulation possible
– risk of coil dislocation ("the last coil is always one too much")

Figure below => Severe active bleeding after liver biopsy seen on contrast-enhanced CT and DSA (red circles in **A** and **B**). Massive haemoperitoneum (asterisks). Successful superselective embolisation using microcoils (arrows in **C**).



Liquid agents like Cyanoacrylate Glue or Onyx have the following feature in common: the liquid embolic material hardens/solidifies upon contact with blood creating a permanent blockage.

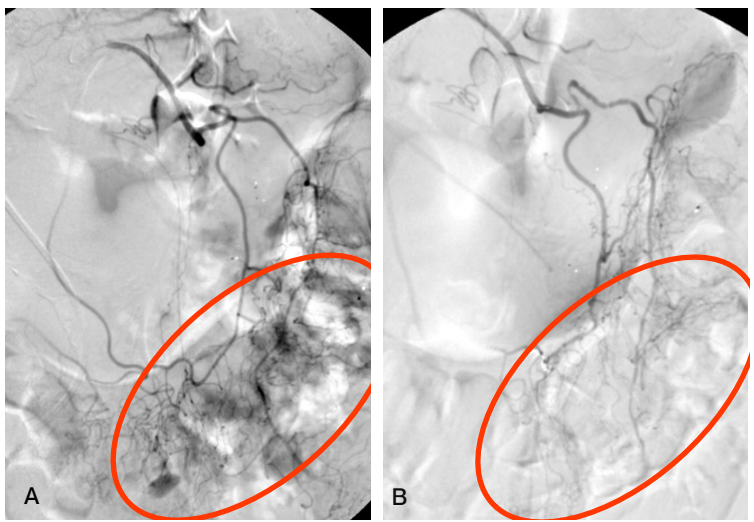
>|< COMPARE

ADVANTAGES:

+ very fast permanent embolisation
+ can also be used if feeding vessel cannot be probed directly (super-selectively)
+ cheap

DISADVANTAGES:

– difficult to control – risk of misembolisation
– polymerisation extremely painful (in case of contact with the peritoneum)



Active gastrointestinal bleeding with patchy extravasation of contrast material (red circle in **A**). Successful embolisation using Glue (circle in **B**).

Stent grafts (stent = tubular metal framework; graft = fabric covering) work by effectively isolating the aneurysm from the bloodstream and preventing rupture.

>|< COMPARE

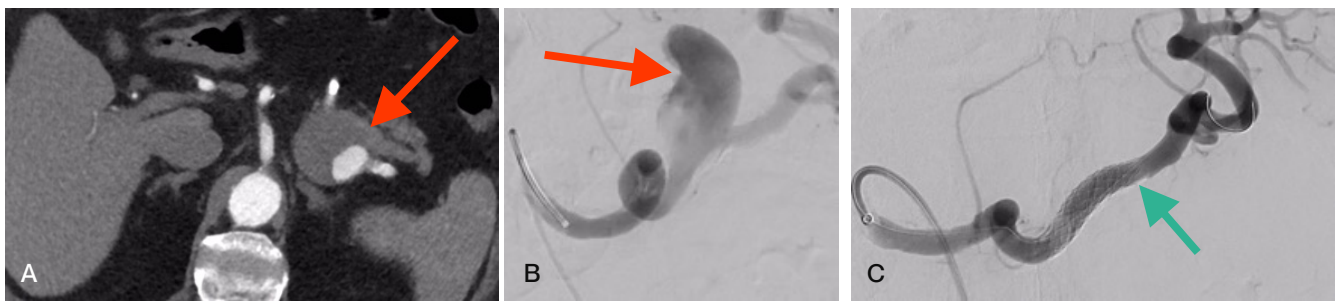
ADVANTAGES:

+ Permanent closure of a vascular lesion
+ even in the case of unsuccessful direct probing of a bleeding side branch

DISADVANTAGES:

– (very) expensive
– large-lumen access required (8-14F)
– Risk of retrograde perfusion of the bleeding vessel

Figure below > Large aneurysm (arrows) of the splenic artery after blunt trauma as seen on contrast-enhanced CT (**A**) and DSA (**B**) Successful embolisation using a stentraft (arrow in **C**).



/ Interventional Radiology

CHAPTER OUTLINE:

/ Hepatic and Gastroduodenal Artery Trauma

The management of hepatic and gastroduodenal artery trauma requires a multidisciplinary approach, prioritising resuscitation, diagnostic imaging and either surgical or endovascular intervention due to the life-threatening nature of these injuries.

General Management Principles

Resuscitation: Immediate stabilisation following Advanced Trauma Life Support (ATLS) protocols is essential. This includes airway management, breathing support and circulatory stabilisation. Continuous haemodynamic monitoring is crucial.

Diagnostic Imaging: Focused Assessment with Sonography for Trauma (FAST) is initially used to assess intra-abdominal haemorrhage. Once stabilised, contrast-enhanced CT angiography is used for diagnosing the extent of vascular injury and planning further intervention. Angiography may also be used for both diagnosis and therapy.

Specific Arterial Injury Management:

Hepatic Artery Trauma:

- **Non-Operative:** Endovascular embolisation for stable patients with minor injuries.
- **Surgical:** for haemodynamic instability or failed non-operative management. Techniques include ligation, arterial repair or bypass grafting.

Gastroduodenal Artery Trauma:

- **Endovascular:** Embolisation is often the first-line treatment for stable patients.
- **Surgical:** When embolisation fails or in unstable patients. Techniques include ligation, primary repair or, in severe cases, a Whipple procedure.

Postoperative Care and Complications:

- Close ICU monitoring with a focus on preventing complications such as re-bleeding, ischaemia and infections.
- The prognosis depends on the injury's severity and the timeliness of intervention, emphasising the importance of rapid and effective management to reduce mortality.

/ Management of the Gastrointestinal Bleeding (GIB)

Gastrointestinal bleeding (GIB) is a complex condition categorised into upper and lower GIB, each requiring distinct management strategies.

/ Upper GIB (UGIB)

UGIB refers to blood loss from a gastrointestinal source above the ligament of Treitz. UGIB often results from liver disease leading to **variceal bleeding** or from **peptic ulcer disease** or **bleeding pseudoaneurysms related to pancreatitis**. Patients typically present with hematemesis and can quickly become haemodynamically unstable.

First-Line Management

Upper GI Endoscopy: The primary diagnostic and therapeutic tool used to achieve haemostasis.

Interventional Radiology (IR)

Embolisation: Reserved for non-variceal bleeds that cannot be controlled endoscopically, particularly useful for high-risk lesions, such as those with a visible artery. The **left gastric and gastroduodenal arteries** are common sources of bleeding, identifiable via mesenteric angiography

Technique: Angiography demonstrates the bleeding site, where haemostasis is achieved using embolic materials like coils. These are deployed distal and proximal to the bleeding source, effectively excluding it. The extensive collateral circulation of the foregut minimises the risk of bowel ischaemia during this procedure.

This approach allows for effective management of complex bleeding scenarios, particularly when endoscopy fails, ensuring comprehensive care for patients with upper GIB.

CHAPTER OUTLINE:

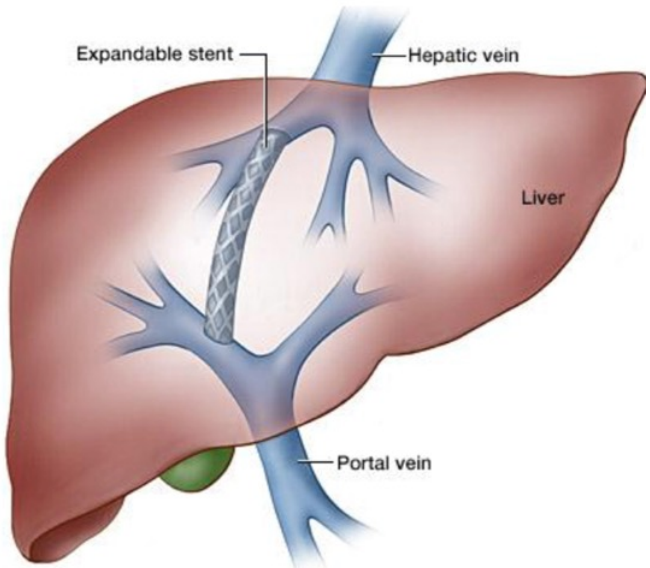
Variceal bleeding which is recurrent or refractory to endoscopic control is essentially the result of uncontrolled portal hypertension. Decompression of the system is often the only definitive treatment.

Transjugular Intrahepatic Portosystemic Shunt (TIPS) is the formation of a tract between the hepatic vein and the portal vein, therefore shunting blood away from the portal venous system and reducing backpressure in the fragile varices.

TIPS is a technically complex procedure involving puncturing the portal vein via a hepatic vein (commonly the right hepatic vein), forming the tract and stenting it to maintain a patency and a more permanent shunt.

Further indications for TIPS include:

- Refractory ascites and/or refractory hydrothorax
- Treatment of gastroesophageal varices as secondary prophylaxis of variceal bleeding
- Bridge in patients awaiting liver transplantation especially patients with portal hypertension complications)



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Interventional Radiology

CHAPTER OUTLINE:

/ Lower GIB

Lower gastrointestinal bleeding (LGIB) refers to bleeding that occurs distal to the ligament of Treitz. Common causes include diverticula, ischaemic colitis, inflammatory bowel disease, NSAID and anorectal disorders.

Proper identification of LGIB is crucial as it influences the management approach, which differs significantly from upper gastrointestinal (UGI) bleeds. Clinically, **melaena (black stool)** can help distinguish between small intestinal and right colonic bleeds, while **haematochezia (fresh blood in the stool)** more often indicates massive bleeding from the lower colon or rectum. In managing LGIB, the anatomical distinction is important, especially for determining the level at which embolisation may be attempted.

Embolisation in the lower GI tract carries a higher risk of bowel ischaemia due to the less extensive collateral blood supply compared to the upper GI tract. Therefore, embolisation for LGIB is reserved for cases where CT imaging identifies specific focal bleeding points that can be targeted with highly selective coil embolisation.

<!> ATTENTION

Colonoscopy is generally ineffective during acute bleeds and should not delay further investigations (CT or transfer to IR). A triple-phase CT scan is essential for identifying active bleeding and distinguishing between diffuse and focal bleeding points. Diffuse bleeding often necessitates laparotomy, whereas focal bleeding is more amenable to targeted interventions.

Common sources of bleeding in the colon include the ileocolic and right colic branches of the superior mesenteric artery (SMA). This approach is critical to effectively managing LGIB while minimising the risks associated with ischaemia.

CHAPTER OUTLINE:

/ Postpartum Haemorrhage (PPH)

/ Introduction

Postpartum bleeding, also known as post-partum haemorrhage (PPH), is defined as blood loss of > 500 ml following vaginal delivery or > 1,000 ml following caesarean section.

It is a potentially life-threatening complication following childbirth. It is a leading cause of maternal morbidity and mortality worldwide. Estimates suggest that PPH accounts for 24% of maternal deaths annually and affects 10% of all living births. About 60 hysterectomies are performed to avoid one maternal death.

IR plays a crucial role in the management of PPH, offering minimally invasive procedures that can swiftly curtail bleeding and safeguard the mother's well-being.

<!> ATTENTION

Causes of PPH > mainly the "4Ts"

- **Tonus:** uterine atony* (50% of PPH)
- **Trauma:** uterine rupture* or severe trauma during delivery*
- **Tissue:** placenta accreta*, increta*, percreta*, retained**
- **Thrombin:** coagulation disorders*
- Infection*

*Early (first 24 h), **Late (> 24 h)

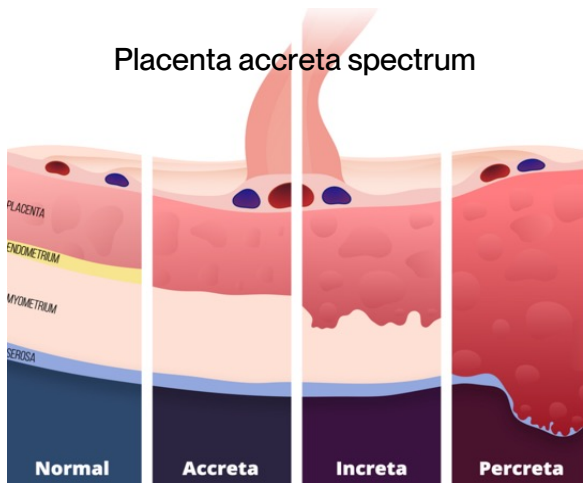


Image reproduced from: Gaillard F, Placenta accreta spectrum (illustration). Case study, Radiopaedia.org (Accessed on 12 Aug 2024) https://doi.org/10.53347/rID-167145

/ **Interventional** Radiology

CHAPTER OUTLINE:

/ Interventional Treatment Options for PPH

A recent health care commission investigating maternal deaths in the United Kingdom recognised the life-saving potential of interventional radiology. In 2006, the Royal College of Obstetricians and Gynaecologists advocated for the early involvement of IR in the management of PPH and the establishment of protocols incorporating IR either in response to PPH or in women at high risk of PPH.

Permanent embolic material: Metallic coils with fibers, enhancing thrombogenicity

>|< COMPARE

Indications of IR in Managing Postpartum Bleeding:

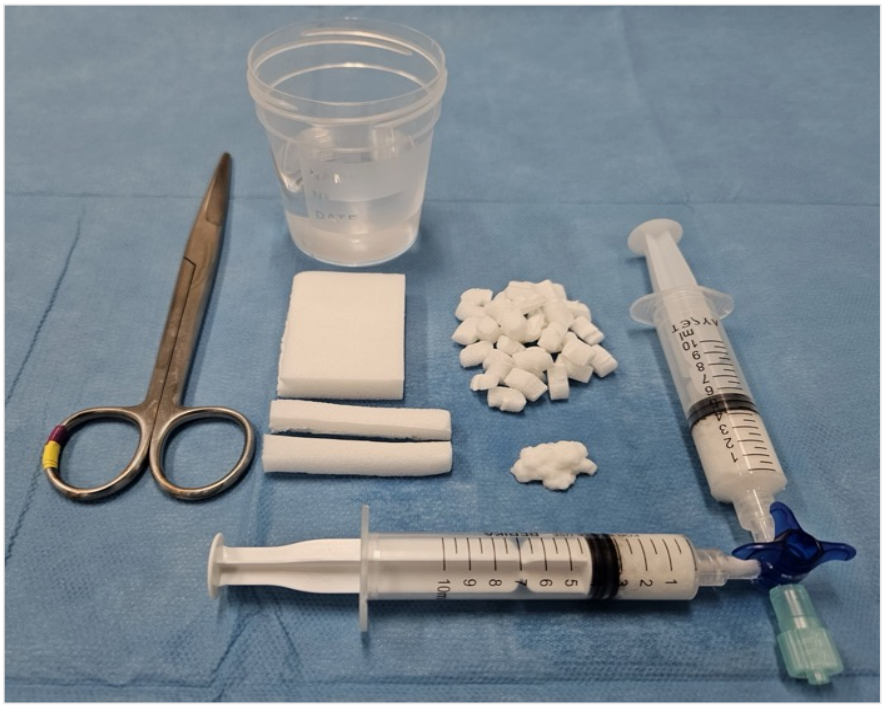
- Genital bleeding following vaginal or caesarean delivery.
- Prophylactic balloon catheter occlusions and/or uterine embolisation in cases of abnormal placental implantation, to assist uterine sparing techniques.

Contraindications of IR in Managing Postpartum Bleeding:

- There are no absolute contraindications, however, uterine rupture and eversion should be treated surgically.

Advantages of IR in Managing PPH:

+ Rapid bleeding control
+ Minimally invasive technique eliminating the need for general anaesthesia and large surgical incision
+ Preservation of fertility



Temporary embolic material: Gelfoam slurry preparation -> Gelfoam is torn into small pieces and placed into one syringe, while the other syringe is filled with 5 to 10 ml of normal saline. Both syringes are attached to a three-way stop cock and then the slurry is mixed by alternating contents between syringes.

Arterial Embolisation (obstetric haemorrhage embolisation, OHE):

- To be performed in a dedicated angiographic suite/operating room equipped with specific equipment and stringent radiation safety measures.
- US-guided puncture (under local anaesthesia) of the common femoral artery followed by a 4-6F sheath insertion; the arteries of interest (uterine or ovarian arteries) are selectively catheterised. Microcatheters are used to facilitate superselective catheterisation and embolisation. In PPH, temporary embolic material (absorbable gelatine sponges, Gelfoam) is preferred, as it gradually absorbs. However, permanent embolic materials are also frequently used (e.g., microparticles, plugs and liquid Cyanoacrylate Glue).

Balloon Tamponade:

- In severe haemorrhage, angiographic balloon catheters may be required to achieve haemodynamic control via occlusion of either the internal or common iliac arteries or even at the level of the distal abdominal aorta. This technique serves as a temporary measure to mitigate blood loss, before further definitive endovascular or surgical therapeutic solutions are employed.

Temporary Balloon Occlusion (TBO)

- TBO of the internal iliac arteries is widely employed to minimise blood loss prior to caesarean section in abnormal placental implantation, thereby allowing for uterus-preserving surgery. The procedure can be performed under local anaesthesia and requires bilateral common femoral artery access (US-guided) for catheterisation and occlusion of both iliac arteries, using dedicated occlusion or standard balloon catheters.

CHAPTER OUTLINE:

Interventional Treatment Options for PPH: Results

Arterial embolisation is a **safe and effective procedure** for PPH and gynaecological haemorrhage despite lack of large randomised studies and limited level of evidence. Reported success rates for PPH range between 79 and 100%.

Factors predicting **embolisation failure** include accessory arterial blood supply, previous surgical ligation, dilatation and curettage, unilateral embolisation, abnormal placentation and a history of caesarean section.

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Avoiding the use of inappropriately small particles or non-selective liquid embolisation techniques is crucial to minimise the risk of the above adverse events, particularly when dealing with shunts or disrupted collateral supply due to previous ligations.

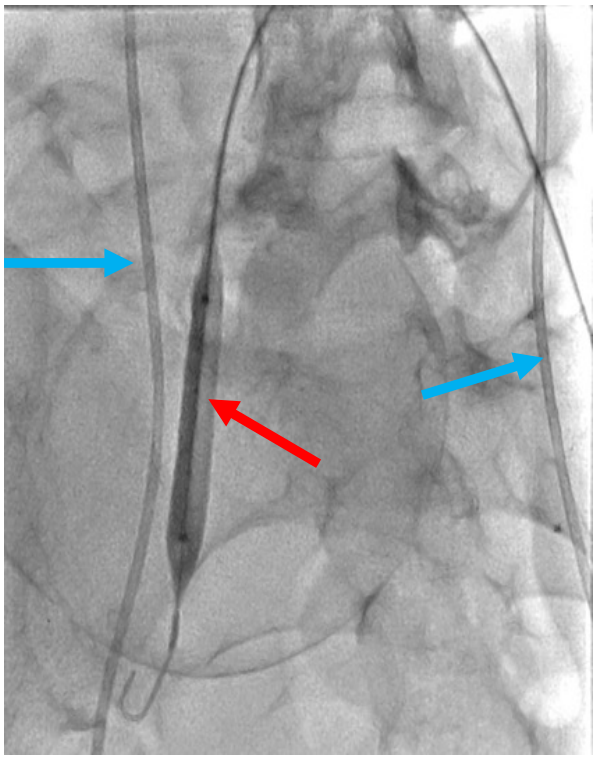
Complications of Interventional Treatment for PPH

- Complications related to arterial puncture and contrast injection (e.g., groin puncture site hematoma, dissections and contrast medium reactions).
- Non-target embolisation (a rare event but can lead to ovarian failure or necrosis of the bladder or rectum).
- Necrosis of the small bowel, uterus, vagina and labia (rarely observed with uterine necrosis requiring hysterectomy being an extremely rare manifestation of this condition).
- Buttock ischaemia and claudication (a potential complication that might appear as a transient and minor complication but could be lifestyle-limiting).
- Neurological complications (very rare but may occur due to communications between the iliac arteries and arteries supplying the spinal cord as well as the sciatic and femoral nerves).
- Transient ovarian failure after OHE (has been reported, however, women can generally expect to resume normal menstrual cycles and fertility following the procedure)

Conclusions

- IR offers safe and effective, minimally invasive treatment options
- Low complication rate
- In-theatre procedures including prophylactic balloon occlusion
- Collaboration with obstetric and gynaecological teams

Particulate agent – Microspheres (Permanent Embolic Material)



Temporary balloon occlusion (red arrow) of the iliac arteries as a valuable strategy for minimising blood loss before caesarean section for abnormal placenta implantation (case of placenta percreta). Bilateral ureteral stents (blue arrows) also seen here, to minimise the risk of unintentional urinary tract injury during surgery.

Interventional Radiology

CHAPTER OUTLINE:

/ Stroke

/ Stroke Types

Stroke is a clinical diagnosis referring to an **abrupt onset of focal neurological deficit of presumed vascular origin**. Despite its global prevalence as a significant contributor to morbidity and acquired disability, mortality rates have been declining in high-income countries attributable to advancements in both primary prevention strategies and acute management modalities.

Stroke can be subdivided into acute ischaemic stroke (AIS) and haemorrhagic stroke (HS).

Acute ischaemic stroke (AIS) is characterised by a sudden interruption of blood flow to the brain, leading to potential brain cell death and focal infarction if circulation is not restored. It accounts for 87% of stroke cases.

The condition arises from one of three primary mechanisms:

- **Large vessel disease:** This includes conditions like atherosclerosis, arterial dissection and artery-to-artery embolism.
- **Small vessel disease:** Often related to lacunar infarctions due to lipohyalinosis or atherosclerosis, leading to the occlusion of penetrating arteries.
- **Cardioembolism:** This can originate from arrhythmia, valvular heart disease, bioprosthetic and mechanical heart valves, patent foramen ovale or cardiomyopathy.

Each mechanism contributes to the clinical presentation and requires specific management strategies to mitigate the risk of lasting damage.

<=> REFERENCE

> See also eBook chapter Central Nervous System

/ Acute Ischaemic Stroke (AIS)

"Time is brain" - Acute ischaemic stroke is a **true emergency**, a "brain attack" although there is high variability of neuronal loss & heterogeneity of infarct growth progression in stroke patients (fast/ intermediate/ slow progressors); the estimated pace of neural circuitry loss in a typical large vessel, supratentorial AIS is 1.9 million neurons lost per minute and the dynamic, time-dependent key concept in

<!> ATTENTION

- **Ischaemic core:** will inevitably die (irreversible ischaemic damage)
- **Oligemia:** will theoretically survive
- **Ischaemic penumbra:** may or may not survive > potentially salvageable brain tissue demonstrating reversible ischaemia if reperfusion is achieved (the part of the vascular territory surviving on collateral flow, small vessels supplying ischaemic tissue through retrograde flow)

AIS pathophysiology is **the division of the hypoperfused tissue into three operational compartments:**

The Onset to Reperfusion Time (ORT) or **Onset to Recanalisation Time** is the time from stroke onset to the time when blood flow is restored. A longer ORT increases mortality rate and haemorrhagic transformation risk and decreases the probability of functional independence at 3 months. Early intervention before leptomeningeal collateral networks collapse and there is irreversible brain tissue damage is essential.

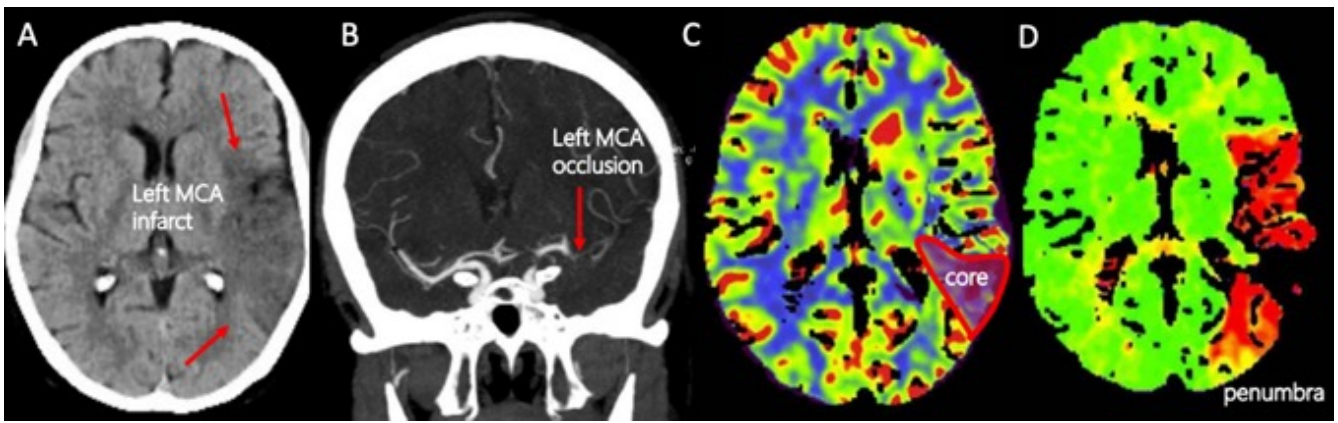
B: balance (loss of balance)
E: eyes (blurred vision)

F: face (one side of the face is drooping)
A: arms (arm or leg weakness)
S: speech (speech difficulty)
T: time (time to call for ambulance immediately)

<!> ATTENTION

The **ischaemic penumbra and the infarct core** are determined on CT perfusion or MRI perfusion using a combination of different parameters.

- **Ischaemic penumbra** > A delayed arrival of iv. contrast material results in a prolonged mean transit time (MTT) and a prolonged time to peak (TTP) while the cerebral blood volume (CBV) can be normal or increased. The cerebral blood flow (CBF) is only moderately decreased.
- **Infarct core** > marked decrease in CBF and decrease in CBV. On MRI, there is restricted diffusion.



Acute ischaemic infarct (arrows) seen as a hypoattenuating area on non-enhanced CT (**A**) in the left middle cerebral artery (MCA) territory. **B.** Coronal reconstruction of an angio-CT series shows occlusion of the left MCA. **C.** The CBV (cerebral blood volume) perfusion parametric map shows the core whereas the penumbra can be assessed on the TTP (time to peak) perfusion parametric map (D).

Figure reproduced from: European Society of Radiology, Laura Oleaga (2022) eBook for Undergraduate Education in Radiology: Central Nervous System. DOI 10.26044/esr-undergraduate-ebook-07

CHAPTER OUTLINE:

/ Haemorrhagic Stroke (HS)

Haemorrhagic stroke (HS), accounting for 13% of strokes, occurs due to rupture in a blood vessel, leading to bleeding within the intracranial cavity.

<!> ATTENTION

HS is subdivided into two main types: nontraumatic intracerebral haemorrhage (ICH) and subarachnoid haemorrhage (SAH).

Intracerebral Haemorrhage (ICH) is the **second most common type of stroke**, often caused by rupture of small arteries due to conditions like hypertensive vasculopathy, cerebral amyloid angiopathy, coagulopathies or vascular malformations. The clinical presentation varies depending on haemorrhage size and location, with primary injury resulting from the **mass effect** of the expanding haematoma and perihaematomal oedema, leading to **increased intracranial pressure (ICP)** and **compromised cerebral perfusion**. Patients may also develop **intraventricular haemorrhage (IVH)** and herniation. Secondary injury includes inflammation, blood-brain barrier disruption, oedema and oxidative damage from free radicals.

Subarachnoid Haemorrhage (SAH) is caused by a **ruptured aneurysm, arteriovenous malformations, vasculitis** or **drug use**. It can also be of **venous origin (perimesencephalic non-aneurysmal SAH)** or due to **vessel rupture following dural venous sinus thrombosis**. SAH often presents with a sudden, severe "thunderclap headache," neck pain, photophobia, vomiting, altered mental status and possibly seizures.

Intracranial aneurysms (IAs) are responsible for most **nontraumatic SAH**, where arterial blood enters the subarachnoid space, increasing ICP and potentially spreading into brain parenchyma. Secondary brain injury may occur from ICH, IVH or delayed cerebral ischaemia. Early diagnosis and treatment are crucial to prevent rebleeding and rapid neurological deterioration.

/ Stroke Management: Imaging

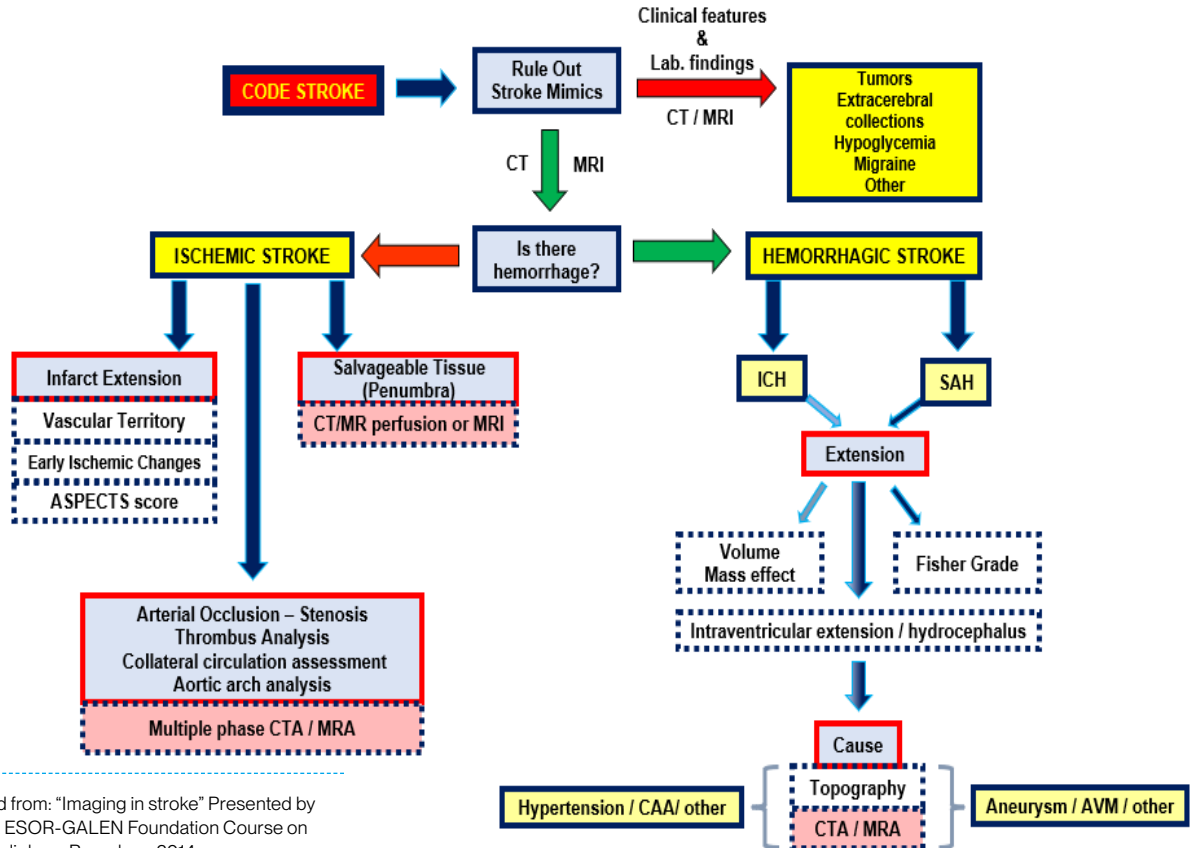
Neuroimaging is a critical component of stroke management (diagnostic work-up & treatment decisions) and **all individuals presenting with suspected acute stroke, should undergo urgent brain imaging evaluation** upon initial hospital admission prior to the initiation of any specific treatment.

A **multimodal radiological study**, consisting of a series without contrast, an angiographic series and a perfusion series, **can be interchangeably performed with CT or MRI in case of AIS** and irrespective of the imaging modality employed, meticulous and structural (early CT signs of ischaemia / thrombus analysis / collateral circulation / penumbra vs infarct) analysis of the data is essential, acknowledging the potential pitfalls and limitations associated with each technique and accessing the 4Pillars, consisting of "Parenchyma-Pipes-Penumbra-Perfusion".

In the setting of **non-traumatic spontaneous subarachnoid haemorrhage (SAH)**, CT angiography or MRI angiography (MRA) can identify the presence and characteristics of an aneurysm, including its location, size, shape and neck morphology. This information is crucial for guiding appropriate intervention and risk stratification.

Prompt evaluation with consecutive imaging examinations is paramount for the identification and management of early- and late-onset complications associated with AIS and HS. These complications principally encompass hemorrhagic transformation in AIS and mass effects, intraventricular dissemination, hydrocephalus, rebleeding, vasospasm and even ischaemia in HS. Early recognition and management of these complications are pivotal for optimising patient outcomes.

Streamlined Diagnostic Pathway for Acute Stroke Management



Modified from: "Imaging in stroke" Presented by P. Vilela, ESOR-GALEN Foundation Course on Neuroradiology, Barcelona 2014

CHAPTER OUTLINE:

/ Stroke Management: Endovascular Treatment for AIS (Mechanical Thrombectomy)

EndoVascular Treatment (EVT) for AIS - also known as **Mechanical Thrombectomy (MT)** - is a minimally invasive endovascular procedure, performed under fluoroscopic guidance, permitting rapid recanalisation of an intracranial occlusion and restoration of the blood flow, by removing thrombotic material. More and more agreement that the risk of intervention is low in comparison to potential benefit, is leading to extension of inclusion criteria.

<!> ATTENTION

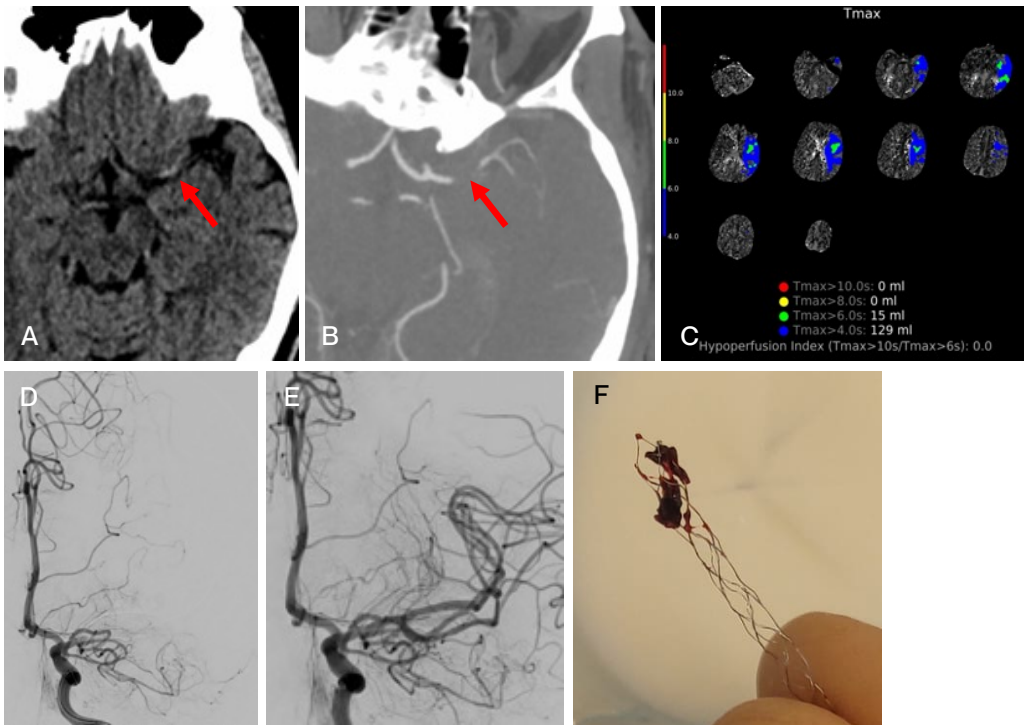
ADVANTAGES:

+ generally effective and safe when treatment can be initiated within 6 h of symptom onset
+ same high treatment effect in cases of AIS secondary to an intracranial large vessel occlusion and a concurrent extracranial (cervical) internal carotid artery or vertebral artery occlusion or severe stenosis (tandem occlusions)
+ seems possible in the late window (6-24 h) in selected patients (need for advanced imaging or collateral flow assessment on CTA and/or close neurological examination for clinical-core mismatch)
+ beneficial for basilar artery occlusion of moderate to severe symptoms, within 24 h of onset, one of the most devastating neurological conditions
+ may be considered for the treatment of large-core AIS (ASPECTS 3-5) within 24 h and of distal intracranial lesions, in an individual approach

/ Stroke Management: Endovascular Treatment for AIS (Mechanical Thrombectomy)

MT techniques and devices have been constantly refined and expanded considerably with several techniques in the armamentarium, including:

- **Direct Contact Aspiration (DCA)** > navigation of an aspiration catheter to the occlusion followed by syringe or pump driven aspiration with an advantage of reduced costs and shorter procedure duration. Clot consistency, size, location and angle of interaction with the aspiration catheter influence DCA efficacy. DCA can be used as a standard first-line treatment followed by stent retriever MT as rescue therapy.
- **Stent Retriever (SR)** > navigating a microwire and microcatheter beyond the occlusion and deployment of a self-expanding stent within the thrombus, allowing time for integration with it before being retrieved along with the thrombus. The innovative design of the stent serves dual purposes: initially, it functions as a temporary bypass, facilitating immediate restoration of blood flow by expanding within the clot. Subsequently, it ensnares the clot within its stent struts, enabling efficient clot retrieval.
- **Combined Approaches** > combination of the advantages of primary - first line aspiration and stent retrievers by additionally placing a distal aspiration catheter at the proximal margin of the thrombus.
- **Intra-arterial Thrombolysis** > adjunctive or rescue therapy during MT, that can also help to recanalise thrombi in small vessels as well as in the microvascular structure, that are inaccessible or too risky for MT devices.



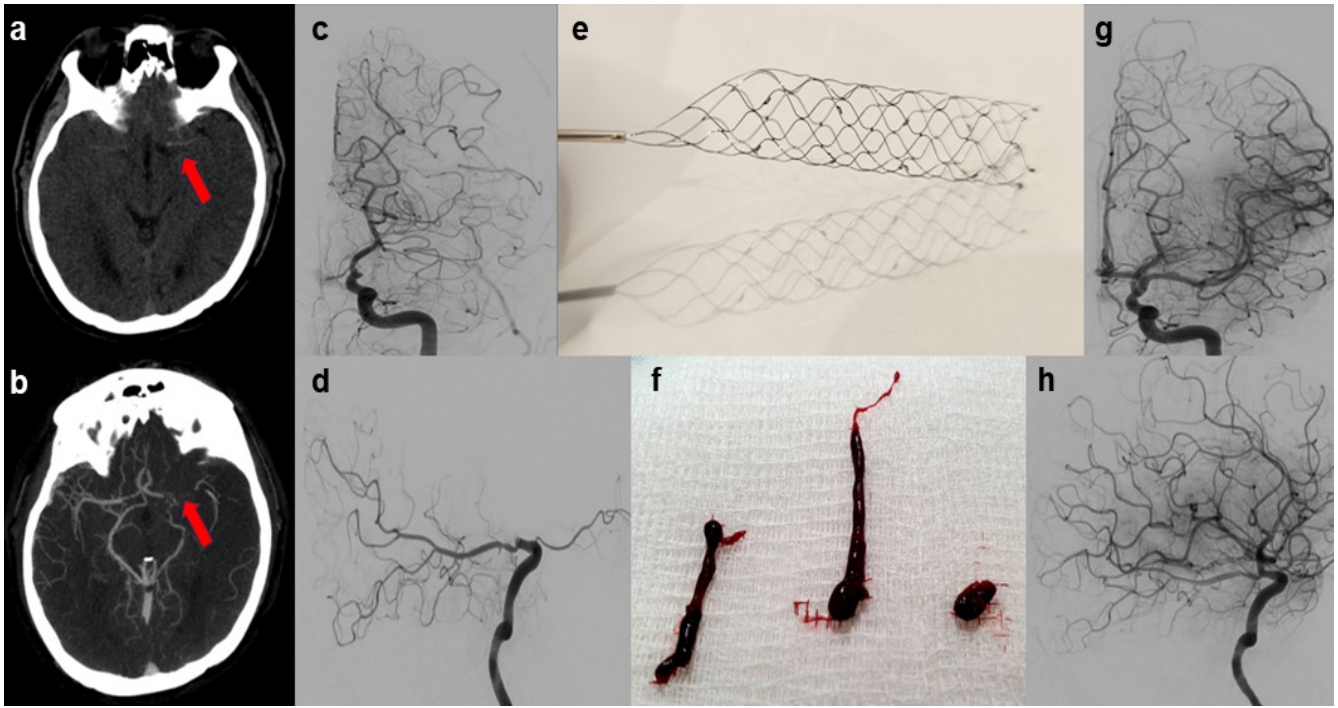
88-year-old man, wake up stroke, mRS 0*, NIHSS 13**. (**A**) CT on admission, with spontaneous hyperdensities at thrombus location (red arrow); (**B**) CTA showing absence of contrast medium filling of the M1 segment of the middle cerebral artery at thrombus location (red arrow); (**C**) Perfusion CT , Tmax with hypoperfusion of the left hemisphere identifying ischaemic penumbra (absence of ischaemic core in CBF < 30%); (**D**) DSA anterior-posterior view showing occlusion of the left M1 segment of the middle cerebral artery; (**E**) DSA anterior-posterior view after recanalisation by stent retriever thrombectomy; (**F**) Stent retriver with embedded thrombus.

Figure courtesy: Dr Gianmarco Bernava, Unit of Interventional Neuroradiology, Geneva University Hospitals, Geneva, Switzerland.

*mRS = Modified Rankin Scale = used to measure disability degree in stroke patients => 0 = no symptoms at all

** NIHSS = National Institute of Neurological Disorders Stroke Scale is used to assess stroke severity. Scores between 6 and 13 require acute inpatient rehabilitation.

CHAPTER OUTLINE:



(**a**) Hyperdense M1 segment of the left middle cerebral artery (MCA) suggestive of red blood clot; (**b**) CT angiography confirming the M1 occlusion: (**c** and **d**) Digital Subtraction Angiography (DSA) before a combined mechanical thrombectomy (MT) technique is applied, showing the MCA occlusion; (**e**) Close-up image of the stent retriever structure; (**f**) thrombotic material removal during endovascular treatment; (g and **h**) anterior-posterior and lateral DSA images after mechanical thrombectomy showing the recanalised MCA.

CHAPTER OUTLINE:

/ Stroke Management: Management of Haemorrhagic Stroke

Coil embolisation is a key endovascular therapy (EVT) for treating haemorrhagic stroke related to a ruptured brain aneurysm. The primary goal is to achieve complete intracranial aneurysm (IA) occlusion to prevent re-bleeding and minimise brain damage while preserving blood flow in the in the parent, branching and perforating vessels.

There is no one-size-fits-all technique technique for EVT due to the varied nature of aneurysms:

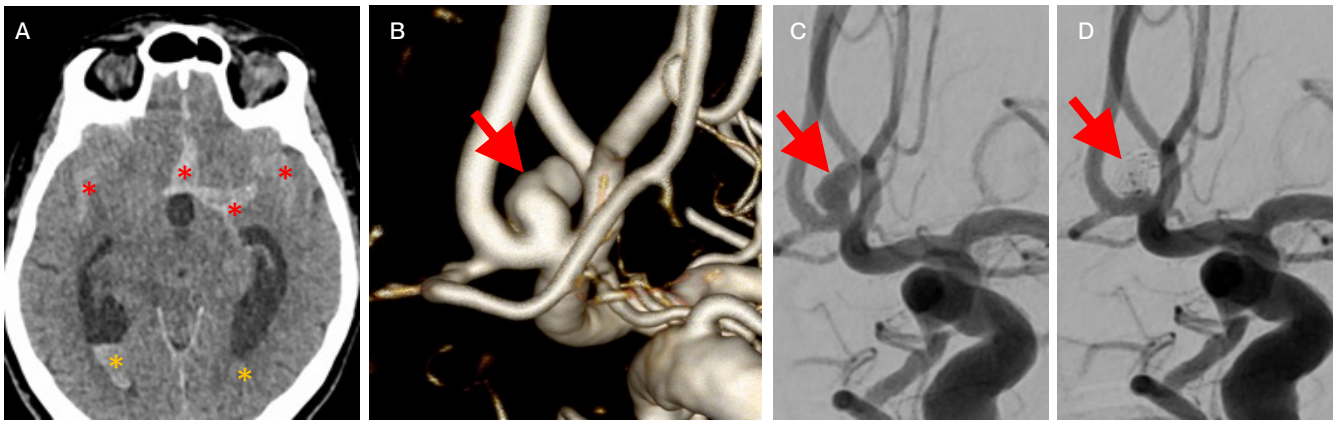
- **Simple coiling** involves navigating a microcatheter into the aneurysmal dome and packing it with detachable coils under general anaesthesia and fluoroscopy. The aim is to induce clot formation within the sac, isolating it from circulation.
- **Balloon-Assisted Coiling** and **Stent-Assisted Coiling** address the limitations of wide-necked or complex aneurysms by providing temporary support to prevent coil prolapse and migration during packing.
- Simple stenting is used to restore vessel wall integrity in intracranial dissecting aneurysms.
- **Flow-diverting stents (FDSs)** represent a newer approach, with less porous mesh designed to reduce flow within the aneurysm sac, promoting thrombosis and vessel remodelling without directly accessing the aneurysm.
- **Intrasaccular Flow Disruptors (ISFDs)** are another promising option, deployed within the sac or neck of complex aneurysms to promote thrombosis and vessel remodelling.
- In certain complex cases, a combination of microsurgical and endovascular techniques may be necessary to achieve complete aneurysm resolution, as no single approach may be sufficient.

Advantages of EVT for Aneurysmal Hemorrhagic Stroke

Continually improving technology for IR devices and techniques has shifted the balance towards an endovascular-first approach (taking into consideration the aneurysm characteristics and patients' profile / co-morbidities & preference), with the benefit of:

+ minimally invasive procedure, accessing the treatment area from within the blood vessel and preventing re-bleeding
+ patient preference
+ tolerability in less healthy patients
+ reduced operative time
+ decreased length of in-hospital stay

CHAPTER OUTLINE:



84-year-old woman, SAH Fisher 4*, Glasgow scale (GCS) = 15. (**A**) CT on admission showing diffuse subarachnoid (red asterisks) and intraventricular (yellow asterisks) haemorrhage and dilatation of the ventricular system; (**B**) 3D angiography showing a saccular aneurysm of the anterior communicating artery (arrow); (**C**) DSA showing an anterior-posterior working projection before endovascular treatment; (**D**) DSA showing an anterior-posterior working projection at the end of endovascular treatment performed with simple coiling.

Figure courtesy: Dr Gianmarco Bernava, Unit of Interventional Neuroradiology, Geneva University Hospitals, Geneva, Switzerland.

* The Fisher scale is used to classify the amount of subarachnoid haemorrhage (SAH) on CT scans. Fisher grade 4 (intraventricular haemorrhage) => incidence of vasospasm is about 31%.

CHAPTER OUTLINE:

/ Stroke Management:

Conclusions

- The **initial critical step** in acute stroke triage is distinguishing between ischaemic and haemorrhagic subtypes, guiding appropriate care such as medical therapy, thrombolysis, thrombectomy or endovascular aneurysm coiling.
- **Timely treatment** is crucial, as the chances of full neurological recovery decrease with every minute of untreated stroke.
- The future of endovascular therapies (EVTs) is promising, with ongoing advancements in technology and understanding pushing the limits of current treatments.
- As stroke awareness increases, it is vital to ensure equitable access to these minimally invasive procedures for all eligible patients.

Image created with the help of DALL-E chatgpt.com

/ **Interventional** Radiology

CHAPTER OUTLINE:

/ Management of the Septic Patient

Clinical teams frequently require the input of IR for the management of septic patients for source control, whether this is for the drainage of **abdominal** or **superficial infective collections, abscesses, ascites** or **empyema**. In addition, IR will often perform **percutaneous nephrostomies for obstructive uropathy, transhepatic cholangiograms and drainages for obstructed biliary systems** or **cholecystostomies**.

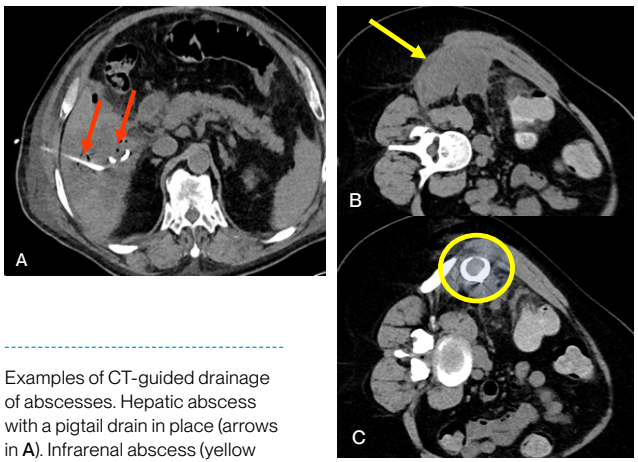
The principles of drain insertion include the Seldinger technique commonly with a drain into a cavity whether this is a dilated native body cavity (biliary or pelvicalyceal system) or an abscess/collection.

/ Intraabdominal Collections

CT or US-guided Drainage

Post-operative patients can develop abdominal collections at sites of anastomoses whilst non-surgical candidates with surgical pathology (e.g., contained appendicitis perforations or diverticular abscesses) will all require drainage of the collection presumed to cause sepsis.

In all procedures, image-guidance for needle and subsequent drain placement are of utmost importance to avoid damage of adjacent structures and to ensure a safe technique. Deep areas in the abdomen or those which cannot be confidently visualised with US often require CT guidance.



Examples of CT-guided drainage of abscesses. Hepatic abscess with a pigtail drain in place (arrows in **A**). Infrarenal abscess (yellow arrow) before (**B**) and after (**C**) CT-guided drainage (yellow circle). The patient in B and **C** is lying on his left side.

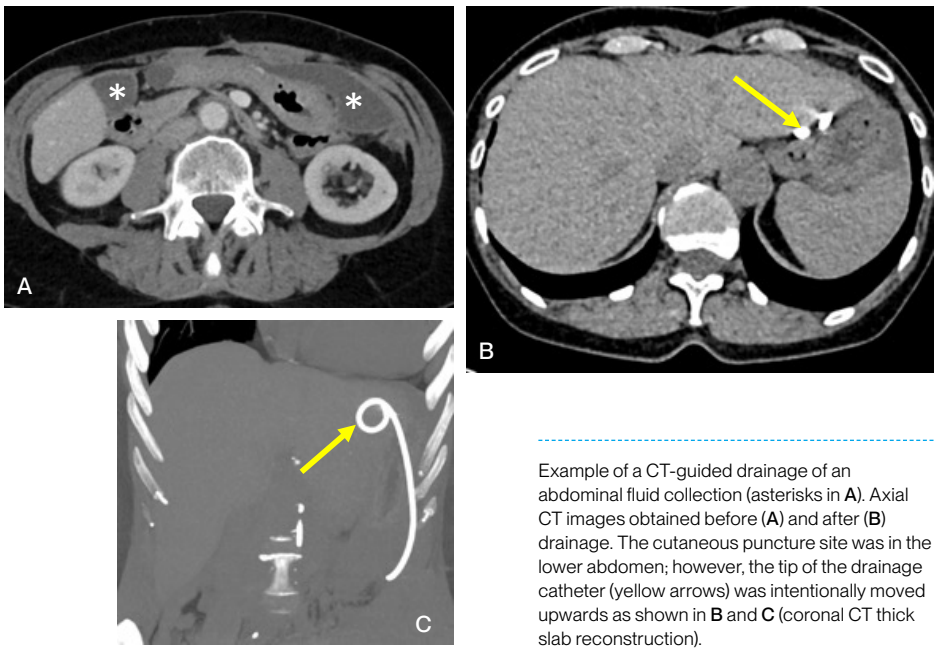
/ Decompensated Liver Disease with Large Ascites

CT or US-guided Transabdominal Ascitic Drain Insertion

Recurrent or refractory tense ascites can have significant complications including respiratory distress and splinting of the diaphragm but more importantly spontaneous bacterial peritonitis which carries high mortality rates.

US-guided or CT-guided drainage of ascites under IR is indicated in patients with peritoneal disease or for which 'blind' drain insertion would be unsafe due to the underling complicated anatomy.

In addition, IR will often insert tunneled drains for the chronic management of reaccumulating ascites despite repeated drainage.



Example of a CT-guided drainage of an abdominal fluid collection (asterisks in **A**). Axial CT images obtained before (**A**) and after (**B**) drainage. The cutaneous puncture site was in the lower abdomen; however, the tip of the drainage catheter (yellow arrows) was intentionally moved upwards as shown in **B** and **C** (coronal CT thick slab reconstruction).

/ Percutaneous Cholecystostomy

Septic patients with acute cholecystitis **deemed** not fit for **surgery (commonly ICU patients)** often require decompression of their distended gallbladder because of the **risk of perforation**.

Inflamed and distended gallbladders are often an 'easier' target if they adhere to the anterior abdominal wall making an anterior transperitoneal approach possible. Failing this, a transhepatic approach is also possible which encourages 'shrinking' of the gallbladder towards the drain and therefore a lower risk of drain displacement. It is important to also ascertain the patency of the cystic duct (CD) with a quick cholangiogram (i.e., injection of radio-opaque contrast and acquisition of fluoroscopic images to confirm contrast flow in the CD) to guide management > an obstructed CD carries a higher risk for re-infection and fistulation.

<∞> REFERENCE

> see also eBook chapters on Biliary Ducts, Pancreas and Spleen Imaging

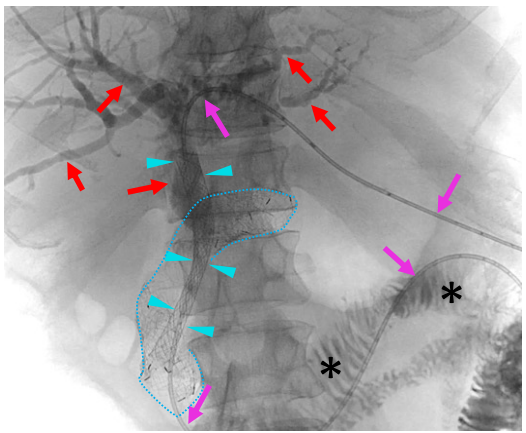
Jaundiced Patient with Cholangiocarcinoma or Hilar Masses

Jaundice secondary to obstructive lesions (e.g., cholangiocarcinoma or pancreatic cancer) with unsuccessful endoscopic drainage is managed with IR techniques. **Pre-operative imaging with MR cholangio-pancreatography (MRCP)** delineating the biliary anatomy, the level and the nature of obstruction with excellent resolution is essential.

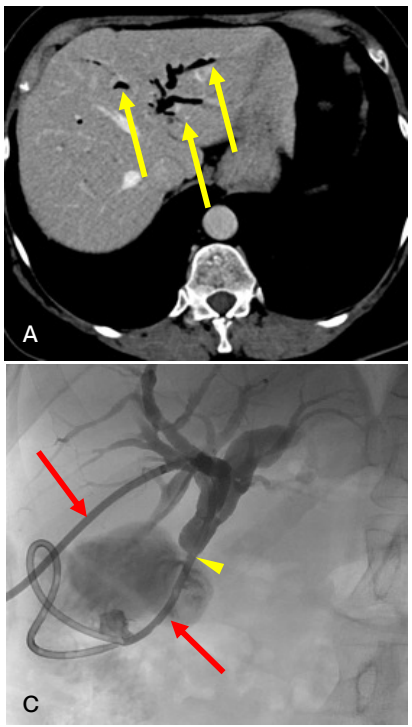
Whether a left or right-sided puncture is chosen to gain biliary access, depends on the underlying biliary dilatation and in both instances it is guided with US. Successful access into the biliary tree (and not the portal or venous systems) is confirmed by the behaviour of the injected contrast material, which tends to travel towards the hilum (as opposed towards the liver periphery). Crossing strictures or obstructions follow similar principles as obstructed vessels and once the intraluminal position is confirmed past the stricture, drainage catheter insertion can follow.

/ Examples of Percutaneous Transhepatic Cholangiography (PTC) and Percutaneous Transhepatic Biliary Drainage (PTBD)

PTC and PTBD are indicated for the evaluation of biliary anatomy in the presence of biliary obstruction when endoscopic retrograde cholangiopancreatography (ERCP) is unsuccessful.



Example of a PTBD (pink arrows). Dilated biliary ducts filled with contrast material (red arrows). Biliary stent (between arrowheads) and endoscopic duodenal stent (dashed line) from previous interventional procedures. Contrast material in the duodenum (asterisks).



Dilated biliary ducts and aerobilia (yellow arrows) seen on CT after iatrogenic damage of the main bile duct (**A** and **B**) and biliodigestive anastomosis. Successful external – internal biliary drainage (red arrows) by means of fluoroscopy-guided PTBD (**C**). Biliodigestive anastomosis site (arrowhead).

/ Urinary Tract Obstruction: Percutaneous Nephrostomy

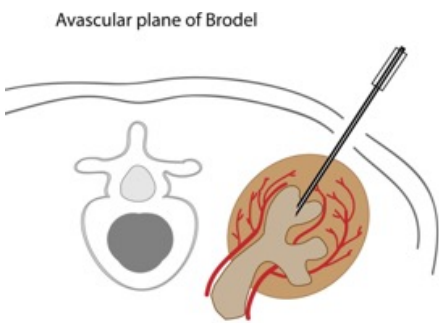
An **infected obstructive uropathy** can rapidly progress to progressive renal loss and septicaemia both of which are an indication for an urgent percutaneous decompressive nephrostomy. A good understanding of the renal anatomy is crucial for acquiring optimal US images and subsequently performing the puncture in the 'safe zone', often referred to as **avascular plane of Brodel**. This includes the most avascular part of the kidney, away from the renal pelvis, with the interpolar calyces in the middle and lower poles often targeted in a posterior approach.

Complications from an anterior approach include major vascular injury (renal artery or vein) or damage to adjacent organs (colon, liver, spleen). The steps followed are those performed in any Seldinger technique, with a pigtail catheter remaining in situ for decompression and source control in pyogenic cases. The established access can form an avenue for future ureteric stent placement in chronic obstructions in an antegrade approach.

/ Empyema: Thoracocentesis

Complicated pleural effusions may develop in a **malignant or parapneumonic setting** which may increase the likelihood of empyema. Whilst clinicians are often confident and skilled at performing 'blind' chest drain insertion on the wards for the drainage of simple or large effusions, an empyema or a complex effusion may require US-guidance.

Complications include pneumothorax and diaphragmatic injury. Good positioning of the patient is important and this is often performed seated with the back facing the operator. It is important to obtain a post-procedural chest radiograph to ensure the lung remains up.



Reproduced from : Bashir O, Avascular plane of Brodel (diagram). Case study, Radiopaedia.org (Accessed on 13 Aug 2024) https://doi.org/10.53347/rID-17859

/ Interventional Radiology

CHAPTER OUTLINE:

Miscel-laneous

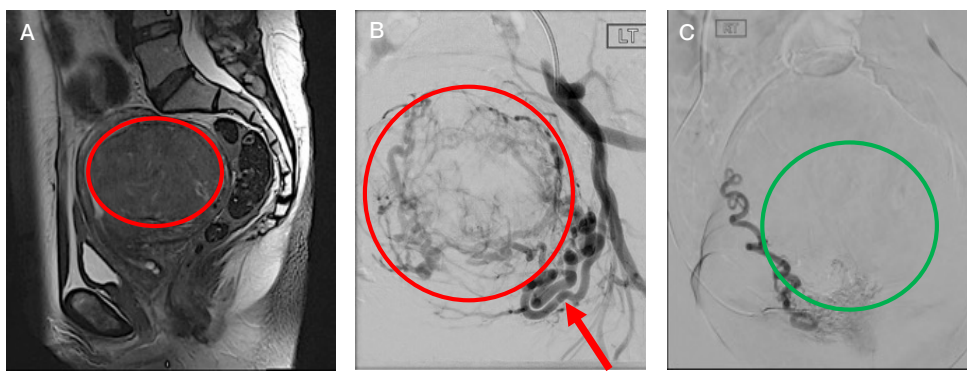
CHAPTER OUTLINE:

/ Women's Health – Uterine Fibroid Embolisation

Uterine fibroids are benign smooth muscle uterine tumours, often multifocal and hypervascular, typically growing during reproductive years. About 20% of women with fibroids experience heavy menstrual bleeding, anaemia, pelvic pain or pressure on adjacent organs. Hormonal treatment (oral contraceptives or intrauterine devices) are the first line treatment.

Uterine Fibroid Embolisation (UFE) is a minimally invasive alternative to surgical options (e.g., hysterectomy or myomectomy). Before UFE, a pelvic MRI is required. UFE involves accessing the femoral, brachial or radial artery and guiding a catheter into both uterine arteries, which appear corkscrew-like on angiography. Tiny particles are injected to block blood flow to the fibroids, causing ischaemic necrosis and reducing fibroid size. Post-procedure, patients often experience transient pelvic pain, fever and nausea requiring overnight hospital observation for management with pain relief, fluids and antiemetics.

UFE has a reduced risk of bleeding, infection and a shorter recovery time compared to surgery. Embolisation spares the uterus; however, there is a low risk (2-3%) of ovarian failure and premature menopause following embolisation.



Preprocedural MRI (**A**) showing a large intramural fibroid (circle). Angiography from the left common iliac artery (**B**) showing an enlarged uterine artery (arrow) with enhancement of the fibroid bed (circle). Right uterine artery angiogram post embolisation shows reduced blood flow (**C**).

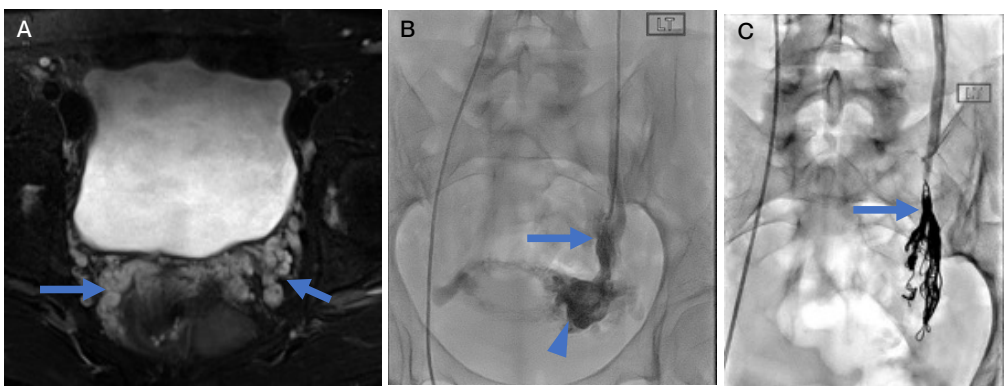
/ Interventional Radiology

CHAPTER OUTLINE:

/ Women's Health – Pelvic Congestion Embolisation

Pelvic congestion syndrome is a potential cause of **chronic pelvic pain**. Ovarian vein insufficiency results in engorgement of the ovarian and parametrial veins which can manifest with chronic pelvic pain, dyspareunia, dysmenorrhea and valval varicosities. On US, retrograde flow can be seen in the engorged ovarian and parametrial veins due to incompetent valves.

Percutaneous ovarian vein embolisation is a minimally invasive approach for treating pelvic venous congestion syndrome. Access is from the jugular or femoral vein. Under fluoroscopic guidance a catheter is advanced into the incompetent ovarian vein. The vein is embolised using coils, sclerosant or glue, thereby excluding the ovarian and parametrial veins from the hydrostatic pressure of the left renal vein and/or IVC. Blood can still drain from the parametrial veins through collateral vessels. The embolisation is a quick procedure. It can be performed on a day case basis resulting in less post-operative pain and quicker recovery times than surgery.



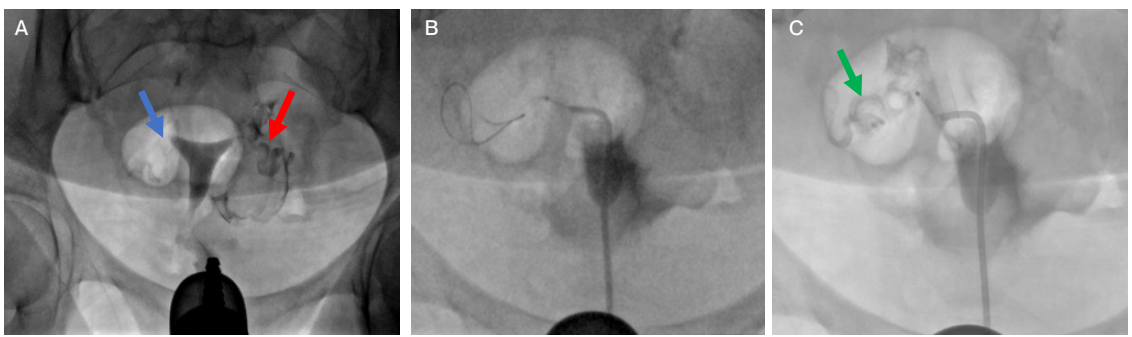
Arrows showing dilated parametrial veins in the pelvis (**A**). Venogram (**B**) demonstrating filling of the grossly dilated left ovarian vein (arrow) and opacification of the parametrial veins (arrowhead). **C**. Coil stack within the embolised left ovarian vein (arrow), stopping reflux of contrast inferiorly into the parametrial veins.

/ Women's Health – Fallopian Tube Recanalisation

Hysterosalpingography (HSG) is done to assess fallopian tube patency in women with subfertility.

A speculum placed in the vagina allows direct visualisation of the cervix. A catheter is then advanced into the uterine cavity. Contrast injected through the catheter should opacify the uterine cavity and fallopian tubes, spilling freely from their fimbriae into the peritoneum. In cases of tubal occlusion the fallopian tubes can be recanalised by clearing the tubal occlusion using hydrostatic pressure or with catheter and wire.

HSG offers a quick and accurate evaluation of tubal patency. Accuracy is superior to US-based assessment. Although laparoscopic evaluation remains the gold standard for assessing tubal patency, HSG is a quicker less invasive test that can be performed without the need for a general anaesthetic.



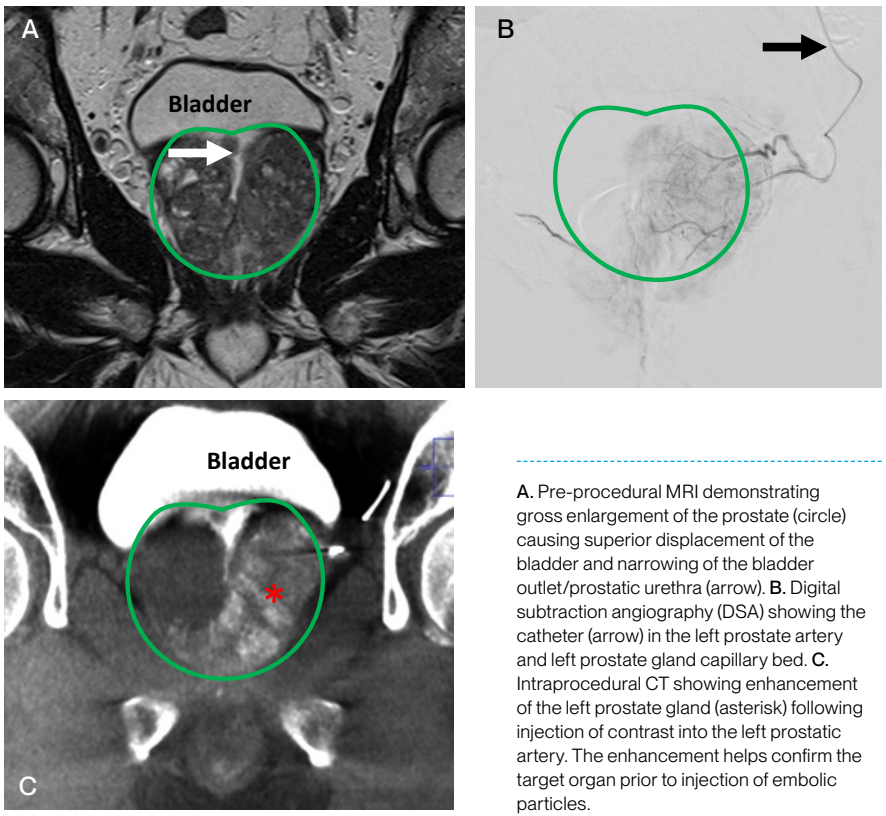
Fluoroscopic HSG images and right fallopian tube recanalisation. **A.** Initial HSG showing a normal uterine cavity and a patent left fallopian tube (red arrow). The right tube is blocked at the isthmus (blue arrow). **B.** Wire and catheter are advanced through the blocked right fallopian tube, clearing the obstruction. **C.** Post recanalisation contrast flush proves right fallopian tube patency (green arrow).

/ Men's Health – Prostate Artery Embolisation (PAE)

Benign prostatic hypertrophy (BPH) affects 70% of males aged > 60 years. Prostate enlargement can cause bladder outflow obstruction, resulting in lower urinary tract symptoms (nocturia, frequent urination and terminal dribbling).

Conventional treatment involves medication and surgical resection, known as transurethral resection of the prostate (TURP). Prostate artery embolisation (PAE) is a newer treatment option for patients with BPH. PAE is a minimally invasive percutaneous procedure performed via the femoral, brachial or radial artery. A catheter is sequentially guided into the left and right prostatic arteries, allowing transcatheter embolisation of the prostatic capillary bed with particles. This results in ischaemic necrosis and diminished prostate gland volume thus reducing outflow obstruction.

PAE offers shorter recovery times and lower rates of complications compared to TURP. Evidence suggests that PAE is also associated with lower rates of erectile dysfunction and retrograde ejaculation than TURP.



A. Pre-procedural MRI demonstrating gross enlargement of the prostate (circle) causing superior displacement of the bladder and narrowing of the bladder outlet/prostatic urethra (arrow). **B.** Digital subtraction angiography (DSA) showing the catheter (arrow) in the left prostate artery and left prostate gland capillary bed. **C.** Intraprocedural CT showing enhancement of the left prostate gland (asterisk) following injection of contrast into the left prostatic artery. The enhancement helps confirm the target organ prior to injection of embolic particles.

/ **Interventional** Radiology

CHAPTER OUTLINE:

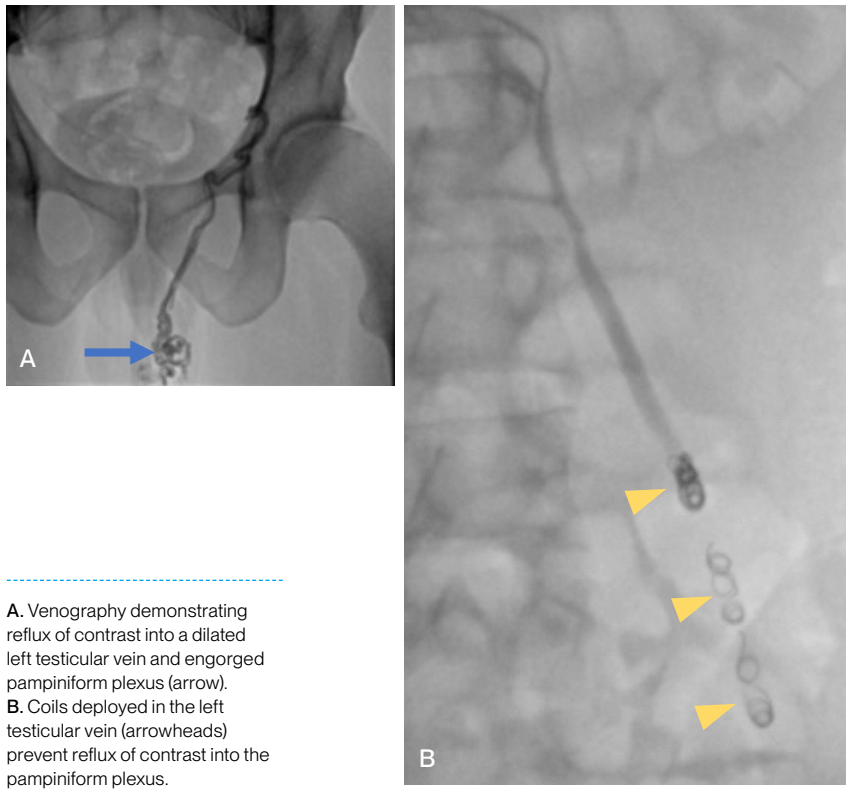
/ Men's Health – Varicocele Embolisation

A **varicocele** is an engorged pampiniform venous plexus in the scrotum caused by testicular vein insufficiency. The dilated venous plexus typically has a "bag of worms" description on clinical exam. 80-90% varicoceles are left sided as the left testicular vein drains into the left renal vein at an obtuse angle. The right testicular vein is less prone to insufficiency as drains at an acute angle into the IVC.

Clinical features include a heavy, dull aching pain in the scrotum. Varicoceles can be associated with reduced sperm counts and subfertility.

IR management of varicoceles involves transcatheter embolisation of the testicular vein via the femoral or jugular vein. The testicular vein is occluded with glue or sclerosant and coils. This act excludes the testicular vein from the hydrostatic back pressure of the left renal vein and IVC, reducing pampiniform engorgement. 89% of patients with symptomatic varicoceles report pain improvement at 1 year. Studies have also reported improvements in sperm counts and fertility rates post embolisation.

Varicocele embolisation is a minimally invasive day case procedure, associated with shorter recovery and hospital stays compared to surgical dissection and ligation.



A. Venography demonstrating reflux of contrast into a dilated left testicular vein and engorged pampiniform plexus (arrow).
B. Coils deployed in the left testicular vein (arrowheads) prevent reflux of contrast into the pampiniform plexus.

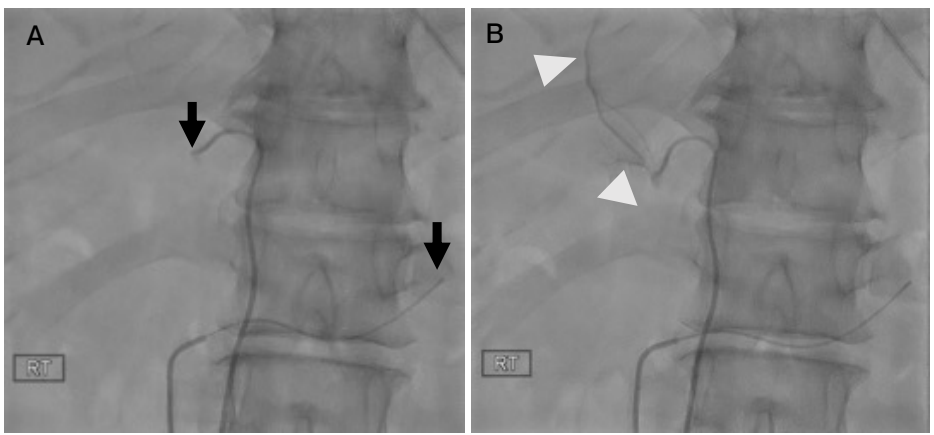
CHAPTER OUTLINE:

/ Adrenal Venous Blood Sampling

Venous sampling can be performed in patients with primary hyperaldosteronism (Conn's syndrome) to lateralise the dysfunctional adrenal gland. This guides surgical management, as identification and resection of the dysfunctional gland may be curative.

The procedure can be performed via the femoral or jugular vein. The adrenal veins are selectively catheterised. The left adrenal vein drains into left renal vein making it relatively straightforward to catheterise. The right adrenal vein is more challenging to catheterise owing to its variable drainage pattern. The adrenal venous plexus has a typical delicate branching pattern on venography. With catheters successfully positioned in both adrenal veins, blood samples are obtained for aldosterone and cortisol. Adrenal vein sampling can also be performed for Cushing's syndrome or in patients with elevated metanephrines and ambiguous imaging findings.

Adrenal venous sampling is a minimally invasive procedure that is vital for localising the dysfunctional adrenal gland to guide surgical resection.



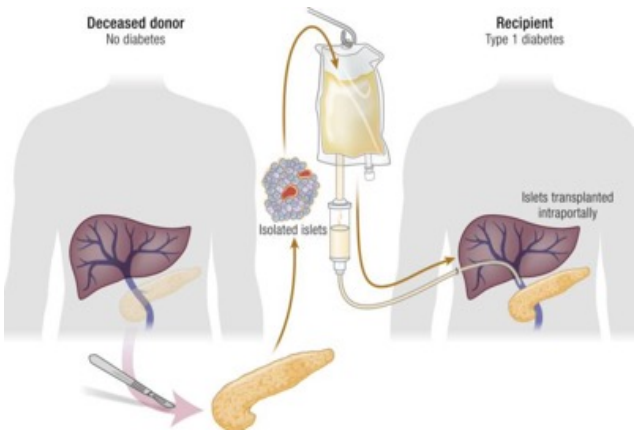
A. Two catheters are simultaneously placed in the right and left adrenal veins (arrows). **B.** Venography of the right adrenal vein. The "spider"-like appearance (arrowheads) is characteristic of the right adrenal venous plexus.

/ Islet Cell Transplant

Islet cell transplantation is a potential therapy for patients with type 1 diabetes who have labile glycaemic control and recurrent hypoglycaemic episodes. Islet cells are responsible for producing endogenous insulin and glucagon and transplantation aims to reduce reliance on exogenous insulin.

Islet cells are extracted from a deceased donor pancreas and prepared for infusion. Under US and fluoroscopic guidance, a catheter is advanced through the liver parenchyma into the portal vein of the recipient. The islet cells are injected into the portal vein and are carried to the liver where they engraft. The procedure may be repeated 2-3 times to achieve adequate levels of endogenous hormone production. Patients must take immunosuppression to prevent rejection.

Studies show that patients **have an improved glycaemic index, reduced insulin requirements and reduced incidence of hypoglycaemic episodes**, with insulin independence in up to 80% of patients at one year. Islet cell transplantation offers a minimally invasive alternative to whole pancreatic transplantation.



Reproduced from: Rickels MR, Robertson RP. Pancreatic Islet Transplantation in Humans: Recent Progress and Future Directions. Endocr Rev. 2019 Apr 1;40(2):631-668. doi: 10.1210/er.2018-00154. PMID: 30541144; PMCID: PMC6424003.

CHAPTER OUTLINE:

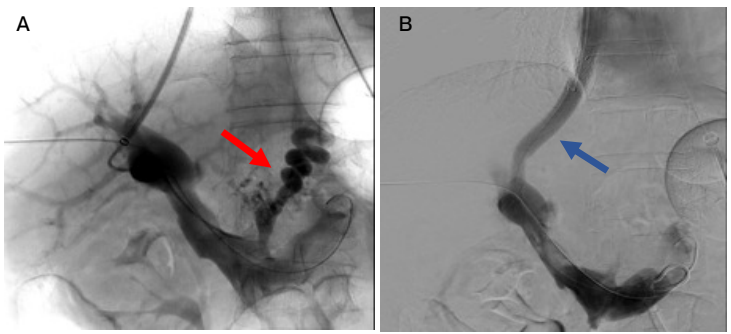
/ Transjugular Intrahepatic Portosystemic Shunt (TIPS)

A **Transjugular Intrahepatic Portosystemic Shunt (TIPS)** is a complex procedure usually performed for refractory ascites or variceal bleeding in patients with chronic liver disease and portal hypertension. Other indications include hepatic hydrothorax, hepatorenal syndrome and Budd Chiari. A portosystemic shunt allows portal venous blood to bypass the high resistance liver bed, relieving portal hypertension. Important contraindications include hepatic encephalopathy and right heart failure, both of which a TIPS can potentiate.

> see also page 91 of this chapter

Via a transjugular access, a catheter is guided into the right hepatic vein. **A specifically designed needle** is used to puncture from the hepatic vein, through liver parenchyma into the adjacent portal vein. A wire is passed between the two venous systems over which a stent is deployed to connect the portal and hepatic veins. Bleeding varices arising from the portal veins can be embolised using the stent as access to the portal system. A subsequent procedure may be required to alter stent diameter which alters the rate of portosystemic shunting depending on clinical need.

TIPS has largely superseded surgical created shunts, as it is a minimally invasive procedure associated with quick recovery times and lower mortality rates.



A. Intraprocedural portal venogram in a patient with intractable upper GI bleeding. Dilated portal venous system with prominent esophageal varices (red arrow). **B.** Repeat portal venogram post TIPS. Injected portal venous contrast bypasses the liver parenchyma into the hepatic vein and right atrium via the newly created shunt (blue arrow). No further filling of the upper abdominal varices.

/ Treatment of Non-Cancer Related Pain

The most common form of chronic MSK pain in non-cancer patients is low-back pain with or without irradiation to the lower limbs. The condition is very common and it negatively impacts patients' quality of life. The social burden is severe due to high consumption of analgesics and high number of working days lost. Underlying clinical conditions include arthritis, disc degeneration/herniation and disco-radicular conflicts.

The goal of most interventional treatments proposed in this scenario is to alleviate the invalidating pain in the acute/sub-acute phase. Interventional treatments are proposed **after failure of conservative measures** (i.e., analgesics, rest) over a period of 2-6 weeks. Before intervention, **patients are evaluated in a dedicated interventional radiology out-patient clinic** with an accurate clinical exam to precisely assess pain type and territory along with other possible associated symptoms (i.e., lower limb paraesthesia, motor deficits, etc.). Then clinical-radiological correlation is done to confirm through imaging the origin of pain and to identify the potential target of subsequent percutaneous treatment. Ideally, a recent (< 6 weeks) MRI is the best imaging modality to be used for this purpose.

Interventions are performed under local anaesthesia and CT or X-ray guidance on an outpatient basis. Strict sterile conditions are mandatory since one of the most worrisome complication is infection (spondylitis, spondylodiscitis, epiduritis, etc.). No antibiotic coverage is needed. After the procedure patients are observed for around 1h in the interventional clinic and are thereafter discharged if the post-procedural observation period is uneventful.

Patients are usually seen 2-4 weeks after intervention to evaluate the clinical result. Precise pain scales, such as the 0-10 visual analogue scale (VAS score) should be used at the baseline and at follow-up to objectively rate the clinical outcome.

Procedure-related adverse events are very rare (< 1%). Other than infections, other possible worrisome adverse events include accidental puncture/lesion of nervous structures including the meningeal layers or accidental puncture of vascular structures. This latter event may eventually lead, although in very rare occasions, to severe neural deficits due to thrombosis of arterial supply to the spinal cord.

/ Epidural and Foraminal Steroid Injections

Epidural and foraminal injections deliver steroids to alleviate pain originating from the anterior epidural area or the foramen, often caused by a herniated disc pressing on neural structures.

The injections aim to provide **local anti-inflammatory effects** by delivering small doses of steroids directly to the affected area. This reduces the painful inflammation associated with mechanical compression without the side effects of high-dose systemic steroids. Although these injections do not resolve the underlying mechanical conflict, the reduction in inflammation usually offers significant pain relief.

These injections are **commonly recommended for patients with low-back pain that radiates to the lower limbs and for those with a narrow spinal canal**. The procedure involves positioning the patient prone on a CT or fluoroscopy table.

In epidural injections, a 22G needle is used to target the posterior epidural space, confirmed by injecting a few ml of sterile CO_2 or iodine contrast medium before delivering the steroids.

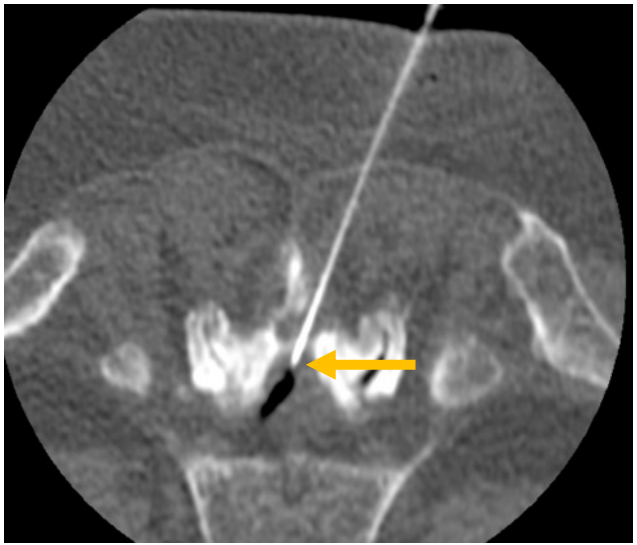
Foraminal injections follow a similar process but focus on the **posterior aspect** of the foramen. To avoid puncturing neurovascular structures, the needle tip is kept outside the foramen and iodine contrast medium is injected to confirm correct placement before injecting the steroids. This procedure can also be performed at the cervical level using a lateral or posterior approach.

Pain relief may take 24-48 hours as long-lasting steroids are used and **relief is reported in up to 70% of patients**. In case of recurrence, the injection can be repeated.

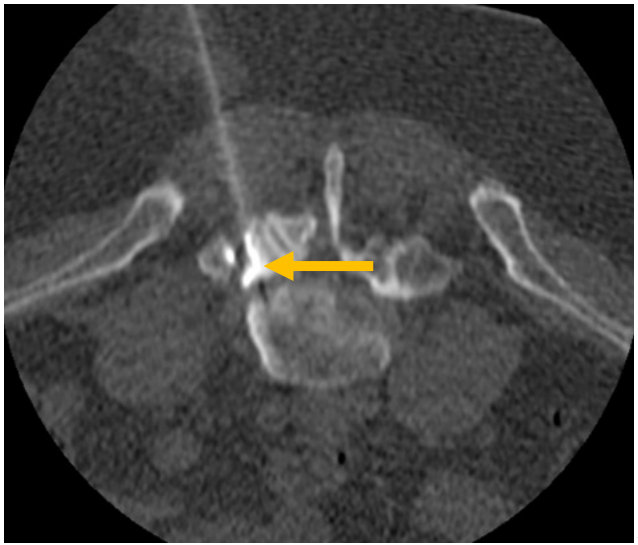
> See examples on the next page.

Interventional Radiology

CHAPTER OUTLINE:



Epidural injection at the L5-S1 level. CO_2 is injected in the posterior epidural space (arrow) to confirm good needle positioning before injecting steroids.



Foraminal injection at the left L5-S1 foramen. Iodine contrast medium is injected at the posterior aspect of the neuroforamen (arrow) to confirm the extra-vascular position of the needle tip before injecting steroids.

/ Facet Joint Injections

Facet joint syndrome is caused by severe arthrosis, leading to pain in the paraspinal area, often radiating to the buttocks or posterior thighs but rarely below the knee. This pain intensifies when patients are seated or standing for extended periods and can be triggered by palpation of the facet joint or hyperextension of the dorsal spine.

Injection therapy involves positioning the patient prone and using a bevelled 22G needle to approach the inferior aspect of the facet joint. Steroids, sometimes combined with anaesthetics, are injected into the joint space. If severe arthrosis blocks needle access to the joint, the injection can be administered close to the joint instead.

The injection serves two purposes:

- providing fast and effective pain relief and
- acting as a diagnostic "block-test." If pain relief, even minimal or temporary, is achieved, it confirms the affected level, making the patient a candidate for rhizolysis

Rhizolysis, often performed using radiofrequency ablation (RFA), destroys the neural structures that supply sensation to the facet joint, offering longer-term pain relief.

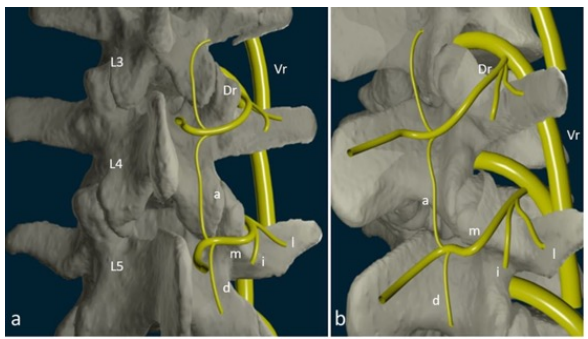
Bilateral facet joint injection at the L5-S1 level. Needles tips are inserted into the articular space by targeting the lower aspect of the facet joints.

/ Radiofrequency Ablation of Facet Joints (Rhizolysis)

Radiofrequency ablation of facet joints, also known as rhizolysis, is exclusively proposed to patients with a previous positive block test (see previous page). The goal of the treatment is to thermically destroy the sensitive branches supplying the facet joint to allow a long-lasting pain relief.

Each facet joint is supplied by nervous filaments arising from the **medial branches of the dorsal rami above and below the joint**. Accordingly, **rhizolysis must be performed on two different levels** to achieve denervation of one level. In order to achieve focal nerve destruction, after administering local anaesthesia in the subcutaneous tissues, an RFA electrode is deployed near the nerve by using precise anatomical landmarks (i.e., superior-medial border of the transverse vertebral processes above and below the pathologic joint).

After, inducing sensitive and motor stimulation to verify that the electrode is not close to the nerve root exiting their respective neural foramina, the electrode is activated at temperatures > 60°C for 90 seconds. This will provide limited necrosis extending to the medial branches of the dorsal rami. Long-lasting pain relief is obtained in up to 70% of patients. In case of pain recurrence, treatment can be repeated. Overall, occurrence of procedure-related complications is anecdotical.



Innervation of facet joints (L3–4, L4–5 levels). Vr: ventral ramus. Dr: Dorsal ramus. m: medial branch. i: intermediate branch. l: lateral branch a: ascending branch. d: descending branch. Posterior (**a**) and posterolateral (**b**) view of the lumbar spine.

Images from: Perolat R, Kastler A, Nicot B, Pellat JM, Tahon F, Attye A, Heck O, Boubagra K, Grand S, Krainik A. Facet joint syndrome: from diagnosis to interventional management. Insights Imaging. 2018 Oct;9(5):773-789. doi: 10.1007/s13244-018-0638-x. Epub 2018 Aug 8. PMID: 30090998; PMCID: PMC6206372.

/ Interventional Radiology

CHAPTER OUTLINE:

/ Take-Home Messages

- **Interventional Radiology (IR) is a minimally invasive technique** that uses fluoroscopy, CT, US and MRI to guide small instruments through the body, often via blood vessels, to treat a variety of conditions without the need for traditional surgery.
- IR procedures are performed with **real-time imaging**, allowing **precise targeting** of treatment areas while **minimising damage** to surrounding tissues.
- Many IR procedures are done on an outpatient basis or require only a short hospital stay, resulting in faster recovery times and less post-procedure pain.
- The spectrum of IR procedures is very wide and includes:
  - Vascular interventions: angioplasty and stenting, embolisation, thrombolysis/thrombectomy, TIPS
  - Oncological Interventions: ablation therapies (RFA, MWA, cryotherapy), chemoembolisation (TACE) and radioembolisation
  - Gastrointestinal and hepatobiliary interventions: percutaneous transhepatic cholangiography, biliary drainage and percutaneous gastrostomy tube (PEG) placement
  - Genitourinary interventions: nephrostomy, uterine artery and prostate embolisation, varicocele embolisation, Fallopian tube recanalisation
  - Spinal and musculoskeletal interventions: vertebroplasty/kyphoplasty, joint injections/aspirations
  - Neurological interventions: intracranial aneurysm coiling, mechanical thrombectomy

- Utility and benefits of IR are numerous. They include:
  - **Targeted treatment** minimising collateral damage to healthy tissue
  - **Reduced risks** compared to open surgery, including lower infection rates and reduced blood loss
  - **Faster recovery** leading to shorter hospital stays and a faster return to normal activities
  - **Broad applicability** across a wide range of medical fields, including oncology, cardiology, gastroenterology, urology and neurology as mentioned above
- IR is a **rapidly evolving field** that offers **effective, less invasive treatment options** for a broad spectrum of diseases. Its use of real-time imaging and minimally invasive techniques makes it a crucial part of modern medicine, offering patients safer and faster alternatives to traditional surgical procedures.

CHAPTER OUTLINE:

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CHAPTER OUTLINE:

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<?> QUESTION

1

47-year-old female presenting with dysuria, reduced urine output and pyrexial. A non-contrast abdominal CT revealed obstructive ureteric stone and upstream unilateral hydronephrosis. Which amongst the following is the most appropriate definitive management step for source control? (one or several correct answers)

- ☐ Percutaneous nephrostomy
- ☐ Urinary catheterisation
- ☐ Use of diuretics
- ☐ Intravenous fluids
- ☐ Intramuscular non-steroidal anti-inflammatory drugs

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27-year-old male presenting with a penetrating injury to the anterior abdomen with haemodynamic instability. A contrast blush is demonstrated in a CT arterial phase study in the gluteal region with an evolving acute haematoma. Which amongst the following is the most appropriate management step for haemorrhage control? (one correct answer)

- ☐ Blood transfusion
- ☐ Tranexamic acid
- ☐ Percutaneous embolisation
- ☐ Referral to trauma surgery
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<?> QUESTION

3 35-year-old female presenting with acute shortness of breath and chest pain. On examination, she is haemodynamically unstable with partial response on initial resuscitation. Having underwent a CT pulmonary angiogram, a large central pulmonary embolus was noted. What is the role of Interventional radiology in pulmonary embolism management? (one or several correct answers)

- ☐ Catheter directed thrombolysis
- ☐ Mechanical thrombectomy
- ☐ Contribution in a Pulmonary Embolism Response Team
- ☐ Help stratify patients in medium/high risk

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4 Which of the following nerve blocks is commonly used to manage pain related to abdominal cancers or chronic pancreatitis? (one or several correct answers)

- ☐ Lumbar Sympathetic Block
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- ☐ Caudal epidural injection
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/ Test Your Knowledge

<?> QUESTION

6 What is/are key advantages of Musculoskeletal (MSK) interventions compared to traditional open surgeries? (one or several answers can be correct)

- ☐ They are suitable in treating complex and extensive lesions
- ☐ They are typically performed through small incisions
- ☐ They result in minimal disruption to surrounding tissues
- ☐ They have greater corrective ability for anatomical deformity than surgery
- ☐ They have lower rates of symptom recurrence compared to surgery

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<?> QUESTION

7 Which of the following is a temporary embolic material? (one correct answer)

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- ☐ 6 hours
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9 Regarding angioplasty and stenting for the treatment of peripheral arterial disease, which of the following is true? (one correct answer)

- ☐ Cannot be performed using only local anaesthesia
- ☐ Cannot be repeated in case of symptoms relapse
- ☐ Results in technical success rates comparable with open surgical procedures, in appropriately selected patients.
- ☐ None of the above

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<?> QUESTION

10 Concerning epidural injections, which of the following statement is false?

- ☐ Needle should target the anterior epidural space
- ☐ Before injecting drugs, goof needle positioning is confirmed by injecting sterile CO_2 or iodine contrast medium
- ☐ They are proposed for low-back pain radiating to the lower limbs
- ☐ They can be proposed to patients with severe symptomatic stenosis of the spinal canal
- ☐ They need fluoroscopic or CT guidance

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