Angiographic Imaging Equipment

MRT Program

Angiographic Suite

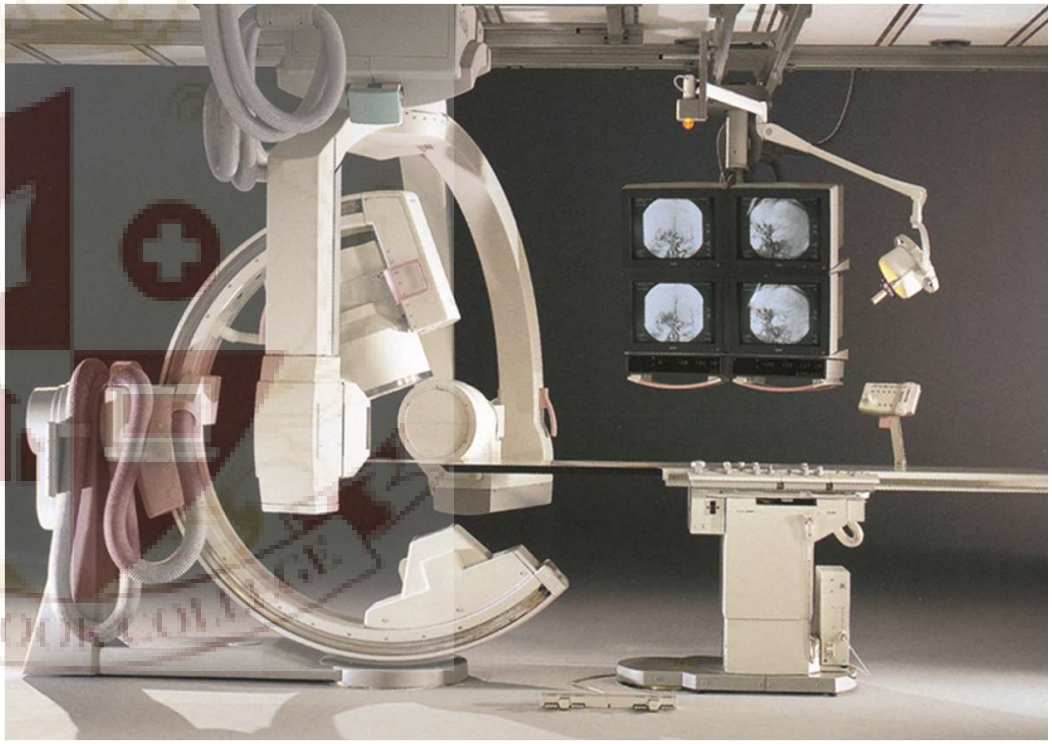
- Larger than conventional radiography room, and has sink/scrub area, patient holding area and a storage area for all the accessory items
- Vascular imaging requires specialized equipment.
- High frequency generators and pulsed tubes are required.
- Additional medical apparatuses may be required for patient support, depending on their condition.
- Outlets for oxygen and suction

Angiography Suite

- Angiography must be performed in a specialized imaging suite.
- 400–600 square feet in size incorporating the procedure suite, the control room and a scrub area.
- Wide door to accommodate stretchers.
- IR suite consists of a c-arm with flat panel detectors and x-ray tube.
- Bank of 3–6 ceiling-mounted LCD monitors or a single 50-inch monitor.
- patient table with tilt or cradle function.
- Biplane configuration to access patient from all sides.
- Many have 3-D rotational and cone beam CT imaging capabilities.

Angiographic Imaging Equipment

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General angiographic room with biplane C-arm digital imaging.

Angiographic Tables

- Floor mounted and off-centre pedestal.
- Narrower than a radiographic table; similar to a CT couch, with cushion for patient comfort.
- Tapered at head end for cerebral studies.
- Free floats in all directions, island type.
- Accommodate table controls:
  - Adjusts in height to raise and lower.
  - Cantilevers to the left and right 15° to 30°.
- Must accommodate vital sign monitoring devices and automatic injectors.

Angiographic Equipment

- Modern vascular suites are equipped with flat detector biplane imaging systems.
- AP and laterally positioned c-arms can take exposures in both planes during one injection of contrast.
- Computer-controlled injectors can deliver pre-protocoled amounts of contrast into the vessel at the correct rate, volume and pressure.

C-Arm Assembly

- C-arm or U-arm design (gantry).
- II/flat panel mounted on one end and tube mounted on opposite side.
- Tube and II/flat panel are always aligned.
- Assembly can rotate to angle the gantry at the attachment point.
- Allows angulations in both AP/PA, lateral and oblique without moving the patient.

High Frequency Generators

- All units are high frequency/tension generators.
- Constant potential generators allow very short exposure times. ≤ 0.001 sec needed for cardiovascular.
- No less than a 3 phase, 12 pulse at 100kW with low ripple.
- Minimum requirement, but all of the new suites use high frequency.

Angiographic Tubes

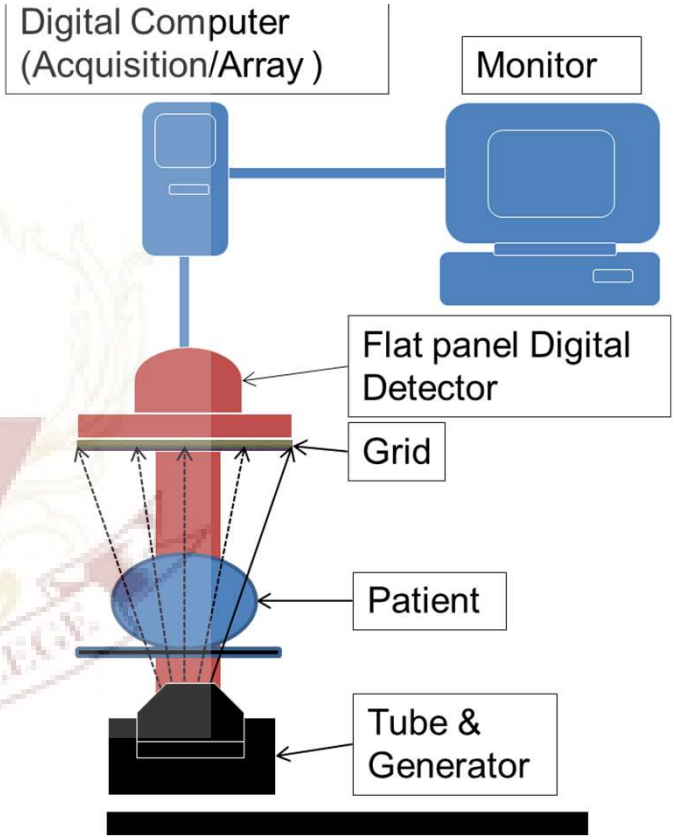
- Superior quality pulsed tube, capable of rapid sequential imaging.
- Most common pulse rates are 7.5, 15 and 30 pulses per second.
- Withstands extremely high and increasing heat loads due to the rapid exposures required.
- Needs to withstand ≥ 500,000 HU.
- General radiographic tubes are commonly ≥ 300,000 HU.
- Extended fluoro times increase anode heat.

Angiographic Tubes (cont'd)

- Metal envelopes and ceramic insulators make the tube more heat resistant.
- Anode is commonly 11° tungsten-rhenium-molybdenum alloy.
- Thicker molybdenum disc and graphite backing dissipates the heat faster allowing for greater heat loading.
- Must provide excellent detail in both small and large focal spots (1.0 mm for heat load/0.3 mm for magnification mode).

Flat Panel Fluoroscopy

- Components:
  - Tube and generator
  - Grid
  - Dynamic FPD
  - Digital computer
  - Monitor



Characteristics of FPD

- Same components and advantages as general fluoroscopy including:
  - Larger dynamic range and faster computing systems allows capability to be used for soft tissue cone beam CT imaging
  - Resistance to image flaring
  - Lack of geometric distortion
  - Better detective quantum efficiency (x-rays to image conversion): decrease patient and staff dose
  - Faster data transfer
  - Higher resolution

Flat Panel Detector

- Flat Panel Image Receptors
- Data is collected in an array/matrix.
- Common framing rates include 3.75, 7.5, 15 and 30 frames per second.
- Capable of a higher frame acquisition.
- Pixels have a fill factor and capacitor similar to the general FPD.
- Detectors and charge coupled device allow continuous interrogation to extinction times.

Flat Panel Detector (cont'd)

- Updates in the two flouro modes:
  - Continuous fluoro mode
  - Pulsed fluoro mode
- Constant updating of data permits smoother dynamic imaging.
- Data transfer is faster with CCD than the plumbicon or vidicon.
- Real-time images are instantaneous.
- May become common for fluoroscopic rooms and C-arms as technology improves.

Storing Fluoroscopic Images

- Fluoro store captures fluoro as a "run":
  - 300–600 images of fluoroscopy (depending on pulse rate).
  - Can be stored, processed and archived.

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General Guidelines for Fluoroscopy

- II kept as close to patient as possible and centered over area of interest.
- Precise collimation.
- Use intermittent or pulsed fluoroscopy and last hold image.
- Use post processing tools effectively.

Reducing Dose to IR Team

- Time (minimize): if you don't need to be in the room then don't be.
- Distance (Inverse Square Law):
  - Increased distance from source of scatter (patient).
  - Use remote controls from control room or within the room far away from patients.
  - Shielding: under-table shielding and over-table mounting shields reduce staff dose dramatically.
  - Personal Protective Devices: lead aprons, thyroid shields and lead glasses used whenever possible.
  - Precise collimation decreases scatter.

Optimizing Patient Dose

- SSD greater than 38 cm (source to skin distance).
- IR as close to patient as possible.
- Use mag mode post-processing instead of during live fluoro.
- Limit fluoro time using last hold image.
- Collimate and move field efficiently to reduce field overlap.
- Use lowest framing rate necessary.

Angiographic Equipment (cont'd)

- Patient monitoring equipment can be integrated into the console or monitors.
  - ECG/blood pressure/heart rate monitored throughout procedure.
  - Physiological/Haemo-Dynamic Monitor (measures arterial/venous pressure and can measure success of intervention.
  - Oxygen (nasal prongs 1–6 l/min and suction also a requirement of room).
- Software can synchronize the timing of the imaging cycle of both c-arms with the injection of contrast.
- Digital subtraction may be used for cardiac and vascular procedures.

Automatic Injectors

- Syringe 60–200 ml capacity
- Smaller syringe (60 ml)
  - Pediatrics, neurological and coronary studies
- Larger syringe (130–150 ml)
  - Aortic, peripheral, hepatic, left ventricular studies
- Multiple studies (200 ml)
  - Abdominal aortic studies where selective angiography may be used

Contrast Injector Control Panel

- Used to set parameters of injection sequence according to procedure protocol.
- Set flow rate of contrast delivery to patient for optimum visualization of vessels.

Use of Contrast Media

- No natural subject contrast between vessels and soft tissue.
- Vessels must be filled with radiopaque iodinated non-ionic contrast.
- Injected by hand or high-pressure injector.
- Target site determines rate of flow of injection.
- Vessel size affects the concentration:
  - The larger the vessel the greater the flow rate to maintain contrast media concentration.
  - Flow rate control determined by contrast viscosity, length and diameter of catheter and injection pressure.

Automatic Injectors (cont'd)

- Injector Power Heads and High-Pressure Mechanism
  - Generally attached to articulating arm that allows for a wide variety of positions during injection.
  - Mechanical stop physically limits injection volume to a preset amount.
  - Acceleration regulators to prevent catheter whip while allowing drive motor to be accelerated over specific time.
  - Pressure limiting devices set maximum pressure to be generated ensuring safe use for low pressure catheters and depends on syringe size and flow scale.
  - Volume limiting device to ensure only required amount of contrast is injected into patient.
- Heating Device
  - Maintains body temperature of contrast.
  - Decreases the viscosity of the contrast which enables setting specific flow rates.

Contrast Media Flow Rate

- Affected by catheter diameter—the larger the internal diameter, the less resistance to flow, requiring less pressure to maintain the flow rate selected.
- Affected by catheter length—overall greater length will provide more resistance to flow versus shorter catheter.
- Affected by contrast viscosity and injection pressure.
- May vary from 4 ml/sec to 30–40 ml/sec.
- Constant flow rate, desired flow rate and time are set.
- Care must be taken to set correctly. Too high may injure patient. Too low, not enough contrast will be seen in vessel.

Contrast Agent Rate/Vol Guidelines

Anatomic Area	Vol/Sec	Total Vol
Abdominal Aorta	25 ml	50 ml
Thoracic Aorta	35 ml	70 ml
Aortic Bifurcation	15 ml	30 ml
Major Vessels off Aorta	10 ml	20 ml
Selective Vessels	5 ml	10 ml
Flow Rate = Amount Delivered per Unit of Time		

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Digital Subtraction Radiology

- DSR is effective for imaging dynamic and real-time image acquisitions.
- Demonstrates vasculature that is normally obscured by superimposed bony structures.
- Acquisition and display speed is controlled by the matrix size, dynamic range of the system and frame rate set by software protocol or the technologist.

Digital Subtraction Radiology (cont'd)

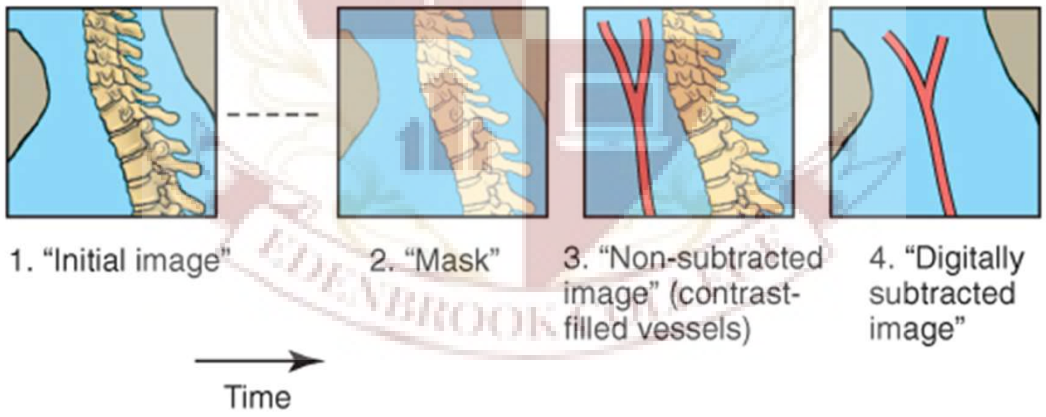
- Image acquisition must be done ≥ 30–50 ms, ≥ 30 f/s depending on the matrix.
- Requires a dedicated array processor that is faster than a microprocessor.
- Additional equipment may have software that is synchronized with the digital angiographic unit:
  - Patient monitoring devices
  - Contrast injection devices

Digital Subtraction Angiography (DSA)

- During DSA a "mask" image (an image without contrast) is taken early in the run and stored in computer memory.
- Software program then subtracts the data from the mask image from subsequent images of contrast-filled vessels.
- Subtracted image appears as reversed image.
  - Demonstrates vasculature free of superimposition of other anatomical structures.
- Image acquisitions can be manipulated, post processed.
- Procedure is sent for interpretation.

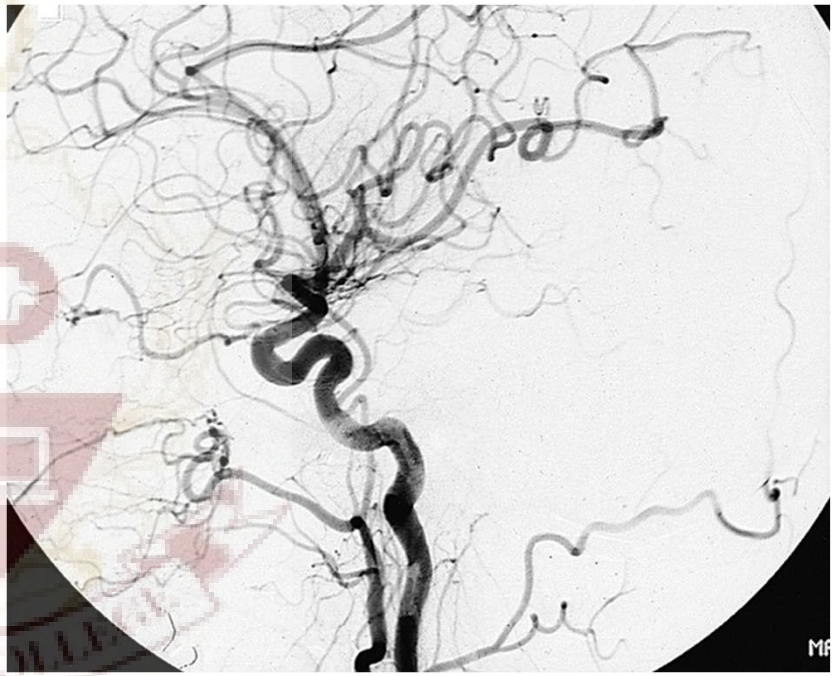
Digital Subtraction Process

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Digital Subtraction Angiography (cont'd)

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- Digitally subtracted carotid angiogram (lateral view)

Digital Subtraction Methods

- Temporal subtraction is most common:
  - Serial mask mode: used for carotid/peripheral, visceral and renal arteriography.
  - Continuous: used for pulmonary arteriography, assessment of heart wall motion.
  - Time interval: cardiac angiography–imaging moving structures.
  - Post procedure: stored image manipulation.
- Energy Subtraction: based on attenuation differences.
- Hybrid Subtraction: combines best of temporal and energy subtraction methods.
  - Images can be produced with motion artifacts eliminated or reduced by subtraction.
  - Requires mask pre-injection of contrast.
  - Images recorded post-injection are then subtracted from the mask leaving only opacified vessels.

Post-Processing Tools

- Digital images can be post-processed by technologist to improve or modify the image.
- Pixel-shifting/remasking:
  - Improves quality of subtracted image by re-aligning the mask image or part of it with contrast-filled vessel/images.
- Image magnification or zoom:
  - Allows visual of fine structures.
  - Saves radiation dose to patient and staff.
- Quantitative Analysis:
  - Measure distances and calculate stenosis of diseased vessel.
- Annotation

Magnification

- Occurs intentionally and unintentionally
- DSA allows different magnification levels by employing different focusing filters inside the II
- Varying the distance of the IR can increase magnification
- Intentional use can result in significant increase in resolution of fine vessel detail

Road Mapping

- A post-processing technique where the peak bolus of contrast is automatically traced over the area of view under fluoroscopy.
- Shows vascular structure completely filled and becomes the "roadmap image."
- Subsequent fluoroscopy shows progress of interventional device (guide wire) over this image.
- Additional exposure runs may be done without losing the original road map, saving contrast and radiation dose.

Misregistration

- Can be major problem with DSA.
- Occurs when the mask and contrasted images do not coincide exactly.
- Caused by patient movement either voluntary or involuntary.
- Voluntary movement can be kept to a minimum if detailed instructions are given to the patient.
- Remasking or pixel shifting software can be used to correct misalignment.

Remasking

- Easiest way to correct misregistration on images.
- Choose another mask (one that was obtained prior to or after contrast injection) that is properly registered to the image.
- Simplest solution but not always successful.
- A suitable mask may not be available.

DSA Stepping Technique

- Stepping software synchronizes the movement of the c-arms or table during contrast injection to co-ordinate with pre-determined individual steps.
- Prior to contrast injection, the system steps though the positions to acquire digital subtraction mask images at each imaging position.
- Contrast is injected and the system steps through the predetermined imaging positions.
- DSA images are produced at each location.
- Safer, less dose to patient and staff, less contrast is used therefore less chance of adverse effects, also decreased cost of exam.

Bolus Chase

- Table or C-arm moves at an estimated speed equal to the speed of the contrast during the acquisition of the images.
- Imaging follows the contrast through the vessels, while table or c-arm is controlled by operator who controls speed.
- Enables imaging from pelvis to toes in one injection.
- Can be programmed to start early or later to observe the vessel filling, or to obtain images with/without contrast.
- Resulting in the ability to image large areas of peripheral vascular anatomy with one injection.
- Imaging system then recreates the movement to produce DSA images.
- Being replaced with MR angio and CT angio techniques.

Rotational Angiography

- C-arm can rotate 240 degrees around patient during injection.
- Anatomy is visualized from a variety of angles with one injection and viewed as cine loop.
- Followed by non-contrast run to allow for subtraction.
- Saves time, decreases patient dose and decreases contrast volume injected by replacing multiple oblique views.
- Rotation over 180 degrees ideal for 3D reconstruction.
- 15–30 frames per second most common.

3D Rotational Angiography

- Software converts rotational angiogram run into 3D image.
- View anatomy from various angles.
- Allows for location, measurement and diameter of vessel lesion.
- Decreases number of DSA acquisition and fluoroscopic time used.
- Decreases radiation dose to patient and staff.
- Decrease amount of contrast required, therefore decreasing risk of adverse reaction.
- Used without contrast for kyphoplasty and facet injection.

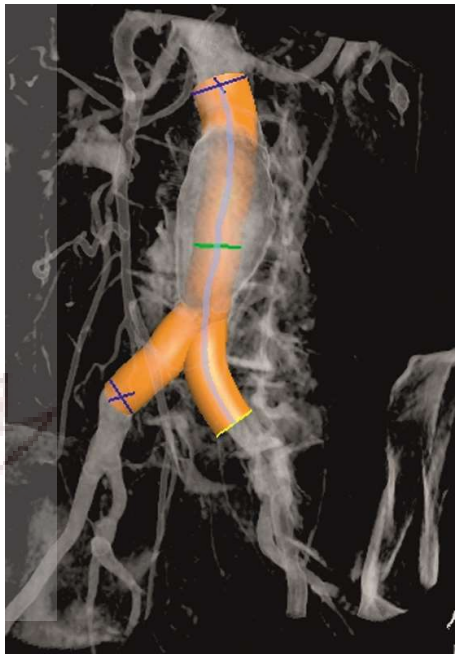
3D Rotational Angiography

- Abdominal Aortic Aneurysm



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- Same patient with Virtual Stent



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View Tracing

- Digital images can be electronically superimposed to produce an image demonstrating the entire contrast flow through the vessels.
- First contrast frame to the last frame, reaching the furthest branches of the arterial/venous vessels.
- Results in contrast through the entire arterial/venous structure.

Landmarking

- Processing software that is applied to a subtracted image to add in landmarks.
- Small amount of the anatomy is put back into the subtracted image.
- Gives surgeons and radiologists anatomic markers to accurately pinpoint where structures are located.

Cone Beam CT Imaging

- Angiographic CT.
- Rotational acquisition of images.
- Gathers many more images (600) than typical rotational angiogram.
- Greater than 180 degree rotation around patient but less than 360 degree of conventional CT scanner.

Coned Beam CT Imaging

- Allows CT imaging capabilities in interventional suite versus having to move patient to CT scanner.
- Can monitor internal bleeding and assist in image-guided biopsies.
- Decreased dose to patient compared to multi-slice CT (up to 85% less).
- Very high spatial resolution although decreased contrast resolution compared to multi-slice CT images

Ultrasound in Interventional Procedures

- Provides real time image guidance.
- Readily available and cost effective.
- Use 2D (most common), 3D or Doppler and intravascular imaging.
- Ultrasound images can be viewed on main monitor boom beside fluoroscopic images.
- Doppler used to measure rate of blood flow through heart and major arteries.
- Intravascular ultrasound used to image arterial walls and used in coronary artery.
- 2D used for drainages and also for arterial puncture site selection.