قسم تقنيات الأشعة والسونار
Radiological procedure

د. زهراء نافع الصافي
بورد عربي (دكتوراه) الاشعة التشخيصية والسونار
M.B.Ch.B CABHS(RAD)
Imaging modalities of bone and joints
Types of modalities of bone and joints imaging:

- Plain film
- Arthrography
- Radionuclide imaging
- Ultrasound (US)
- Computed tomography (CT)
- Magnetic resonance imaging (MRI)
Plain films:

- These are inexpensive, widely available, and valuable screening tools.
- Very useful in the characterization and differential diagnosis of disease—e.g. trauma, bone tumours, and arthritis.
- The single most important investigation in the characterization of bone tumors.

**Limitation**

Pathological processes producing osteolysis or osteosclerosis, e.g., infection, tumours, articular erosions, are well advanced before they become radiographically visible, and radiographs may appear normal.
Arthrography

- The injection of contrast medium directly into the joint
- The examination can then be supplemented with:
  - **CT**: injection of radiographically positive (iodinated) or negative (air) contrast medium
  - **MRI**: using a dilute gadolinium-diethylenetriaminepenta-acetic acid (DTPA) solution
Radionuclide imaging

- Bone scintigraphy have a high sensitivity but a low specificity.
- Demonstrates increased specificity for infection and stress injuries/fractures.
- It is widely used in the detection and follow-up of metastatic disease, and painful joint arthroplasties.
- Characterization of lesions detected by other modalities.
Musculoskeletal US is now commonly used for evaluating disorders in both adult and pediatrics age groups.

Periarticular structures (capsule, ligaments, and tendons) are optimally imaged.

Under US guidance, therapy to soft-tissue disease can be accurately targeted, and joint fluid aspirated and arthrographic agents instilled into joints.
CT.

- This is very useful in complex bone trauma for accurate surgical planning, and also in many applications in assessment of bone tumors and infection.

- CT optimally depicts joint anatomy and pathology in joints that are difficult to image in two perpendicular planes and where there is bone overlap—e.g. shoulder, hip, sternoclavicular, and sacroiliac joints.

- When employed as CT arthrography, the intraarticular status of joints can be optimally assessed.
MRI is the best imaging modality for joint assessment.

In the knee, it can be the first and only form of imaging required.

In the shoulder, MRI alone is used to image the rotator cuff, but MR arthrography is required for optimal imaging of the ligaments, capsule, and labrum in posttraumatic instability.

MRI arthrography can also be used in the hip primarily to image the labrum in the wrist to assess the interosseous ligaments of the proximal carpal row and the triangular fibrocartilage.

Indirect MR arthrography: intravenous (i.v.) injection of contrast, which diffuses into the joint via the synovium, is used in the detection of active synovitis, e.g. RA, and also valuable in small joints and in the postoperative assessment of large joints.

MRI is widely used in the assessment of bone pathology, such as tumor or infection.
Thank You!
MUSCULOSKELETAL MAGNETIC RESONANCE IMAGING
**General points:**

- There is a large variety of MR sequences used in MSK imaging:

<table>
<thead>
<tr>
<th>Tissue types</th>
<th>T1 + T2</th>
<th>STIR</th>
<th>T1 contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Cartilage, meniscus</td>
<td>PD</td>
<td>T2 +/- FS</td>
<td></td>
</tr>
<tr>
<td>Labrum</td>
<td>T1FS (arthrogram)</td>
<td>PD (arthrogram)</td>
<td>PD Fat sat</td>
</tr>
<tr>
<td>Tendons/ligaments</td>
<td>T2 FS</td>
<td>PD</td>
<td>T1</td>
</tr>
<tr>
<td>Muscle</td>
<td>T1</td>
<td>T2 FS</td>
<td>STIR</td>
</tr>
<tr>
<td>Synovium</td>
<td>T1 fat sat (i.v. gadolinium)</td>
<td>T1 spin echo (i.v. gadolinium)</td>
<td>PD fat sat</td>
</tr>
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</table>
PD vs T2FS
T1FS arthrogram
Tendon
i.v. gadolinium-DTPA is used in musculoskeletal imaging for:

- (a) infections—to differentiate abscess from phlegmon
- (b) tumors—to differentiate viable tumour from necrosis, to differentiate solid from cystic components
- (c) postoperative spine—to differentiate recurrent disc herniation from scar tissue
- (d) synovial disease, e.g. rheumatoid arthritis, to determine activity/response to treatment
- (e) avascular necrosis, e.g. Perthes’ disease, scaphoid fracture, to show viable tissue
- (f) indirect MR arthrography—to delineate articular cartilage status, meniscal repair
**Direct MR arthrography** involves joint puncture and the intraarticular injection of a dilute gadolinium. (Saline and local anaesthetic can also be used.) The

- concentration of gadolinium needed to is very small (2 mmoL, 1.5 T),
- allows accurate visualization of the labrum of the hip, the operated meniscus in the knee, and demonstrating associated osteochondral defects, loose bodies, and synovial pathology,
- T1 spin echo, T1 fat-saturated and proton density (PD) sequences are used routinely in MR arthrography

**Indirect MR arthrography:**
Thank You!
Arthrography
**General points:**

- The conventional radiographs should **always** be reviewed prior to the procedure.
- Aspiration of an effusion should **always** be performed before contrast medium is injected. The aspirate should be sent for microscopy, culture, crystal analysis, cytology, and biochemistry.
- The needle should be correctly sited within a joint space, a test injection of a small volume of contrast medium will stream away from the needle tip around the joint. However, if it is incorrectly sited, the contrast medium will remain in a diffuse cloud around the tip of the needle.
- Needle placement may be ‘blind’ or under image guidance, e.g. fluoroscopy, CT, CT fluoroscopy, or US.
- The contrast medium is absorbed from the joint and excreted from the body within a few hours. However, intraarticular air may take up to 4 days to be completely absorbed from the joint space. Every effort should be made to eliminate air bubbles at injection for MR arthrography, as they create artifacts.
General points:

- Arthrography is well tolerated by patients.
- Arthrography is a very safe procedure with low complication rates.
- In a major study there were 3.8% minor complications (vasovagal reaction, pain, synovitis) and 0.02% major complications (anaphylactic reaction, infection).
- In the scheduling of CT and MR arthrography, it is important to ensure that the examination is carried out within 30–45 min of intraarticular contrast medium instillation. After this, time contrast medium absorption can potentially result in a suboptimal examination with resultant difficulties in interpretation.
Indications of arthrography

• 1. Intraarticular structural abnormalities—e.g. cartilage, labrum (osteochondritis dissecans in knee, ankle), labral tears (shoulder and hip),
2. Capsular, ligamentous, and tendon injuries—Information regarding the presence, type, extent, gap, and edges of torn

3. **Loose body**: solitary or multiple, radiolucent, or radio-opaque. CT arthrography using dilute contrast medium solution best depicts radiolucent bodies. Double-contrast CT arthrography using only a small amount of positive contrast medium is best to delineate radio-opaque loose bodies, determine true size, and assess articular status of the joint.

4. **Para-articular cyst**—Synovial cysts and ganglia

5. **Prosthesis assessment**—e.g. loosening, infection.

6. **Pain block**—e.g. ropivacaine ± steroid therapy.
• **7. Diagnosis and distension therapy in adhesive capsulitis** employed in the shoulder in the treatment of frozen shoulder, the combination of anaesthetic, steroid, and saline can be used to distend and rupture the joint after arthrographic confirmation of the diagnosis.

• **8. Intraarticular chemical therapy**—e.g. hyaluronic acid, fibrinolysis, in mild to moderate osteoarthritis reducing pain and increasing the articular cartilage thickness.
Contraindications

• 1. Local sepsis
• 2. Allergy to iodine or gadolinium
• 3. Contraindication to MRI; consider CT arthrography.
Contrast Medium

- **Conventional/computed tomography arthrography**
  - Low osmolar contrast material (LOCM) is used.
  - For the purposes of CT arthrography, a dilute solution (100–150 mg iodine/100 mL).
  - The volume of the contrast medium needed is directly proportional to the capacity of the joint e.g. 15 mL in the shoulder, 6 mL in the elbow, and 3 mL in the wrist.
  - Double-contrast examination of the knee for a CT arthrogram to assess the patellofemoral joint requires 4 mL iodinated contrast medium with 40 mL of air.

- **Magnetic resonance arthrography**
  The contrast used may be made up to contain both dilute gadolinium-DTPA and iodinated contrast (which is needed to confirm correct needle placement during injection), e.g. a combination of:
  - (a) 0.1 mL gadolinium-DTPA,
  - (b) 10 mL sterile saline solution, and
  - (c) 2 mL LOCM 200 mg I mL−1.
• **Equipment**
  1. Fluoroscopy unit with spot film device and fine focal spot.
  2. Overcouch tube
• **Patient Preparation**
  None.
• **Preliminary Images**
  Routine acquisition and evaluation of joint radiographs is recommended.
• **Aftercare**
  Driving after the procedure is not advisable.
  The patient is warned that there may be some discomfort in the joint for 1–2 days after the procedure.
  The injected air for a double-contrast procedure precludes air travel.
Complication

• *Due to the contrast medium*
  • 1. Allergic reactions
  • 2. Chemical synovitis

• *Due to the technique*
  • 1. Pain
  • 2. Infection
  • 3. Capsular rupture/extravasation
  • 4. Trauma to adjacent structures—e.g. neural/vascular structures
  • 5. Air embolus (rare)

• *Other Vasovagal reaction.*
Thank You!
Radionuclide Bone Scan
Indications

• 1. Staging of cancer and response to therapy, especially breast and prostate.
• 2. Assessment and staging of primary bone tumors.
• 3. Painful orthopedic prostheses to differentiate infection from loosening
• 4. Bone or joint infection
• 5. Trauma not obvious on x-ray, e.g. stress fractures
Indications

• 6. Bone pain
• 7. Avascular necrosis and bone infarction
• 8. Assessment of nonaccidental injury in children
• 9. Metabolic bone disease for complications such as fractures
• 10. Arthropathies, e.g. rheumatoid
• 11. Reflex sympathetic dystrophy
• 12. Assessment of extent multifocal disorders such as Paget’s disease and fibrous dysplasia
**Contraindications**: poor renal function

- **Radiopharmaceuticals**
  - $^{99m}$Tc-methylene diphosphonate (MDP) or other $^{99m}$Tc-labelled diphosphonate
  - These compounds are phosphate analogues, which are stable rapidly excreted by the kidneys, providing a good contrast between bone and soft tissue.

- **Equipment**
  - Gamma-camera, preferably with SPECT-CT and whole body imaging..
• **Patient Preparation:**
  The patient must be well hydrated.
  Remove any metal object.
  Optimized renal function test.

• **Technique**
  1. 99mTc-diphosphonate is injected i.v.

  A three-phase study is then performed with arterial, blood-pool, and delayed static imaging.

• **Three-phase**
  1. *Arterial phase 1:* 1–2 s frames of the area of interest for 1 min post injection
  2. *Blood pool phase 2:* 3-min image of the same area 5 min post injection
  3. *Delayed phase 3:* views ≥2 h post injection, as for standard imaging
Technique ..

• 2. The patient should be encouraged to drink plenty and empty the bladder frequently to minimize radiation dose.
• 3. The bladder is emptied immediately prior to imaging to prevent obscuring the sacrum and bony pelvis.
• 4. \textbf{(Delayed static imaging)} is performed $\geq 2$ h after injection—up to 24 h for imaging of extremities and up to 6 h for those patients on dialysis or in renal failure.
Images

• **Standard**
  High-resolution images are acquired of The whole skeleton.

• Anterior oblique views of the thorax are useful to separate sternum and spine uptake.

• For examination of the posterior ribs, scapula, or shoulder, an extra posterior thorax view with arms above the head should be taken to move the scapula away from the ribs.
• **Aftercare**
  Normal radiation safety precautions.

• **Complications**
  None.

• **Competing modalities**
  • FDG-PET and whole body MRI (e.g. with diffusion weighted techniques) may be competitive for oncological purposes.
  • MRI is often preferred for localized orthopedic applications, but has limited applicability in the presence of a prosthesis; however, recent advances in MRI techniques are now allowing excellent assessment of prosthesis.
Normal vs Paget
Stress fracture vs metastasis
Thank you!
Method of imaging the brain

DR. ZAHRAA NAFAEA
M.B.CH.B.CAB(RAD)
Imaging the brain’s structure and examining its physiology, both in the acute and elective setting are:

- **1. Computed tomography (CT).**
  
  This is the technique of choice for the investigation of serious head injury; for suspected **intracranial hemorrhage (ICH), stroke, infection and other acute neurological emergencies.**
  
  CT is quick, efficient and safer to use in the **emergency situation** than MRI.
2. MRI

- **Magnetic resonance imaging (MRI).** This is the best and most sensitive imaging modality for the brain.

- Widely used in epilepsy imaging, acute stroke, aneurysm detection and follow-up posttreatment of neoplastic and vascular disorders.

- It is the only effective way of diagnosing multiple sclerosis.
3. Angiography

- Angiography. This is very important in:
  - ICH (intracranial hemorrhage), especially subarachnoid hemorrhage (SAH) and management of ischemic stroke.
  - Preoperative assessment of tumors.
  - Vascular malformations (AVM = arteriovenous malformation).
  - Angiographic is vital for the performance of many neuro-interventional procedures.
4. Radionuclide imaging.

- There are two principal methods.
- The first is **regional cerebral blood flow scanning**, e.g. dementia, and in movement disorders such as Parkinsonism.
- second is positron emission tomography (PET). By this method, focal hypermetabolism may be shown using 18F fluorodeoxyglucose (e.g. in epilepsy and tumor).
5. Ultrasound (US).

- This is particularly helpful in neonates and during the first year of life using the fontanelles as acoustic windows. to image:
  - hemorrhagic and ischemic syndromes.
  - developmental malformations.
  - hydrocephalus

- In adults, transcranial Doppler may be used for intracerebral arterial velocity studies to assess the severity of vasospasm.
6. Plain films

- Plain Xray of the skull. These are of little value except in head injury.
THANK YOU!
Method of Brain imaging 2

DR. ZAHRAA NAFEA
Specialist Radiologist
CT brain imaging

- **Indications**
  1. **Following major head injury** (if the patient has lost consciousness, impaired consciousness, or has a neurological deficit). The presence of a skull fracture.
  2. In suspected intracranial infection (the use of contrast enhancement is recommended).
  3. For suspected ICH and cases of ischemic and hemorrhagic stroke. These can be combined with vascular imaging.
  4. In suspected raised intracranial pressure

In other situations, such as epilepsy, migraine, suspected tumor, demyelination, dementia and psychosis, **CT is a poorer-quality tool**. If imaging can be justified, MRI is greatly preferable.
Technique

1. Most clinical indications are covered by 3-mm sections parallel to the floor of the anterior cranial fossa, from the foramen magnum to the vertex, window Review of all trauma studies should be done on brain windows, bone and ‘blood windows’.
Brain, bone and blood window
2. In suspected infection, tumors, vascular malformations and subacute infarctions, the sections should be repeated following intravenous (i.v.) contrast enhancement.
3. CT angiography: using iodinated contrast are used in head trauma, the assessment of intracerebral bleeding, aneurysmal SAH, ruptured arteriovenous shunts and dural venous sinus thrombosis.
MRI brain imaging

- Improved contrast resolution between grey and white matter and cerebrospinal fluid (CSF); the removal of artifact due to bone close to the skull base and in the posterior fossa.

- T1-weighted sequences: Short TR and short TE sequences
  - T1 spin echo
  - Post gadolinium
  - MRA (angiography) time of flight 2D,3D
  - Contrast enhanced MR angiography
- **T2 weighted sequences**: Long TR and long TE.
  - T2-weighted turbo spin echo imaging

- **Proton density sequences**: long TR and short TE - used mostly for the assessment of demyelination and intraarticular disc changes in the temporomandibular joints.
Gradient-echo T2-weighted sequences (T2*)

- very sensitive to the presence of blood products (Hemosiderin produces focal loss of signal).
- Uses: all patients with a history of head injury, SAH and cavernomas, and other causes of hemorrhage, and can be used in deposition disorders (hemochromatosis).
susceptibility weighted imaging (SWI)

- High resolution, 3D gradient echo (GE)
- More sensitive than T2* for **small amount** blood and ca+.
FLAIR sequences (fluid attenuated inversion recovery)

T2WI with suppression of fluid signal

- Used in the detection of demyelinating plaques (multiple sclerosis) and infarcts, and have the advantage that juxta ventricular pathology contrasts with dark CSF, and is not lost by proximity.
Angiographic sequences.

This is a very short TR, T1-weighted gradient echo 3D sequence.

- Image display is by so-called MIP = maximum intensity projection,
- high signal from blood products in the subarachnoid space may reduce the sensitivity to aneurysms.
- **Contrast-enhanced MR angiography** requires a pump injector and is less susceptible to flow artifacts.
diffusion weighted imaging (DWI).

- Uses of DWI on all patients with suspected stroke, vasculitis, encephalitis, abscesses and in the workup of intracranial tumors.
- DWI examines the free movement, or Brownian motion, of water molecules at a cellular level. In acute infarcts cytotoxic oedema prevents free movement of water, whereas in tumors there is no restriction.
- All DWI should be reviewed together with conventional sequences and apparent diffusion coefficient (ADC) maps.
- Acute infarcts are hyperintense on DWI and hypointense on ADC.
Infarction
Abscess
tumor
Methods of Imaging the Thyroid and Parathyroid Glands

DR. ZAHRAA NAFEYA
M.B.CH.B.CAB.(RAD)
SPECIALIST RADIOLOGIST
Methods of scanning:

- 1. US
- 2. CT
- 3. MRI
- 4. Radionuclide imaging, including PET.
- 5. Plain film (limited to for assessment of superior mediastinal extension of thyroid goiter and any secondary tracheal displacement and narrowing).
Ultrasound of the thyroid gland

- **Indications**
  - 1. Palpable thyroid mass.
  - 2. Screening high-risk patients.
  - 3. Suspected thyroid tumor.
  - 4. ‘Cold spot’ on scintigraphy or increased avidity on PET.
  - 5. Suspected retrosternal extension of thyroid.
  - 6. Guided aspiration or biopsy.
Contraindications: None.
Patient Preparation: None.

- **Equipment**

- High-frequency transducer—minimum 10 MHz (although in larger patients an assessment of larger goitres via lower frequency probe may be needed).
Technique

- The patient is supine with the neck extended.
- Longitudinal and transverse scans are taken of both lobes of the thyroid and the isthmus.
- **Nodules** are assessed for echogenicity, margin, vascularity and architecture.
- Cervical lymph nodes should be routinely assessed at the same time.
Longitudinal and transverse scan.
Fine-needle aspiration (FNA) is a frequent adjunct to US examination, and ideally US should be undertaken with the facility to routinely proceed to FNA where there is concern about the US appearance.
Normal parathyroid glands cannot be visualized by US because of their small size and similar texture to surrounding adipose tissue.

US is performed using a similar technique as for the thyroid for the detection of parathyroid enlargement by adenomas, hyperplasia and carcinoma.
CT and MRI imaging of thyroid and parathyroid glands

- **Indications**
  1. Staging of known thyroid malignancy
  2. To assess extension of substernal goiter and tracheal compromise
CT of the thyroid is routinely performed without i.v. contrast?

- Because of its iodine content, normal thyroid is hyperdense relative to adjacent soft tissues on non-contrast-enhanced CT.
- Particular care must be taken if iodinated i.v contrast is administered to hyperthyroid patients.
- Other than for staging medullary thyroid cancer.
- For MRI, gadolinium-based i.v. contrast agents can be used.
In parathyroid disease, contrast-enhanced CT and MRI are used:

- 1. to detect ectopic or otherwise occult parathyroid adenomas in primary hyperparathyroidism
- 2. in patients with persistent or recurrent hyperparathyroidism following neck exploration
Radionuclide imaging of thyroid

- **Indications**
  1. Assessment of thyroid uptake prior to radio-iodine therapy for benign conditions
  2. Follow-up assessment of treated thyroid malignancy
  3. Assessment of neonatal hypothyroidism
  4. To locate ectopic thyroid tissue, e.g. lingual or in a thyroglossal duct cyst
  5. Evaluation of toxic nodular goitre and thyroiditis

- **Contraindications** =Pregnancy.
Radiopharmaceuticals

- 1. **99mTc-pertechnetate**: Pertechnetate ions are trapped in the thyroid by an active transport mechanism, but are not organified. Cheap and readily available, it is an acceptable alternative to 123I.

- 2. **123I-sodium iodide**: Iodide ions are trapped by the thyroid in the same way as pertechnetate, but are also organified, allowing overall assessment of thyroid function. 123I is the agent of choice, but it is relatively expensive with limited availability.

- **131 I-sodium iodide** can also be used for imaging but is associated with a significantly higher radiation dose, so it is generally used in the context of whole-body imaging post-131I ablation.)
Equipment
1. Gamma-camera
2. Pinhole, converging or high-resolution parallel hole collimator
Patient Preparation

- None, but uptake may be reduced by antithyroid drugs, iodine based preparations and radiographic iodinated contrast media.
Technique

- **99mTc-pertechnetate**
  - 1. Intravenous injection of pertechnetate
  - 2. After 15 min, immediately before imaging, the patient is given a drink of water to wash away pertechnetate secreted into saliva.
  - 3. Start imaging 20 min post injection.
  - 4. The patient lies supine with the neck slightly extended and the camera anterior. For a pinhole collimator, the pinhole should be positioned (usually 7–10 cm from the neck).
  - 5. The patient should be asked not to swallow or talk during imaging.
  - An image is acquired with markers on the suprasternal notch, clavicles, edges of the neck and any palpable nodules.
123I-sodium iodide

- The technique is similar to that for pertechnetate, except for the following:
  1. Sodium iodide may be given i.v. or orally.
  2. Imaging is performed 3–4 h after i.v. administration or 24 h after an oral dose.
  3. A drink of water is not necessary, since 123I is not secreted into saliva in any significant quantity.

**Imaging**

- 1. Anterior
- 2. LAO and RAO views as required, especially for assessment of multinodular disease.
Radionuclide imaging of parathyroid gland.

- **Indications**
  - Preoperative localization of parathyroid adenomas and hyperplastic glands.

- **Contraindications**
  - Pregnancy.

- **Radiopharmaceuticals**
  - 1. $^{99m}$Tc-methoxyisobutylisonitrile (MIBI or sestamibi).
  - Both MIBI and TC $^{99}$ pertechnetate are trapped by the thyroid, but only MIBI accumulates in hyperactive parathyroid tissue. With computer subtraction of pertechnetate from MIBI images, abnormal accumulation of MIBI may be seen. MIBI also washes out of normal thyroid tissue faster than parathyroid, so delayed images (1–4 h) can highlight abnormal parathyroid activity.
Equipment

- 1. Gamma-camera.
- 2. High-resolution parallel hole collimator is preferred to a pinhole collimator.
- 3. Imaging computer capable of image registration and subtraction

**Patient Preparation**
- None, but uptake may be **modified** by antithyroid drugs and iodine based medications, skin preparations and recent iodinated contrast media.
Parathyroid radionuclide imaging.

1. 80 MBq 99mTc-pertechnetate is administered i.v. through a cannula.
2. After 15 min the patient is given a drink of water immediately before imaging, to wash away pertechnetate secreted into saliva.
3. The patient lies supine with the neck slightly extended, and the camera is positioned anteriorly over the thyroid.
4. The patient should be asked to not move during imaging. Head immobilizing devices may be useful, and marker sources may aid repositioning.
5. Without moving the patient, 500 MBq 99mTc-MIBI is injected i.v. through the previously positioned cannula (to avoid a second venipuncture which might cause patient movement).
6. Ten min post injection, a further 10-min 128 × 128 image is acquired.
Sestamibi scan
BREAST IMAGING

DR. ZAHRAA NAFAEA
M.B.CH.B.CAB.RAD
METHODES OF IMAGING THE BREAST

1. Ultrasound
2. Mammography
3. Magnetic resonance imaging (MRI)
4. Radionuclide imaging
5. Imaging-guided biopsy
ULTRASOUND OF BREAST:

Indications

1. Focal signs in women younger than 40 years in the context of triple assessment (i.e. clinical, radiological and pathological).

2. As an adjunctive method to improve diagnostic sensitivity and specificity in women with a mammographic and/or clinical abnormality.

3. Following diagnosis of breast cancer to assess initial tumor size or response to neoadjuvant therapy.

4. Assessment of implant integrity.
5. Diagnosis, drainage guidance and follow-up of breast abscess
6. Localization of both palpable and impalpable breast lesions for biopsy.
7. To guide axillary lymph node biopsy.

*Not Indicated*

For screening in any age group
Equipment: high frequency prob.

**Technique**

1. The patient’s arm on the side to be examined should be placed behind the head.
2. The patient lies supine for examination of the medial aspect of the breast.
3. The patient lies in the lateral, oblique position for examination of the lateral and axillary aspects of the breast and axilla.
MAMOGRAPHY:

**Indications**

1. Focal signs in women aged ≥40 years in the context of triple (i.e. clinical, radiological and pathological) assessment

2. Following diagnosis of breast cancer, to exclude multifocal/multicentric/bilateral disease


4. Population screening of asymptomatic women with screening interval of 3 years

5. Screening of women with a moderate/high risk of familial breast cancer.
Not Indicated

1. Asymptomatic women without familial history of breast cancer, aged younger than 40 years
2. Investigation of generalized signs/symptoms—e.g. cyclical mastalgia or non focal pain/lumpiness
3. Prior to commencement of hormone replacement therapy
4. To assess the integrity of silicone implants
Equipment: full-field digital mammography (FFDM),

**Technique:**

Standard and screening mammographic examination comprises imaging of both breasts in two views—the mediolateral oblique (MLO) and craniocaudal (CC) positions.

**Compression of the breast is an integral part of mammographic imaging resulting in:**

1. reduction in radiation dose
2. immobilization of the breast, thus reducing blurring
3. reduction in breast thickness, thus reducing scatter/noise achieving higher resolution
MRI breast:

**Indications**

1. Detection/exclusion of recurrent malignant disease in the conserved breast ≥6 months following surgery.
2. Assessment of implant integrity
3. Monitoring response to neoadjuvant therapy
4. Combined with mammography as a screening tool in women at high risk of developing breast cancer
5. Investigation of occult breast cancer;
Technique

1. Contraindications as for standard MRI examinations

2. Lying prone, with breasts placed in surface coil, images are obtained pre and post contrast (0.1–0.2 mmol kg⁻¹ gadolinium contrast, given i.v. via pump injector). The presence, degree, speed and morphology of the pattern of enhancement are analyzed.

3. For implant integrity, nonenhanced scanning is adequate.
Methods of imaging of arterial system and introduction to catheter techniques
**Definition**: Visualization of the blood vessels with or without contrast media.

According to type of vessels can be classified to:
1. Arteriography: Imaging of the arteries
2. Venography: Imaging of the veins
3. Angiocardiography: Imaging of the heart and related structures.
4. Lymphangiography: Imaging of the lymphatic system.
Arterial system

The basic technique of arterial catheterization is also applicable to veins.

Invasive and non-invasive are terms widely used in angiography. The following methods are currently used:

1. Invasive with radiation- intravascular catheterisation.
2. Mildly invasive plus radiation-multislice spiral CT with IV Contrast.
3. Mildly invasive and radiation free-MRI with IV gadolinium.
Direct needle puncture had advantages of speed and simplicity, and many radiologists became very skilled in this technique, but it was less common than the catheter technique, which eventually replaced it. Percutaneous arterial catheterisation is based on the original work of Seldinger in Stockholm (Seldinger 1953). The use of a special needle and guide-wire permits the percutaneous introduction of catheter into a superficial and palpable vessel. Most catheterisations are now performed with relatively small catheters, usually of 5 Fr gauge, or less. Superselective catheterisation is sometimes achieved, particularly with intracranial vessels by passing very fine catheters (2 or 3 Fr) through a larger catheter.
The Seldinger technique

To visualize the vessel of interest, a catheter must be introduced into the patient’s vasculature, through which the contrast media is injected.

1-It is a percutaneous (through the skin) technique that can be used on arterial or venous access.
2-Four vessels are typically considered for catheterization:

**Puncture sites**
1. Femoral artery - most frequently used
2. Brachial artery
3. Axillary artery.
4. Radial artery.
Angiography is performed by a team of health professionals, including:
- (1) radiologist,
- (2) nurse,
- (3) radiology technologist
1. The patient will need admission to hospital. However, with the introduction of smaller diameter catheters, day case admission may be all that is needed for routine peripheral angiography using 3-5-F catheters and some simple angioplasty cases.
2. If the patient is taking anticoagulants, he should be monitored to ensure that they are within their therapeutic 'window'.
3. The radiologist should see the patient on the ward prior to the examination in order to:
   a. explain the procedure
   b. obtain informed consent
   c. examine the patient, with special reference to blood pressure and peripheral pulses as a baseline for post-arteriographic problems.
A sterile tray contains the equipments necessary for Seldinger catheterization.

* Needles, Guide-wires and Catheters
* Basic sterile items include the following Preparation sponges, Scalpel blade, Syringe with needles and local Anesthetic.
Seldinger technique

(a) Both walls of vessel punctured, (b) Stilette removed. Needle withdrawn so that bevel is within the lumen of the vessel and blood flows from the hub. (c) Guide-wire inserted through needle, (d) Needle withdrawn, leaving guide-wire in situ, (e) Catheter threaded over wire, (f) Guide-wire withdrawn
Step 1. Insertion of compound needle (with inner cannula)

Step 2. Placement of needle in lumen of vessel (inner cannula removed)

Step 3. Insertion of guidewire

Step 4. Removal of needle

Step 5. Threading of catheter to area of interest

Step 6. Removal of guidewire
GENERAL COMPLICATIONS OF CATHETER TECHNIQUES

1-Due to anesthetic .. 2-Due to the contrast medium ..
3-Due to the technique Local and Distant ..

Local
The most frequently encountered complications occur at the puncture site.
The incidence of complications is lowest with the femoral puncture site.
1. Haemorrhage/haematoma.
2. Arterial thrombus
3. Infection at the puncture site.
4. Damage to local structures, especially the brachial plexus during axillary artery puncture.
5. Pseudoaneurysm. Rare at the puncture site, usually 1-2 weeks after arteriography.

Distant
1. Peripheral embolus
3. Air embolus. May be fatal in a coronary or cerebral artery.
4. Artery dissection.
5. Catheter knotting.
6. Catheter impaction
The contrast media of choice is a water-soluble, nonionic iodinated substance because of its low osmolality and reduced risk of allergic reaction. The amount required of the contrast material depends on the patient weight and vessel being examined.
Digital acquisition allows images to be archived directly to the PACS, if available, with all the inherent advantages (e.g., ease of access to images by specialists, elimination of lost films, simultaneous viewing of images). If there is no PACS, the images may be printed and archived as hard copies. PACS is a modality of imaging technology which helps in image transmission from the site of image acquisition to multiple locations. This technology not only is economical (film-less department), but give access to multiple modalities (radiographs, CT, MR, ultrasound etc.) simultaneously at multiple locations within hospitals or across the globe.
1. input from digital devices (image acquisition device), which may be any radiological modality e.g. x-ray, CT, MRI or ultrasound..
2. image storage device/server..
3. transmission network: local or web-based
4. Display imaging *workstation*.
Digital subtraction angiography (DSA)

Digital subtraction angiography is used to produce images of the blood vessels without interfering shadows from overlapping tissues. This provides a clear view of the vessels.

The non-contrast image (mask image) of the region is taken before injecting contrast material and therefore shows only anatomy, as well as any radiopaque foreign bodies (surgical clips, stents, etc.) as would a regular x-ray image. Contrast images are taken while contrast material is being injected. These images show the opacified vessels superimposed on the anatomy and are stored on the computer. The mask image is then subtracted from the contrast images pixel by pixel. The resulting subtraction images show the opacified vessels only.
1. “Initial image”
2. “Mask”
3. “Non-subtracted image” (contrast-filled vessels)
4. “Digitally subtracted image”

Time
Digital Subtraction Angiography (DSA)

- DSA refers to a technique which compares two images of a region of the body before and after a contrast medium has been injected into the body for the purpose of studying blood vessels.
https://youtu.be/6lPEcy2WMyo
https://youtu.be/aMjZRx1ILhc
https://youtu.be/EFnUaYRAdro
FEMORAL ARTERY PUNCTURE

This is the most frequently used puncture site providing access to the left ventricle, aorta and all its branches.
It also has the lowest complication rate of the peripheral sites.

Relative contraindications
1. Femoral artery aneurysm
2. Marked tortuosity of the iliac vessels may prevent further advancement of the guide-wire or catheter.
   In such a case, high brachial artery puncture may be necessary.
Technique

1. The patient lies supine on the X-ray table, the right side is technically easier (for right-handed operators).

2. Before beginning, the appropriate catheter and guide-wire are selected and their compatibility checked by passing the guide-wire through the needle.

3. Using aseptic technique, local anaesthetic is infiltrated either side of the artery down to the periosteum. A 5 mm transverse incision is made over the artery.
4. The actual point of puncture of the femoral artery must be considered. Correct puncture is made with the needle directed 45° to the skin surface and slightly medially.

5. The artery is immobilized by placing the index and middle fingers of the left hand on either side of the artery, and the needle is held in the right hand. The needle is advanced as described in seldinger technique.
Poor flow may be due to:

a. femoral vein puncture
b. the end of the needle lying sub-intimally
c. hypotension - due to vasovagal reaction during the puncture
d. Atherosclerosis (narrowing and stenosis).
6. The catheter is advanced up the descending aorta, under fluoroscopic control, and when in a satisfactory position the guide-wire is withdrawn.

7. The catheter is connected via a two-way tap to a syringe of heparinized saline (2500 units in 500 ml of 0.9% saline), and flushed. Flushing should be done rapidly. Continuous flushing throughout the procedure must be undertaken.
8. At the end of the procedure the catheter is withdrawn and compression of the puncture site should be maintained for 5 min. If continued bleeding becomes a concern, consideration should be given to neutralizing the effects of heparin by giving protamine sulphate, 1 mg for each 100 units of heparin.
Aftercare

1. Bed rest - if a 5-F system (or less) is used on a day-case basis, then this should be for at least 4 h. Larger catheters require longer bed rest and observation.
2. Careful observation of the puncture site.
3. Pulse and blood pressure observation half-hourly for 4 h and then 4-hourly for the remainder of 24 h, if the larger catheter systems are used.
Indications
As for femoral artery puncture, but as this approach is associated with a higher incidence of complications, it should only be used if femoral artery puncture is not possible.

Contraindications
1. Atherosclerosis of the axillary or subclavian arteries.
2. Subclavian artery aneurysm.
The patient lies on the X-ray table with his arm in supination and the brachial artery localized approx. 10 cm above the elbow.

2. A small incision is made in the skin, 1-2 cm distal to the selected point of arterial puncture.

3. A single-wall puncture needle is used, with an acute angle of entry into the artery.

4. A straight, soft-tipped guide-wire is introduced when good pulsatile flow is obtained.
5. A 5-F pigtail catheter is introduced over the guide-wire and its pigtail formed in the aorta.

6. At the end of the procedure the catheter tip is straightened using the guide-wire and then removed. This reduces the risk of intimal damage during withdrawal of the catheter.
Indications

As for femoral artery puncture, but this approach is associated with a higher incidence of complications and should only be used if femoral or high brachial artery puncture is not possible.

Contraindications

1. Atherosclerosis of the axillary or subclavian arteries
2. Subclavian artery aneurysm.
1. The patient lies supine on the X-ray table with his arm fully abducted. The puncture point is just distal to the axillary fold, which is infiltrated with local anaesthetic.

2. A small incision is made in the skin, 1-2 cm distal to the point of the arterial puncture.

3. The needle is directed more horizontally than the femoral approach and along the line of the humerus.

4. Following satisfactory puncture the remainder of the technique is as for femoral artery catheterization.
ASCENDING AORTOGRAPHY

is an angiographic study of the aorta

Indications

1. Aortic aneurysm or dissection (echocardiography, CT with intravenous contrast enhancement, and MRI can also be used to demonstrate a dissection).
2. Atheroma at the origin of the major vessels.
3. Congenital heart disease - particularly the demonstration of congenital or iatrogenic aorto-pulmonary shunts and coarctation.
4. Aortic trauma.
Equipment
1. Digital fluoroscopy unit with C-arm capable of 20-30 frames s⁻¹.
2. Pump injector
3. Catheter:
   a. pigtail or
   b. Gensini.

Contrast medium
LOCM 370, 0.75 ml/kg (max. 40 ml).
Inject at 18-20 ml/s.
Technique

1. The catheter is introduced using the Seldinger technique via the femoral or radial artery, and its tip sited 1-3 cm above the aortic valve.
2. The patient is positioned 45° RPO to open out the aortic arch, and to show the aortic valve and the left ventricle to best advantage.
3. A test injection is performed to ensure that:
   a. the catheter is correctly placed in relation to the aortic valve (which is particularly important in the hyperkinetic heart)
   b. the catheter tip is not in a coronary artery.

Films
20-30 frames s⁻¹.
Four segments of thoracic aorta:
1. Aortic bulb
2. Ascending aorta
3. Aortic arch
4. Descending aorta

Catheter insertion sites
The thoracic aorta extends from the aortic bulb to the diaphragm and is generally divided into three main sections: Ascending aorta, arch, and descending aorta. The classic pattern of branching consists of a right brachiocephalic, left common carotid, and left subclavian artery.
An aneurysm is an abnormal bulge or ballooning in the wall of a blood vessel. "A proportion of these patients will go on to have a rupture."

Aortogram clarifies the saccular arch aneurysm arising distal to the origin of the left subclavian artery in addition to the fusiform aneurysmal dilatation of the lower descending aorta.
Indications
1. Arterial ischaemia
2. Trauma
3. Arteriovenous malformation.
Both lower limbs
1. Catheter angiography - using a pigtail catheter introduced into the Femoral, Brachial or axillary arteries puncture and sited proximal to the aortic bifurcation.

One lower limb
1. Using a femoral artery catheter:
   a. introduced retrogradely and sited in the ipsilateral common iliac artery
   b. introduced retrogradely from the contra-lateral side and sited in the common iliac, external iliac or femoral artery (Sidewinder catheter)
   c. introduced antegradely.
If thin 4-F catheters are used, only day case admission is necessary
All of these techniques can be performed under local anaesthesia and LOCM are, therefore, appropriate.

10-20 ml of 300 mg l ml$^{-1}$ concentration is suitable for the examination of one limb. 50 ml of 350 mg l ml$^{-1}$, at a rate of 12-15 ml s$^{-1}$, is suitable for the catheter aortogram.
VASCULAR DILATATION
(Balloon angioplasty)

Also known as percutaneous transluminal angioplasty or balloon dilatation.
Indications

1. Dilatation of localized vascular stenoses, mainly of the renal, iliac, lower limb and coronary arteries.
2. Dilatation of occluded segments of vessels in selected cases.

Dilatation procedures are often combined with preparatory diagnostic angiography in the same session; the majority are done under local anaesthetic.
Equipment

1. Digital fluoroscopy unit with C-arm capable of angiography.
2. Catheters.
   a. Gruntzig double-lumen dilatation catheters (these vary in length of catheter, and are chosen in relation to the particular lesion to be treated)
   b. straight Teflon or polyethylene catheters.
4. Streptokinase may be infused into recently thrombosed vessels, prior to dilatation. This is diluted and used with a pressure injector to infuse 5000 units/h.
Heparin, 500 units h⁻¹, may also be infused to prevent catheter thrombosis.
Technique

Principles
1. Adequate angiograms must be available before any dilatation is attempted.
2. The balloon diameter is selected by reference to the measured size of the normal artery on the preceding angiogram. Usually the iliac arteries take a 7-mm and the superficial femoral artery a 5-mm balloon.
3. Adequate vascular surgical assistance must be readily available before attempting dilatation.
4. If the history suggests that a thrombosis has occurred within the previous 3 weeks, streptokinase lysis may be helpful.
5. The patient should be anticoagulated during the procedure, using 3000-5000 units of heparin.
6. Dilatation is always performed with the guide-wire remaining across the stenosis or occlusion until the procedure is completed.
A deflated balloon attached to a catheter (a balloon catheter) is passed over a guide wire into the narrowed vessel.

B then inflated to a fixed size, the balloon forces expansion of the blood vessel and the surrounding muscular wall, allowing an improved blood flow.

C the balloon is then deflated and withdrawn.
Balloon Angioplasty

- Artery with plaque
- Catheter with uninflated balloon inverted
- Balloon inflated, plaque compressed
- Widened artery
1. The balloon-tipped catheter is positioned in the artery.

2. The uninflated balloon is centered in the obstruction.

3. The balloon is inflated, which flattens plaque against the artery wall.

4. The balloon is removed, and the artery is left unoccluded.
To assist in maintaining patency of the vessel across the treated area during the angioplasty.
Atherosclerotic plaque

Stent is closed

Balloon inflated
Stent is expanded

Expanded stent is left in place
Complications

Due to technique

1. Perforation of iliac artery leading to retroperitoneal haemorrhage
2. Embolization of clot or atheroma distally, down either leg.
3. Occlusion of main artery.
4. Major haematoma formation, which may suddenly develop several hours after the procedure is completed
5. Increased risk of false aneurysm formation at the puncture site.
Aftercare

1. The pulses distal to the artery that has been dilated and the colour of the toes should be observed half-hourly for 4 h.
2. Aspirin 150 mg daily (for life, unless there is a contraindication).
Embolization is a minimally invasive procedure that blocks or closes a specific blood vessel.
Indications:

1. To control bleeding - from the gastrointestinal and genitourinary tracts, from the lungs and after trauma.
2. To infarct or reduce the blood supply to tumours or organs.
3. To reduce or stop blood flow through arteriovenous malformations, aneurysms, fistulae or varicoceles.
1. Digital fluoroscopy unit with C-arm capable of angiography and preferably with 'road mapping' facilities.

2. Catheters; end hole only. Size and shape will depend on the particular problem. Balloon occlusion catheters may also be useful.
3. Embolic materials
   a. Liquid - 50% dextrose alcohol, quick-setting glues.
   b. Particulate - gel-foam, polyvinyl-alcohol.
   c. Solid - steel coils, detachable balloons.
   The material used depends on the lesion, its site and the duration of the occlusion required.
1. As for arteriogram.
2. Some procedures and materials are painful and sedation may be needed.
Technique

Principles

1. All therapeutic occlusions are potentially dangerous: the expected gain must justify the risk.
2. Adequate angiograms must be available before commencing.
3. The operator must be an experienced angiographer.
4. The lesion must be selectively catheterized. When permanent occlusion is required, the centre of the lesion should be filled with non-absorbable material (e.g. silicone spheres, polyvinyl-alcohol) before the supplying blood vessels are occluded.  
5. Reflux of embolic material is likely to occur as the blood flow slows down; injection of emboli should be done slowly with intermittent gentle injections of contrast medium to assess flow and progress.  
6. It is safer to come back another day than to continue for too long.
Figure: Digital subtraction angiogram showing large aneurysm at basilar tip (a) successfully treated by coil deployment (b & c).
Complications

1. Misplacement of emboli: this may occur without the operator being aware that it has happened.
2. There may be propagation of thrombus, with embolization to the lungs or elsewhere.
3. The infarcted tissue may become infected.
1. Infarction of tissue often causes pain, and adequate pain relief should be provided.
2. Arterial clotting may be progressive, and observations on the tissues distal to the occluded vessel should be maintained for 24 h.
3. Many patients have fever for up to 10 days. However, infarcted tissue may become infected, and so antibiotics should be used with care.
Methods of imaging the venous system & peripheral venography.
Methods of imaging the venous system

1. Contrast medium venography.
2. US Doppler.
3. CT can show inferior vena cava involvement and renal vein involvement in renal cell carcinoma and Wilms' tumour.
4. MRI will show the presence or absence of flowing blood. The ability of MR to image in the plane of the vessel makes it well suited to assessing the venous system. It can produce excellent visualization of the venous system.
5. Radioisotopes. The patency of blood vessels may be examined using 99mTc- injected into a supplying vessel with fast-frame dynamic imaging.
Indications
1. Deep venous thrombosis
2. To demonstrate incompetent perforating veins
3. Oedema of unknown cause.
4. Congenital abnormality of the venous system (rare).

Contraindications
Local sepsis.
PERIPHERAL VENOGRAPHY (Venogram)

LOWER LIMB (Intravenous venography)
Anatomically veins of lower limbs divided to deep and superficial systems.
Contrast medium
LOCM 240.

Equipment
1. Fluoroscopy unit with spot film device
2. Tilting radiography table.
Technique

1. The patient is supine and tilted 40° head up, to delay the transit time of the contrast medium.
2. A tourniquet is applied tightly just above the ankle to occlude the superficial venous system.
3. A 19-G butterfly needle (smaller if necessary) is inserted into a distal vein on the dorsum of the foot.
4. 40 ml of contrast medium is injected by hand. The first series of spot films is then taken.
5. A further 20 ml of contrast are injected quickly whilst the patient performs a Valsalva manoeuvre to delay the transit of contrast medium into the proximal and pelvic veins. The patient is tilted quickly into a slightly head down position and the Valsalva manoeuvre is relaxed. Films are taken 2-3 s after releasing pressure.
6. At the end of the procedure the needle should be flushed with 0.9% saline to avoid the risk of phlebitis due to stasis of contrast medium.
Fig. 16.2  (A,B) Normal ascending phlebogram of the deep veins.

Fig. 16.6  Phlebogram showing venous thrombosis in deep veins of the calf. The clot shows as a central filling defect with marginal contrast (arrow).
Films
(Collimated to include all veins)
1. AP of calf
2. Both obliques of calf (foot internally and externally rotated)
3. AP of popliteal, common femoral and iliac veins.
Complications

Due to the contrast medium
1. As for the general complications of intravascular contrast media mainly due to allergic reaction.
2. Thrombophlebitis.
3. Tissue necrosis due to extravasation of contrast medium. This is rare, but may occur in patients with peripheral ischaemia.
4. Cardiac arrhythmia - more likely if the patient has pulmonary hypertension.

Due to the technique
1. Haematoma
2. Pulmonary embolus - due to dislodged clot or air.
UPPER LIMB (Intravenous venography)

Upper Extremity Veins

- **Axillary Vein**
- **Subclavian Vein**
- **Cephalic Vein**
- **Brachial Vein**
- **Antecubital Vein**
- **Basilic Vein**
- **Radial Veins**
- **Ulnar Veins**

**Deep Veins**

**Superficial Veins**

Bas. V. pierces fascia and becomes a deep vein in the upper arm.
Indications
1. Oedema
2. To demonstrate the site of a venous obstruction
3. SVC obstruction.

Contrast medium
LOCM 300.

Equipment
Fluoroscopy unit with spot film device.
Preliminary film
PA shoulder.

Technique
1. The patient is supine.

2. An 18-G butterfly needle is inserted into the medium cubital vein at the elbow.
   The cephalic vein is not used, as this bypasses the axillary vein.

3. Spot films are taken of the region of interest during a hand injection of 30 ml of contrast medium.
Upper Limb Venograms

- Most often for thrombosis or occlusion
- Contrast injected in a superficial vein in the elbow or wrist
  - Using a catheter or needle
  - 40-80ml at a rate of 1-4ml/sec
Complications: Same as lower limbs.

Further reading
https://slideplayer.com/slide/5896324/
CENTRAL VENOGRAPHY

SUPERIOR VENA CAVOGRAPHY

INFERIOR VENA CAVOGRAPHY

Dr. Ahmed Mudkhre Shareef
Indications

1. To demonstrate the site of a venous obstruction.
2. Congenital abnormality of the venous system, e.g. left-sided superior vena cava.
Anatomically speaking

Major veins superior to the heart

- right internal jugular vein
- right external jugular vein
- right subclavian vein
- right brachiocephalic vein
- left internal jugular vein
- left external jugular vein
- left subclavian vein
- left axillary vein
- left brachiocephalic vein
- superior vena cava
- azygous vein
- left brachial vein

Superior vena cava
- Blood high in oxygen
- Blood low in oxygen

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Contrast medium
LOCM 370, 60 ml.

Equipment
Rapid serial radiography unit.

Patient preparation
Nil orally for 5 h prior to the procedure.

Preliminary films
PA film of upper chest and lower neck.
Technique

1. The patient is supine.
2. 18-G butterfly needles are inserted into the median antecubital vein of both arms.
3. Hand injections of contrast medium 30 ml per side, are made simultaneously, as rapidly as possible by two operators. The injection is recorded by rapid serial radiography. The film sequence is commenced after about two-thirds of the contrast medium has been injected.

NB: If the study is to demonstrate a congenital abnormality, a 5-F catheter with side holes, introduced by the Seldinger technique, may be used.
Films Aftercare
Rapid serial radiography is performed: one film per s for 10 s.
Complications
Due to the contrast medium
Superior Venacavagram
Digital subtraction venogram of the right upper extremity veins and right-sided central venous system performed by way of a peripheral vein in the dorsum of the right hand.
Superior vena cavogram was performed to measure the extent of SVC stenosis before stenting procedure.
Superior vena cava syndrome caused by multiple pacing leads
Inferior Vena Cavoangiography

Indications

1. To demonstrate the site of a venous obstruction, displacement or infiltration.
2. Congenital abnormality of the venous system.
Tributaries of the Inferior Vena Cava

- **Hepatic veins**
- **Inferior vena cava**
- **Right suprarenal vein**
- **Renal veins**
- **Left suprarenal vein**
- **Left ascending lumbar vein**
- **Lumbar veins**
- **Left gonadal vein**
- **Common iliac vein**
- **Right gonadal vein**
- **External iliac vein**
- **Internal iliac vein**

*Figure 19.23*
Contrast medium
LOCM 370, 40 ml.
Technique

1. With the patient supine, the catheter is inserted into the femoral vein using the Seldinger technique. A Valsalva manoeuvre may facilitate venepuncture by dilating the veins.
2. An injection of 40 ml of contrast medium is made in 2 s by the pump injector, and recorded by rapid serial radiography.
Aftercare
Pressure at venepuncture site.
Routine observations for 2 h.

Complications
Due to the contrast medium
Due to the technique
Inferior Vena Cavogram

- To view the inferior vena cava to determine strictures, tumor blockage and location of blood clots.
- A catheter is inserted in the femoral vein & positioned in the common iliac vein or the inferior aspect of the inferior vena cava.
- The contrast is injected through a multiple side hole catheter.
Inferior Venacavagram
Double Inferior Vena Cava Anomaly
92-year-old male patient with hepatic metastasis of gastric cancer. a Inferior cavography depicts high-grade compression of the intrahepatic IVC with development of collateral vessels. b Balloon post-dilatation after deployment of the stent within the malignant stenosis. c Final cavography demonstrates significant improvement of the venous backflow and absence of venous collateral blood flow.
Inferior Vena Cava Filters
Inferior Vena Cava Filter Placement
Portal venography
Methods

1. Late-phase superior mesenteric angiography.
2. Trans-splenic approach (will discuss below).
3. Transhepatic approach.
4. Paraumbilical vein catheterization.
Portal System

- Hepatic veins
- Inferior vena cava
- Portal vein
- Splenic vein
- Superior mesenteric vein
- Inferior mesenteric vein
Indications

1. To demonstrate prior to operation the anatomy of the portal system in patients with portal hypertension.
2. To check the patency of a portosystemic anastomosis.

Contrast medium
LOCM 370, 50 ml.
Equipment

1. Rapid serial radiography unit.
2. Arterial catheter (SMA approach).
3. 10-cm needle (20-G) with stilette and outer plastic sheath, e.g. Longdwell (trans-splenic approach).
Patient preparation

1. Admission to hospital. A surgeon should be informed in case complications of procedure arise (for the trans-splenic approach).
2. Clotting factors are checked.
Technique

For trans-splenic approach

1. With the patient supine, the position of the spleen is identified with ultrasound. The access point is as low as possible in the midaxillary line, usually at the level of the tenth or eleventh intercostal space.

2. The region is anaesthetized using a sterile procedure.
3. The patient is asked to hold his breath in mid-inspiration, and the needle is then inserted into the spleen (about three-quarters of the length of the needle is inserted, i.e. 7.5 cm). The needle and stilette are then withdrawn, leaving the plastic cannula in situ. Blood will flow back easily if the cannula is correctly sited. 

The patient is then asked to breathe as shallowly as possible to avoid trauma to the spleen from excessive movement of the cannula.

4. A test injection of a small volume of contrast medium under screening control can be made to ensure correct sitting of the cannula.
5. When the cannula is in a satisfactory position, the splenic pulp pressure may be measured with a sterile manometer. (It is normally 10-15 cm H₂O.)

6. A hand injection of 50 ml of contrast medium is made in 5 s, and recorded by rapid serial radiography. The cannula should be removed as soon as possible after the injection to minimize trauma to the spleen.

7. Occasionally a patent portal vein will fail to opacify, owing to major porto-systemic collaterals causing reversed flow in the portal vein. The maximum width of a normal portal vein is said to be 2 cm.

Films
Rapid serial radiography: One film per s for 10 s.
Trans-splenic portal venography
Portal hyper tension with dilated portal vein and varices
Portogram through a calibrated pigtail catheter positioned in the splenic vein confirmed the successful access to the portal vein. Note the persistent opacification of the gastroesophageal varices (arrow) due to the portal hypertension.
Complications

*Due to the contrast medium*

*Due to the technique*

1. Haemorrhage
2. Subcapsular injection
3. Perforation of adjacent structures (e.g. pleura, colon)
4. Splenic rupture
5. Infection
6. Pain (especially with an extracapsular injection).
Methods of imaging the heart
Methods of imaging the heart

1. Chest radiography
2. Fluoroscopy
3. Angiocardiography
4. Echocardiography, including the transoesophageal technique
5. Radionuclide imaging
   a. ventriculography
   b. myocardial perfusion imaging
   c. acute myocardial infarction imaging
6. CT
7. MRI.
Indications
1. Congenital heart disease and anomalies of the great vessels
2. Valve disease
Contrast medium
LOCM 370. 1 ml kg\(^{-1}\) at 18-20 ml/s

Equipment
1. Biplane fluoroscopy and cine radiography, preferably digital and preferably with C-arms to facilitate axial projections.
2. Pressure recording device
3. ECG monitor
4. Blood oxygen analyser
5. Catheter
   a. For pressure measurements and blood sampling: Cournand (Fig. 8.1), 4-7-F
   b. For angiocardiography: NIH (Fig. 8.2) or pigtail (Fig. 8.3), 5-8-F.
Figure 8.1  Gournand catheter.

End holes: 1  Side holes: 0

Figure 8.2  NIH catheter.

End holes: 0  Side holes: 4 or 6

Figure 8.3  Pigtail catheter.

End holes: 1  Side holes: 12
Technique

1. Right-sided cardiac structures and pulmonary arteries are examined by introducing a catheter into a peripheral vein. In babies the femoral vein may be the only vein large enough to take the catheter. If an atrial septal defect is suspected, the femoral vein approach offers the best chance of passing the catheter into the left atrium through the defect.

2. In adults the right antecubital or basilic vein may be used. The catheter, or introducer, is introduced using the Seldinger technique.
3. In children it is usually possible to examine the left heart and occasionally the aorta by manipulating a venous catheter through a patent foramen ovale. In adults the aorta and left ventricle are studied via a catheter passed retrogradely from the femoral artery.

4. The catheter is manipulated into the appropriate positions for recording pressures and sampling blood for oxygen saturation. Following this, angiography is performed.
1. The recording of cardiac images is now most commonly performed using digital subtraction at 30 frames per s.
2. Angled views which place the lesion at right-angles to the X-ray beam increase diagnostic accuracy.

The first principle of axial cine-angiography is axial alignment of the heart, i.e. aligning the X-ray beam perpendicular to the long axis of the heart (Fig. 8.4).
3. Useful views are:

**A. 40° caud-cranial (sitting up) view.**

This manoeuvre places the pulmonary trunk and its bifurcation perpendicular to the X-ray beam, this projection is ideal for demonstrating the pulmonary trunk, pulmonary valve, annulus and bifurcation into right and left pulmonary arteries.
B. 40° cranial/40° LAO (four-chamber) view.

This view places the beam perpendicular to the long axis of the heart and aligns the atrial septum and posterior interventricular septum parallel to the beam.
C. Long axial 20° RAO (long axial oblique) view.

With a C-arm arrangement, the lateral tube and image intensifier is angled 25-30° cranially, to align with the long axis of the heart, and 20° RAO.
Coronary arteriography is a procedure that uses X-ray imaging with contrast to see heart's blood vessels.
Normally there are three main arteries that supply the heart with blood as can be seen above. Pay attention to the left anterior descending artery (LAD) as it supplies the entire front wall of the heart and much of the side wall. A tight blockage or total blockage at the beginning of the LAD (long red arrow) is known as the *Widowmaker*. Now look at the left main artery, it supplies the LAD and the left circumflex. A major blockage in the left main is the mother of all Widowmakers!
Indications

1. Diagnosis of the presence and extent of ischaemic heart disease
2. After revascularization procedures

Contrast medium
LOCM 370, given as a hand injection for each projection.
Equipment

1. Digital angiography with C-arm.
2. Pressure recording device and ECG monitor
3. Catheters
   - Judkins (Fig. 8.5) or Amplatz (Fig. 8.6) - the left and right coronary artery catheters are of different shape.
Figure 8.5  Judkins' coronary artery catheters.

Figure 8.6  Amplatz coronary artery catheters.
Patient preparation
1. As for routine arteriography.
2. β-blockers are stopped 48 h prior to the procedure.

Preliminary film
Chest X-ray.
The catheter is introduced using the Seldinger technique and advanced until its tip lies in the ostium of the coronary artery.
Angiography (30 frames/s) is performed in the following positions:

**Right coronary artery**
1. 60° LAO
2. 30° RAO
3. Right lateral.

**Left coronary artery**
1. 30° RAO
2. 60° LAO
3. Left lateral.
In addition to the general complications discussed in patients undergoing coronary arteriography are particularly liable to:
1. Sudden death
2. Myocardial infarction
3. Arrhythmias.
https://www.youtube.com/watch?v=z2mqnn easuU

https://www.youtube.com/watch?v=Kg_4O1 uKHN0
CT ANGIOGRAPHY
This is a CT image of the blood vessel opacified by contrast. It is generally performed following an intravenous injection of non-ionic intravascular contrast medium.
The introduction of spiral or helical CT with its capability of imaging large columns of tissue very rapidly in a 20-30 s breath-hold has led to the development of CT angiography.
The recent introduction of multislice spiral scanners has further enhanced the potential of CT vascular imaging.

Computed Tomography (CT)

X-ray tube and detector rotate around the patient, transversal slices are constructed following each rotation by computer.
16, 64, 128 and 256 slices
Clinical application of CTA

CT angiography is used in:
1- Assessment of thoracic and abdominal aortic aneurysms to see if they are suitable for endovascular repair.
2- The diagnosis of aortic dissection.
3- The diagnosis of coronary arterial disease (CAD).
4- The diagnosis of pulmonary embolic disease.
5- In the investigation of cerebral, carotid, renal and peripheral vascular disease.
PATIENT PREPARATION

NPO
Blood urea  7-20 mg/dl
S.creat.  0.6 –1.2 mg/dl
If Iodine allergy- Give steroid therapy
Usually routine CT precedes a CTA exam. The routine exam is used as a reference scan helping to determining the scanning range in CTA.

**Slice thickness:**
Slice thickness increase spatial resolutions decrease
Slice thickness cerebral CTA 1 mm
Abdominal CTA 3 mm Thoracic CTA 3 mm

**Spiral pitch**
Pitch increase spatial resolution decrease

**kVP, mA, time**
Similar to non-CTA exam of the same body part
Pitch\textsubscript{x} Definition

= beam pitch

Pitch\textsubscript{x} = \frac{\text{Table travel per rotation}}{\text{Slice width (or beam width)}}

\frac{15}{10} = 1.5
\frac{20}{10} = 2.0
Contrast administered with power injector

POWER INJECTOR PARAMETERS

VOLUME OF CONTRAST - ml

RATE ml/sec

TIME OF INJECTION – sec

SCAN DELAY TIME - sec
Canula gauge suitable for cta18 or 20

Possible Veins for Venipuncture
Most common: median cubital, cephalic, and basilic veins

- Superficial dorsal veins
- Basilic vein
- Dorsal venous arch
- Cephalic vein
- Median cubital vein
- Basilic vein
- Median vein of forearm
- Cephalic vein
- Radial vein
SMARTPREP is a feature that allows real-time monitoring of IV Contrast enhancement in one particular section of anatomy that is in the area of interest. GE CARE Bolus (Combined Applications to Reduce Exposure) Online-visualization of contrast enhancement for exact timing. Siemens SURESTART. Toshiba Manual delay.
SMART PREP
CARE BOLUS
SURE START
POSTPROCESSING TECHNIQUES

3D VISUALIZATION TOOLS IN CTA

**MPR** (Multiplanar reformation or reconstruction)
**MIP** (Maximum Intensity Projection)
**SSD** (shaded surface display)
**VR** (Virtual reality)
**CINE** (Ultrafast (Cine) CT scanning provides cross-sectional millisecond tomography, and therefore combines digital imaging and high resolution.

https://www.youtube.com/watch?v=-bOFRHgCOVo
MPR simple, fast any plane visualization but less useful in complex vessel imaging
MIP thrombus and calcification detection but require editing
SSD fast little data used, little editing but less accurate and with artifact generation.
SSD - CTA
VR all data used accurate, good for stenosis detection but need complex computer processing.

VR - CTA
ABDOMINAL AND FEMORAL RUNOFF
CARDIAC ANGIOGRAM
CTA - MPR
PE?
Coronary CT Angiography
What is Coronary CTA?

-Coronary CTA is a minimally-invasive procedure to directly visualize the coronary arteries through administration of IV contrast.

-It allows visualization of the coronary arteries similar to a cardiac catheterization with additional information about the WALL of the artery and composition of plaque (calcified or non-calcified).
Normal anatomy of coronary arteries

- Coronary arteries:
  - right coronary artery – RCA
  - left (main) coronary artery - LCA
    - left descending artery - LAD
    - left circumflex artery - LCx
CLINICAL APPLICATION OF CARDIAC CT ANGIO

- Coronary arterial morphology (angiographic display).
- Examine plaque components
- Coronary calcium score
- Postop. Evaluation (CABG)
- Evaluate stent patency
- Assess cardiac function LV wall thickness and function,
- Cardiac anatomy and pericardium assessment
Contraindications

Atrial Fibrillation Tachycardia
Beta Blockade Contraindication
Heart Block
Renal Failure (Creat>1.5)
Contrast Allergy
Which? MDCT is optimum

64 slice CT and higher 128, 256...

- 64 slice CT - sensitivity: 97%, specificity: 92%

- **Image quality depends on:**
  1. Heart rate – Image quality improves with heart rate less than 65.
  2. Proper coronary CTA scan and post processing protocol.
  3. The synchronization of raw image data with electrocardiography (ECG) information
Patient positioning for scanning

- Patients are positioned on the CT examination table in the supine position.
- ECG leads are attached to obtain an adequate ECG tracing.
- Intravenous access via a large intravenous line (18 gauge cannula) is necessary to ensure easy injection of the viscous contrast agent at a flow rate of 5 mL/s.
- Training of patients with repeated breath holds.
ECG gating protocols

- For ECG synchronized scanning of the cardiac region, two different approaches are taken.

1. Prospective ECG gating

2. Retrospective ECG gating
PROSPECTIVE ECG GATING

- Scan acquisition is triggered by the ECG signal at the prospected mid-diastolic phase of the cardiac cycle.

- Between 40% and 80% of the R-R interval

- Benefits: Smaller patient radiation dose
RETROSPECTIVE ECG GATED SCANNING

- Heart region is scanned continuously
- Contiguous data of cardiac region are acquired
- Patient’s ECG is recorded at the same time
- Scan data with least cardiac motions, usually the diastolic phase, are selected later for image reconstruction

Advantage:
• Entire volume is acquired continuously and gapless
• Image may be reconstructed with overlap

Disadvantage:
• Higher patient radiation exposure
Image acquisition and reconstruction

- The acquisition of the dataset for coronary CTA consists of 3 steps:
  1. Topogram
  2. Contrast medium protocol: to ensure homogeneous contrast enhancement of the entire coronary artery tree
  3. Coronary CTA scan
Coronary Calcium Scoring
## Calcium scoring scanning without contrast

<table>
<thead>
<tr>
<th>Maximal HU</th>
<th>Weighting factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>130–199</td>
<td>1</td>
</tr>
<tr>
<td>200–299</td>
<td>2</td>
</tr>
<tr>
<td>300–399</td>
<td>3</td>
</tr>
<tr>
<td>≥ 400</td>
<td>4</td>
</tr>
</tbody>
</table>

The total as well as individual coronary artery calcium score is calculated using special software at the workstation.
The CAC score can be classified into five groups:

1) zero, no coronary calcification;
2) 100, mild coronary calcification;
3) > 100 to 399, moderate calcification;
4) >400 to 999, severe calcification;
5) > 1000, extensive calcification.
Contrast Medium Protocol

- Optimal coronary artery opacification depends on:
  
  1. The iodine medium concentration – (300-400 mg iodine/ml is used)
  2. The volume and rate of contrast administration
  3. Timing of the contrast medium delivery.
Volume and rate of contrast administration

Using 64 detector MDCT technology:

- 80ml of contrast agent is injected at 6 ml/sec f/b 40ml saline solution at 4ml/sec

- Delivery of contrast medium s/b timed to ensure that the scan of cardiac region will occur at the peak of opacification of the coronary tree.

- It can be assessed by **two techniques**-

1. **Automated contrast bolus tracker technique** - the ROI is placed on ascending aorta. When ct value of ROI is greater than predetermined threshold of 100-150 HU, the scan begins.

2. **Test bolus scan** – here a small bolus of contrast is injected to determine contrast transit time. The time from the start of the injection to the peak contrast enhancement in the ascending aorta determines the scan delay after the initiation of contrast material administration.
After contrast administration, CT is obtained in single breath-hold.

Scan volume covers the entire heart from the proximal ascending aorta (approximately 1–2 cm below the carina) to the diaphragmatic surface of the heart.
Post processing protocol

- The axial source images obtained are utilized for multiplanar reconstructions in at least 2 planes

- Commonly used techniques are:
  - Maximum intensity projection (MIP),
  - Volume rendering (VR),
  - Multiplanar reconstruction (MPR) or
  - Curved planar reconstruction (CPR)
Multiplanar reconstructions. The coronary arteries can be easily reconstructed with good image quality using automatic vessel detection. This technique provides a two-dimensional display of the entire vessel, which is very helpful in detecting and quantifying coronary stenoses. (A) 3D model of the heart with a path through the LAD (green line). (B) cMPR of the LAD. (C) cMPR of the LCX. (D) cMPR of the RCA. Ao, aorta; LV, left ventricle. (Color version of figure is available online.)
Vessel Analysis, Curved Reformation
GRADING

- 0 Normal: Absence of plaque and no luminal stenosis
- 1 Minimal: Plaque with <25% stenosis
- 2 Mild: 23%-49% stenosis
- 3 Moderate: 50%-69% stenosis
- 4 Severe: 70%-99% stenosis
- 5 Occluded

CORONARY CT ANGIOGRAPHY OF NON-CALCIFIED PLAQUE
A significant stenosis of LAD is confirmed on coronary angiography.

Extensive calcified plaques are noticed in the proximal and middle segments of left anterior descending (LAD) on curved multiplanar reformatted images.

Extensive calcified plaques are noticed in volume rendering images.
Coronary CT angiography of mixed plaques. Mixed plaques are observed in the proximal segment of the left anterior descending (LAD) artery with > 50% stenosis (a, arrow). Coronary angiography confirms the significant stenosis of the LAD (b, arrow).
A patent coronary stent is noticed in the proximal left anterior descending (LAD) artery on a curved multiplanar reformatted (MPR) image with clear demonstration of the intrastent lumen without in-stent restenosis.
ADVANTAGES OF MDCT

- Non invasive procedure without any hospital stay.
- MDCT CA can precisely identify total occlusion, indicate cause and extent.
- Morphology of the occluded segment and the time the artery was occluded
- In acute obstruction, low density intraluminal defect caused by thrombosis with an increase in luminal area and diameter are seen.
- In chronic cases, the obstruction shows calcified or mixed plaques with the artery lumen with normal or slightly narrowed lumen
Limitations of CT coronary angio

- Rapid (>80 bpm) and irregular heart rate.
- High calcium scores (>800-1000)
- Presence of stents
- Contrast requirements
- Small vessels (<1.5 mm) and collaterals
- Obese and uncooperative patients
- Radiation exposure
Cases review
(A) Normal aortogram of transverse arch in patient suspected of having traumatic aortic injury. Note the normal origins of the brachiocephalic artery (BA), left common carotid artery (LCC), and left subclavian artery (LSC) from the arch of the aorta. (B) Aortogram in a patient with acute traumatic aortic injury. The site of injury is the focal outpouching at the insertion of ductus arteriosus (arrow).
Figure 1-3. An aortogram demonstrated transection (arrow) of the aortic arch at the aortic isthmus extending about 4 cm below.
Popliteal artery angiography, DSA vs. DA. (A) Popliteal artery surrounded by bone and basically taken with DSA. (B) DA view shows well visualized stenosis but most collateral vessels unclear.
FIGURE 2. This series of angiograms depicts (A) stenosis of a right lower pulmonary artery branch, (B) during balloon inflation before the waist was eliminated, and (C) after intervention. The red arrows indicate the stenosis before and after dilation.
Preoperative tumor embolization. A: The digital subtraction angiography (DSA) shows a hypervascular contrast staining mass with an arterial feeder from the MCA and PCA. B: The postembolic DSA shows near total occlusion of the feeding arteries and decreased size of the contrast staining mass.
(A) Pre-procedure right internal carotid artery (ICA) angiogram demonstrated a 14 mm cavernous carotid artery aneurysm. The patient underwent coil embolization without stent assistance. (B) Post-procedure right ICA angiogram demonstrated complete occlusion of the aneurysm.
DVT

Ascending venography showing extensive intraluminal filling defects most evident in the popliteal and femoral arteries diagnostic of deep vein thrombosis
A) Preoperative CT aortogram showing the ascending and aortic arch aneurysm. (B) Postoperative image depicting a well expanded true lumen and stent induced new entry. (C) Preoperative CT scan demonstrating a 9-cm distal arch aneurysm and a heavily calcified aortic valve. (D) Postoperative CT scans demonstrating the repair.
Figure 1. Extensive acute central PE with “saddle embolus” extending into both central pulmonary arteries in a 72-year-old
(A) Right Coronary Artery
(B) Left Anterior Descending Artery
(C) Left Circumflex Artery
Methods of imaging the spine.
These are of little management value in chronic back pain because of the prevalence of degenerative changes in both symptomatic and asymptomatic individuals of all ages. They are, however, indicated in suspected spinal injury, in developmental malformations and for the demonstration of spondylolisthesis.
This is used for the lumbar spine where neither CT or MRI are available, or for the cervical spine where MRI is unavailable. There is an occasional requirement where MRI is contraindicated or unacceptable to the patient.
is not widely practiced in the UK, though still regard it as the only technique able to verify the presence and source of discogenic pain, and it is widely accepted by American radiologists.
4. Facet joint arthrography.

This is a technique for the verification of pain of facet joint origin, and for injection of local anaesthetic. The radiological appearances of the arthrogram are not helpful for the most part.
5. CT with CSF opacification by intrathecal contrast medium, or CT myelography. This is a sensitive technique for cervical radiculopathy studies, but declining with improving MR instrumentation.
This is largely performed for suspected bone metastases, for which it is a sensitive and cost-effective technique. Plain films are required in addition to tracer images as focal high activity may result from associated degenerative disease.
7. Magnetic resonance imaging, if necessary with intravenous gadolinium enhancement. This is the preferred technique for most spinal pathology. It is the only technique for diagnosing spinal multiple sclerosis, and by far the best technique for the acute management of spinal compression.
8. Ultrasound

Is of use as an intraoperative method, and has uses in the infant spine.
Despite the known limitations of plain films, it is often helpful to obtain routine radiographs of the lumbar spine before other investigation is requested. The role of plain radiographs can be summarized in the following points:

1. They assist in the diagnosis of conditions that can mimic mechanical or discogenic pain, e.g. infection, spondylolysis, ankylosing spondylitis and bone tumours, though in most circumstances, CT and MRI are more sensitive.
2. They serve as a technical aid to survey the vertebral column and spinal canal prior to myelography, CT and MRI, particularly in the sense of providing basic anatomical data regarding segmentation. Failure to do this may lead to errors in interpreting correctly the vertebral level of abnormalities prior to surgery.

3. Correlation of CT or MRI data with plain film appearances is often helpful in interpretation.
CONTRAST MEDIA

Historically the contrast media that have been used for myelography include gas (CO₂, air), myodil, (Pantopaque), meglumine iothalamate (Conray), iohexol (Omnipaque) and iotrolan (Isovist). The early oil-based media were diagnostically poor and led to arachnoiditis. The early water-soluble media were very toxic and also led to arachnoiditis. Only iohexol, iopamidol and iotrolan are currently available and licensed for use in the thecal sac. All are well tolerated with some slight advantage in favour of iotrolan, and all are sufficiently safe to allow the use of myelography in outpatients.
Subarachnoid space

- The space between the arachnoid and the underlying pia mater
  - Filled with CSF
  - Bathes brain and spinal cord with nutrients
  - Cushions against shock and blows
  - Where contrast media is injected for myelograms
Lumbar Myelography/radiculography

This is performed by injection of contrast medium into the lumbar thecal sac.

**Indications**
Suspected lumbar root or cauda equina compression, spinal stenosis and conus medullaris lesions in patients in whom CT is inconclusive, and who are unable or unwilling to undergo MRI.

**Contraindications**
Lumbar puncture is potentially hazardous in the presence of raised intracranial pressure, arachnoiditis, blood in the CSF and previous allergy to contrast.
Tilting X-ray table with a C-arm fluoroscopic facility for screening and radiography in multiple planes.
AP and lateral projections of the region under study.

Preliminary examination of plain films is helpful to assess the anatomy of the spine, in order to facilitate the lumbar puncture, and to assist in interpretation of the images. A clear description of any anomaly is required, e.g., lumbarization or sacralization. There is a potential danger of operating at the wrong level if this is not made absolutely clear in the report, together with a statement of how the vertebrae have been numbered in the report.
1. The lumbar thecal sac is punctured at L2/3, L3/4 or L4/5.
2. Lumbar puncture can technically be performed in the lateral decubitus position, in the sitting position, or even in the prone position. The sitting position allows easy lumbar puncture but is unsatisfactory for two reasons. First, the injected contrast medium drops through a large volume of CSF to accumulate in the sacral sac, and becomes diluted as it descends. Second, patients may faint in this position.
3. Accordingly, lumbar puncture should be carried out in the lateral decubitus position. Moderate spinal flexion is desirable. The relevant interspace is one or two spinous processes above the plane of the iliac crest. If the spinous process cannot be felt, lateral fluoroscopy may help.
Needle Placement & Injection Process
4. While needle bevel traversing the thecal sac, there is a characteristic sudden loss of resistance as the needle enters the thecal sac, and at this time the stilette should be withdrawn to verify CSF flow out of the needle. It should then be reintroduced and the needle advanced about 2 mm to ensure that the whole of the bevel has entered the thecal sac. A flexible connector is attached.
7. Most difficulties are technical, arising from non-midline positioning of the needle. In most cases, radiologists will prefer to observe the entry of contrast medium into the thecal sac on the fluoroscopic screen, and this is especially important if there has been any difficulty in achieving a good needle position.
8. After the contrast medium has been injected, the patient turns to lie prone, and a series of films is obtained. Before taking films ensure that the relevant segment of the spinal canal is adequately filled with contrast medium. This usually requires some degree of feet down tilt of the table.
1. AP and oblique views are obtained. (About 25° of obliquity is usual to profile the exit sleeves of the nerve roots of the cauda equina.)
2. A lateral view with a horizontal beam is useful, but further laterals in the erect or semi-erect position on flexion and extension are very useful, adding a dynamic dimension to the study not available on CT or MRI.

Additional technique
Post-myelographic CT may be required for good visualization of the conus.
https://www.youtube.com/watch?v=a4JBIDELYho
https://www.youtube.com/watch?v=SGzTpbGbT3E
IODINATED CONTRAST IN THECAL SAC

THECAL SAC

NERVE ROOTS

LUMBAR MYELOGRAM AP VIEW