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*Original Article*

# Digital Subtraction Angiogram: Beginners Perspective

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## Abstract

*Digital Subtraction Angiography (DSA) is a modern technique which integrates digital data collection and computer processing to produce a medical image. X-ray signals are detected electronically rather than on film and then converted to digital form to be processed by a computer before being displayed. DSA is an integral investigation in the management of patients with neurovascular diseases. It is basically used for diagnosis, but in many instances, it may be therapeutic in the same sitting. Indications for diagnostic DSA include both extracranial and intracranial vascular diseases. A sound understanding of the principles of appropriate periprocedural care and anatomy, catheter technique and basic disease pathology are vital to use DSA as a diagnostic as well as therapeutic purposes.*

*Keywords: Digital Subtraction Angiography, neurovascular diseases*

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## Introduction

Digital Subtraction Angiography (DSA) is an integral procedure in the management of patients with neurovascular diseases. It is used for both diagnosis as well as interventional treatment in the same sitting.[1]

A sound understanding of the principles of appropriate periprocedural care and anatomy, angiography technique, and angiographic appearance of pathology are vital for the test to be diagnostic. For a beginner it is very important to know the relevant anatomy, basics of the procedure, periprocedural preparations as well as pathology to avoid complications, interpret the findings and plan treatment.[2]

## Relevant Anatomy

Embryologic development explains the many anatomic variants of cerebrovascular circulation. However, details about embryology are beyond the scope of this article.

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**Aortic Arch**

The challenges posed by complex aortic anatomy demand specific considerations in choice of introducer catheters. It must be emphasized that catheter manipulation in atherosclerotic arches is likely a significant source of embolic complications. So it is very important to know about the anatomy of the arch for a successful procedure.

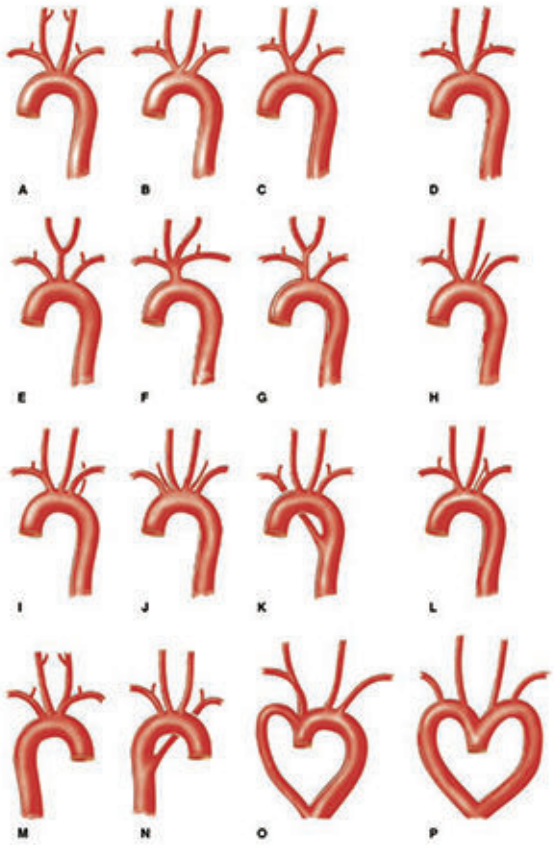


Figure 1: (A–P) Aortic arch variations and anomalies. Schematic illustration of the major groups of aortic anomalies.[3] 1-d is bi-innominate artery.This is a rare entity. The aortic arch has a symmetric appearance with each innominate artery giving a common carotid and subclavian artery.aBerrant right SuBclavian artery (1-k) is a common anomaly and has an association with trisomy 21. The term usually refers to the origin of the right subclavian artery from a point distal to the left subclavian artery. Bicarotid trunk where both carotids originate from the same trunk making catheterisation very difficult(1-c,1-e). Double aortic arch where usually, each arch will give off a common carotid artery and a subclavian artery (Fig. 1-o and p) . Right aortic arch (Fig 1-m and n) may be an incidental finding or may be associated with known congenital heart disease or a vascular ring.This variant is one of the greatest challenges for cerebral angiography when it is encountered in late adulthood. The carotid vessels can be very proximal in their origin on the aorta and very difficult to catheterize.

Extracranial Carotid System (Figure-2)

- Common carotid artery (CCA): Left CCA from the aortic arch and right CCA from the brachiocephalic trunk.
- External carotid artery (ECA): From the upper border of the thyroid cartilage (C4 vertebral level) to terminal branches. Branches include the following:
  1) Superior thyroid artery
  2) Ascending pharyngeal artery
  3) Lingual artery
  4) Facial artery
  5) Occipital artery
  6) Posterior auricular artery
  7) Terminal branches '! superficial temporal and internal maxillary arteries.

**Anterior Circulation**

- Internal carotid artery (ICA) (1,2,4): Bouthillier classification,from below upward
- C1—Cervical segment. From the common carotid bifurcation to entry into the carotid canal.
- C2—Petrous segment. Completely within the bony carotid canal. Small branches not appreciable on digital subtraction angiography (DSA).
- C3—Laceral segment. Up to the petrolingual ligament. First 1 cm of the ICA after exit from the carotid canal.
- C4—Cavernous segment. Up to the proximal dural rim, just inferior to the clinoid process. Branches are meningohypophyseal trunk and inferolateral trunk.
- C5—Clinoid segment. Smallest segment, by the side of the anterior clinoid segment. Ophthalmic artery can arise from it, else no significant branches.
- C6—Ophthalmic segment from distal dural ring up to the posterior communicating artery (PCOM).
- C7—Communicating from PCOM to ICA bifurcation.

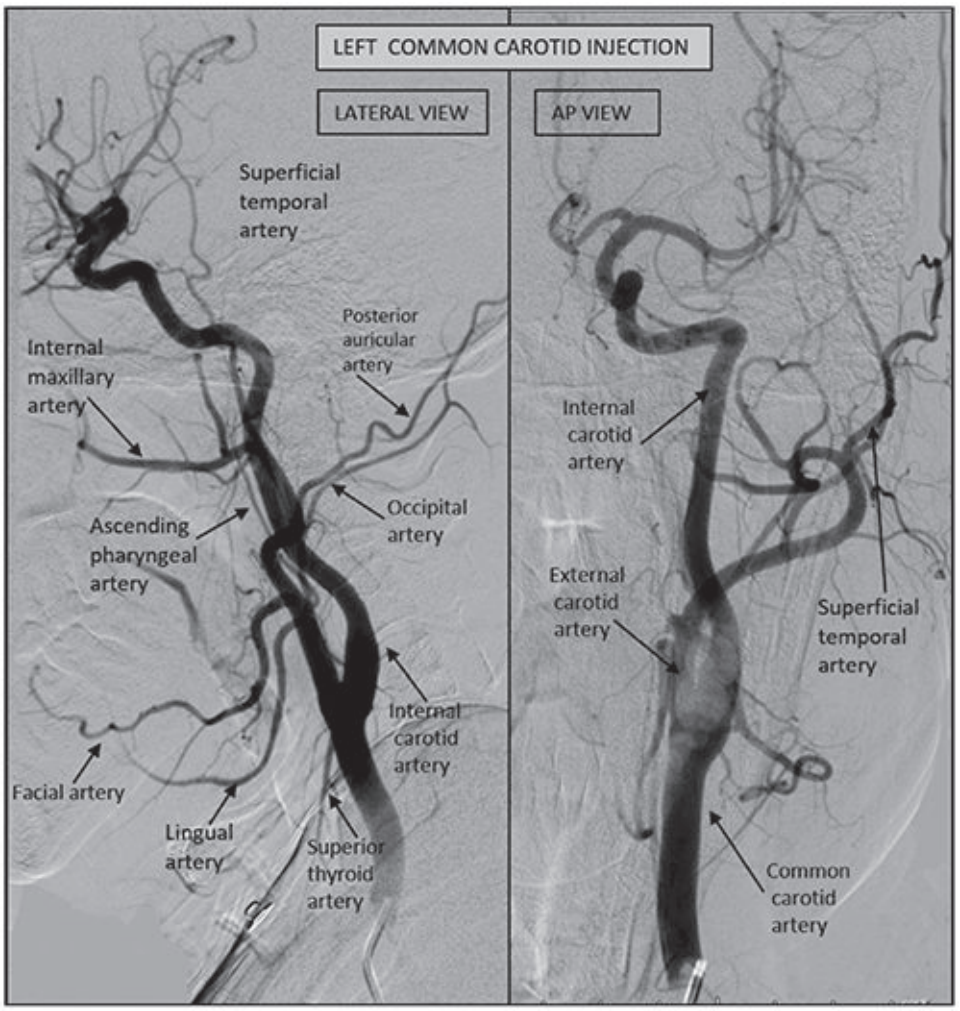


**Fig.-2:** *Common carotid artery injection showing its primary and secondary branches (2).*

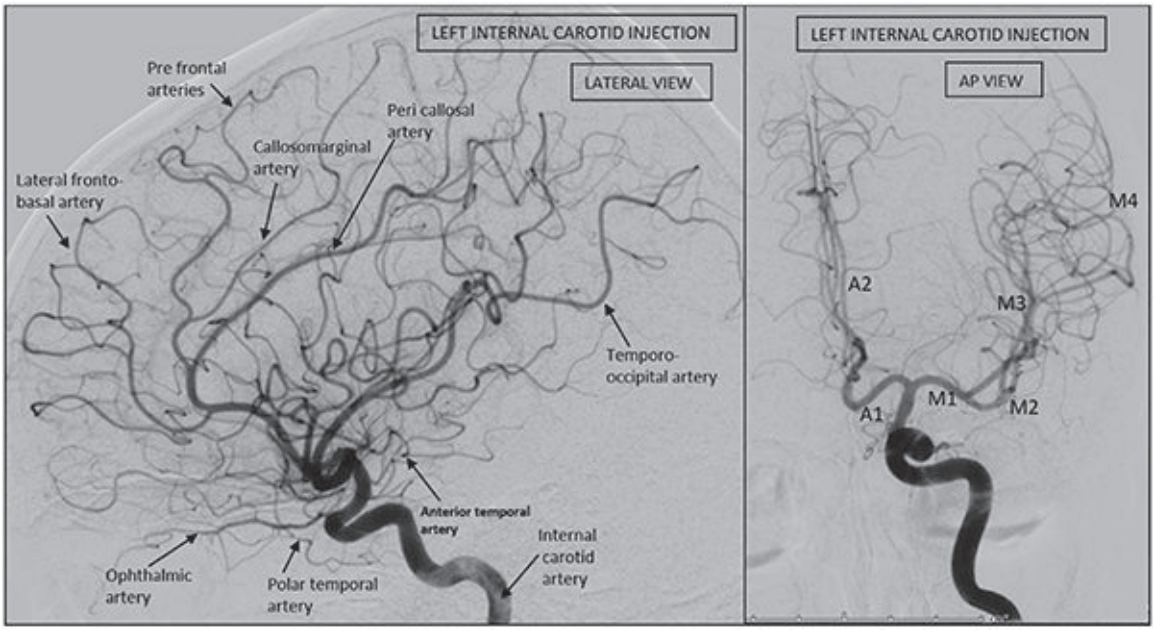


**Fig.-3:** *Anterior Circulation*

Middle cerebral artery (MCA)

- M1—Up to insula, not the bifurcation. The bifurcation can be of the early or lateral type.
- M2—Curved course over the surface of the insula.
- M3—Descends along the circular sulcus of the insula/ operculum up to the cortical surface.
- M4—Along the convex cortical surface.

Figure 4(5) :Superior and Lateral views showing the MCA segments: M1, sphenoidal segment; M2, insular segment; M3, opercular segment; and M4, cortical seg- ments. AChA, anterior choroidal artery; ICA, internal carotid artery; IT, inferior trunk; LSA, lenticulostriate artery; OphA, ophthalmic artery; PCoA, posterior communicating artery; ST, superior trunk.

Anterior cerebral artery (Fig.4)

- A1—From ICA bifurcation to anterior communicating artery (ACOM).
- A2—ACOM to origin of the pericallosal and callosomarginal artery.
- A3—Precallosal segment.
- A4—Supracallosal segment.
- A5—Postcallosal segment.

Figure 4:(5)Lateral views, showing the five ACA segments and 12 arteries that can enter the surgical field around an anterior communicating artery (ACoA) aneurysm. The five ACA segments are as follows: A1, precommunicating or horizontal segment; A2, postcommunicating or infracallosal segment; A3, precallosal segment; A4, supracallosal segment; and A5, postcallosal segment. CmaA, callosomarginal artery; FpA, frontopolar artery; ICA, internal carotid artery; LSA, lenticulostriate artery; MCA, middle cerebral artery; OfA, orbitofrontal artery; PcaA, pericallosal artery; RAH, re- current artery of Heubner.

Posterior Circulation (Fig. 5 and Fig. 6)

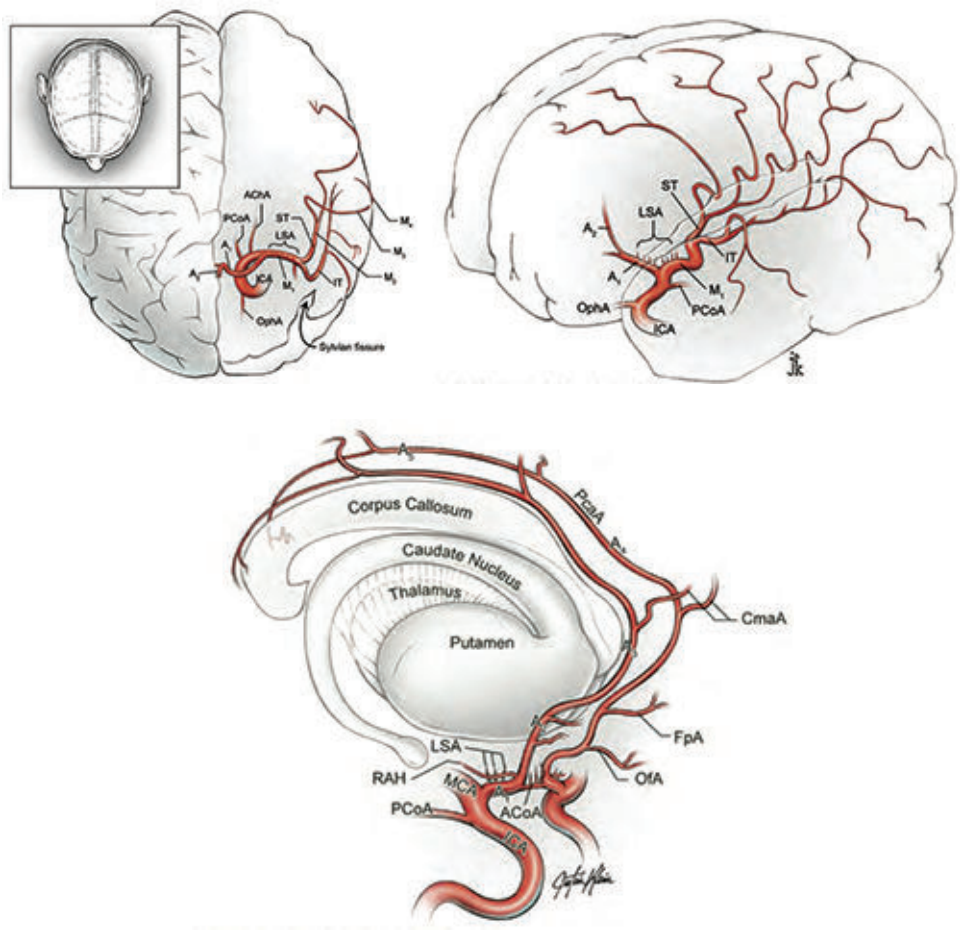


**Fig.-4:** *Anterior Circulation*

Vertebral artery

- V1—Origin from the subclavian artery to the foramen transversarium of C6.
- V2—C6 to C2 foramen transversarium (acute bend in course)
- V3—C2 to the dura (focal constriction), where it has a lateral, superior, and superomedial course.
- V4—Intradural part of vertebral artery, up to the formation of the basilar artery.

Basilar artery

Branches include the following:

- Anterior inferior cerebellar artery versus posterior inferior cerebellar artery balance '! supplement each other.
- Basilar perforators—not seen on DSA.
- Superior cerebellar artery

Posterior Cerebral Artery

- P1—Basilar bifurcation to the PCOM.
- P2—Around the ambient cistern up to the posterior margin of midbrain.
- P3—within the quadrigeminal plate cistern.
- P4—Enters parieto-occipital and calcarine sulcus.

Branches: Thalamo perforator, posterior medial choroidal, lateral choroidal, splenial artery, and thalamogeniculate artery.

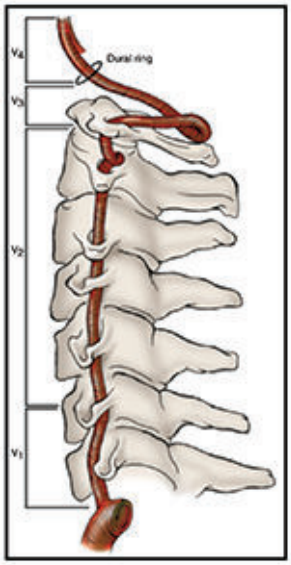


**Fig.-5:** *Vertebral artery segments*

**Venous Anatomy**

Superficial and deep venous system are detailed and marked0in the images provided (Fig. 5).

Figure:Superior group of dural venous sinuses. (1) Superior sagittal sinus; (2) inferior sagittal sinus; (3) straight sinus; (4) occipital sinus; (5) transverse sinus; (6) sigmoid sinus.

**Physiologic Phases(7)**

Circulation time: time taken from contrast reaching the cavernous ICA to first cortical vein; Around 3.5 seconds is normal. It represents the physiologic perfusion time. More than 7 second periods are abnormal.Arterial, capillary (parenchymal), and venous - circulation times at least in two different planes need to be assessed.

**Indications (2)**

**Intracranial**

- Nontraumatic subarachnoid hemorrhage (SAH) of unknown etiology.
- Acute stroke.
- Nontraumatic parenchymal cerebral hemorrhage.
- Intracranial aneurysm: To study cross flow/ complex aneurysm anatomy.
- Cerebral vasospasm.
- Mass lesions: Preoperative tumor embolization, e.g., meningioma, cavernous sinus hemangioma.
- Intracranial arteriovenous malformations to classify (- Spetzler-Martin score) and plan intervention.
- Dural arteriovenous fistulas.
- Wada test.
- To obtain hemodynamic flow information—cross flow, circulation time, and collateral flow.

**Extracranial**

- Extracranial carotid stenosis.
- Carotid blowout.
- Subclavian steal.
- Cervical trauma.
- Epistaxis.
- Preoperative tumour embolization juvenile nasopharyngeal angiofibroma (JNA).

**Contraindications**

No absolute contraindications.

Relative Contraindications:

- Contrast allergy

**Remedy**

- Standard prophylaxis using methylprednisolone, 12 and 2 hours before the procedure.
- Low osmolar contrast media (LOCM) and judicious use of iodinated contrast.
- Pre- and postprocedure hydration with normal saline.
- Renal insufficiency: Dialysis pre- and postprocedure, if dialysis dependent.
- Coagulopathy: Should be corrected when possible.

Patient Preparation(2,4,6,8)

Preprocedural Workup

- Informed consent should be taken from the patient.
- A brief neurological exam must be conducted to establish a baseline, should a neurologic change occur during or after the procedure.
- The patient should be asked if he or she has had a history of iodinated contrast reactions.
- The femoral pulse, as well as the dorsalis pedis and posterior tibialis pulses, should be examined.
- Blood work, including a serum creatinine level and coagulation parameters, should be reviewed.
- Review of available imaging to assess arch anatomy or variants that may aid in catheter selection in case of vessel tortuosity/ atherosclerotic disease.

**Laboratory parameters(2)**

- Complete blood cell count to assess the haemoglobin status and rule out acute sepsis.
- Serum creatinine or glomerular filtration rate (GFR) for baseline record of renal status and to rule out renal dysfunction.
- Prothrombin time/international normalised ratio (PT/INR) to rule out coagulopathy.
- Anticoagulants should be withheld when possible.
- Nil per oral for at least 6 hours preprocedure.
- The morning insulin dose should be reduced in half.
- Bilateral inguinal regions and/or the left arm (radial/ brachial access) should be prepared and made sterile depending on the case.
- An immediate pre-sedation/anaesthesia neurological status assessment should be performed and documented.

**Sedation, Analgesia and position**

- Sedation with intravenous midazolam and analgesia with fentanyl is used.
- Patients should be positioned supine with a headrest, and arms are placed beside the body in extension with support.
- Uncooperative patients may need to have their head gently taped to reduce motion.

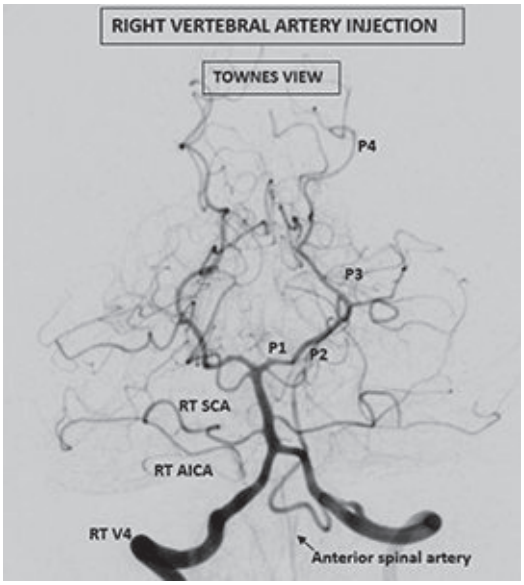


**Fig.-6:** *Vertebral artery injection showing posterior circulation arteries. AICA, anterior inferior cerebellar artery; RT, right; SCA, superior cerebellar artery.*

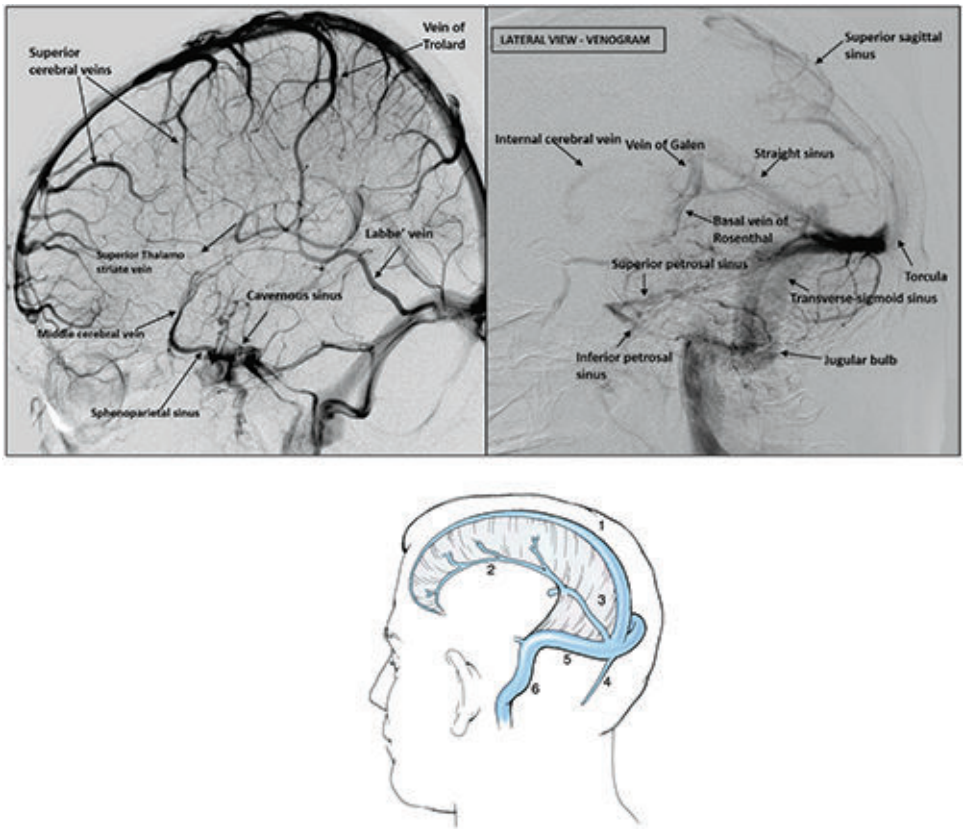


**Fig.-7 :** *Venogram showing superficial and deep venous drainage of the brain.*

- Instructions should indicate patients to stay motionless,especially during image acquisition, and also be told about a potential sensation of warmth within the head with each injection and to avoid swallowing when imaging the neck vasculature, both aimed to reduce motion-related artefact.

**Contrast Agents Used(3)**

Despite its relative expense, nonionic contrast is now the standard for cerebral angiography. Nonionic contrast agents are denominated according to the content of organic iodine per millilitre; for example, Omnipaque 300 contains 647 mg of iohexol per millilitre, equivalent to 300 mg of organic iodine per millilitre.

**Table-I**

*Contrast agents used*

| Name | Solution (mg/mL) | Osmolality (m0smol/kg water)[a] | Viscosity (cp at 37°C)[b] | Iodine Content (mgl/mL) |
|---|---|---|---|---|
| Isovue 200 iopamidol | 408 | 413 | 2.00 | 200 |
| Isovue 300 iopamidol | 612 | 524 | 4.70 | 300 |
| Omnipaque 180 iohexol | 388 | 408 | 2.00 | 180 |
| Omnipaque 300 iohexol | 647 | 672 | 6.30 | 300 |
| Optiray 240 | 509 | 502 | 3.00 | 240 |
| Optiray 300 | 606 | 651 | 5.70 | 300 |
| Optiray 320 ioversol | 678 | 702 | 5.80 | 320 |
| Visipaque 270 | 550 | 270 | 6.3 | 270 |
| Visipaque 320 iodixanol | 652 | 290 | 11.8 | 320 |

$$\frac{\text{Weight kg x 5(adult) 4(child)}}{\text{Serum creatinine mg/dL}} = \text{tolerable volume of 300 nonionic contrast}$$

**Projections and views**

Biplane angiography is the standard of care for cerebral angiography. It allows for orthogonal images to be simultaneously obtained with a single contrast injection, limiting the time and amount of contrast needed to adequately visualise the cerebral vasculature. Monoplanar cerebral angiography is acceptable only when biplane equipment is not available.

Figure-8 (6):Standard PA and lateral projections.(a)Standard PA.The Petrous Bones Lineup with the upper margin of the orbits. (b) Straight PA. No cranial, or caudal angulation is done. In this case, the petrous bones are at the lower edge of the orbits. (c) Caldwell. 25° caudal angulation. The petrous bones are about one third of the way up the orbits. (d) Towne. 35° cranial angulation. The foramen magnum (arrow) can be seen through the calvarium,(e) Water. The view is from below with 45° caudal angulation; the maxillary sinuses (arrow) can be seen clearly. (f) Submento-vertex. The view is from way below, with as much caudal angulation as possible; the vertex of the skull should be framed by the mandible. (g) Lateral. On a straight lateral view, the floor of the left and right anterior fossa directly overlap.

Angiographic positions for common anatomical targets. ICA internal carotid artery, PCA posterior cerebral artery, SCA superior cerebellar artery, AICA anterior inferior cerebellar artery, PICA posterior inferior cerebellar artery.

**Arterial Puncture**

- Right common femoral artery (CFA) is preferred for intraarterial access.
- When CFA access is not optimal, radial/brachial artery access may be required.
- Micropuncture systems with/without ultrasound guidance versus standard 18G access needles can be used for arterial puncture, and a J-wire (atraumatic curved tip) is used, over which the arterial sheath is advanced (Fig. 9).
- A 5F arterial sheath is placed in situ with a continuous heparinized saline sheath infusion to prevent perisheath clotting

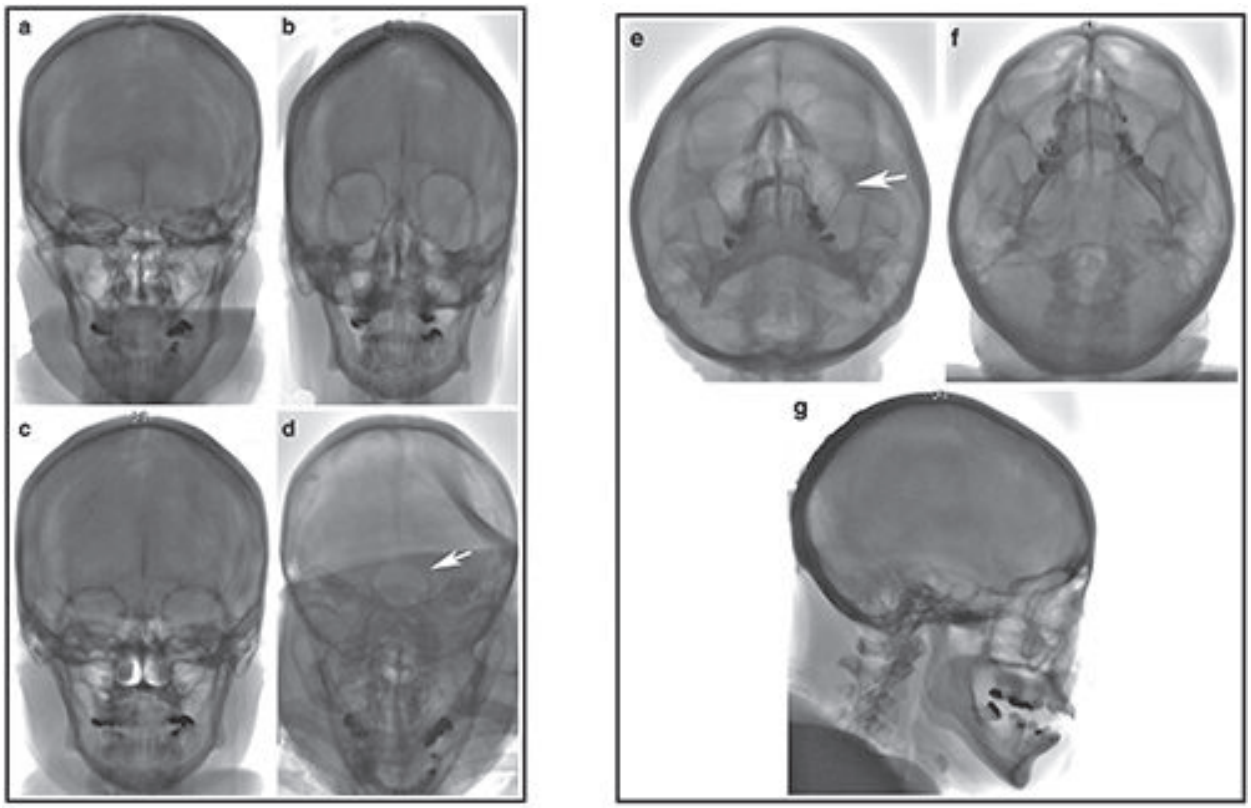


**Fig.-8:**

**Table-II**

*Standar views(6)*

| Target | Optimal views | Additional views/comments |
|---|---|---|
| Carotid bifurcation | Standard PA | Ipsilateral oblique |
| | Lateral | |
| Anterior intracranial circulation | Standard PA | |
| | Lateral | |
| ICA cavernous segment | Caldwell | Haughton |
| | Lateral | |
| ICA ophthalmic segment | Caldwell | Transorbital oblique |
| | Lateral | |
| Posterior communicat-ing artery aneurysms | Haughton | Lateral |
| | Transorbital oblique | |
| ICA bifurcation | Transorbital oblique | |
| Anterior communicating artery aneurysms | Transorbital oblique | Sometimes submentovertex |
| Middle cerebral artery aneurysms | Transorbital oblique | |
| | Submentovertex | |
| Middle cerebral artery candelabra | Lateral with Haughton | |
| | Waters with oblique | |
| Vertebral artery origin | Towne | The vertebral artery arises from the posterior aspect of the subclavian artery |
| Posterior circulation | Water | Ipsilateral oblique |
| | Lateral | |
| Basilar artery | Water | Ipsilateral oblique |
| | Lateral | Water will “elongate” the basilar artery trunk |
| PCA, SCA, AICA, PICA | Towne | Towne elongates PCA. Ipsilateral oblique helps |
| | Lateral | Caveat: Paired vessels overlap |
| Basilar apex aneurysms | Water | Ipsilateral oblique |
| | Lateral | |

**Femoral Artery Puncture**

- Prepare and drape both the groin areas.
- Palpate the femoral pulse at the inguinal crease, and infiltrate local anesthesia (2% lidocaine), first by raising a wheal and then injecting deeply toward the artery.
- Advance it at a 45° angle to the skin, pointing toward the patient’s opposite shoulder.(Fig. 9)
- Attempt a single-wall puncture especially if heparin or antiplatelet agents are used. Do it by looking for blood return from the hollow stylet of the Potts needle. Advance the needle 1–2 mm after the first blood return since the stylet protrudes that far beyond the tip of the needle.
- Make a two-wall puncture by advancing the needle through-and-through both vessel walls, remove the stylet, and slowly withdraw the needle until pulsatile blood return is obtained.
- When bright red, pulsatile arterial blood is encountered, gently advance a J-wire through the needle for 8–10 cm.
- Exchange the needle for a 5F sheath, and secure it with a silk stitch.

Figure 9:(A-D) Femoral arterial puncture. A line between the anterior superior iliac spine and the pubic tubercle corresponds with the inguinal ligament (a). In an adult patient, a puncture site 3 fingers’ breadth below this line along the pulse of the artery pro- vides a useful guide (arrow in b). From here, a needle thrust at 45 degrees toward the umbilicus will usually find a lie in a position suit- able for compression against bone after the case (X in a). Among the difficulties encountered in pass- ing a wire retrogradely into the femoral artery is the possibility of selecting the circumflex iliac artery (C). With a J-wire, this problem can be sidestepped counterintuitively by directing the wire toward the offending artery. The J-curve against the arterial wall will bounce the wire medially and up toward the external iliac artery (D).(3)

**Hydrophilic Wires**

0.035 in. angled Glidewire® (Terumo Medical, Somerset, NJ) is soft, flexible, and steerable.The 0.038 in. angled Glidewire® (Terumo Medical, Somerset,

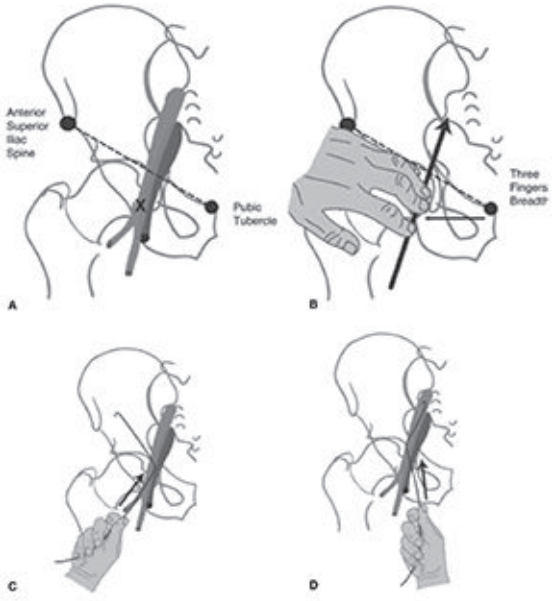


**Fig.-9:** *Common femoral artery puncture technique*

NJ) is slightly stiffer than the 0.035 in., making it helpful when added wire support is needed.

**Catheters**

Many catheters are suitable for cerebral angiography (Fig. 10). As a general rule, use 100 cm long catheters that have a curve that allows selection of the vessels from the arch. Simpler curves (e.g. Berenstein curve) are adaptable to many anatomic situations and are most appropriate for young patients with straighter vessels.

Figure 10:Recommended diagnostic catheters: 5F Angled Taper, Good all-purpose diagnostic catheter. 4 or 5F Vertebral, Good all-purpose diagnostic catheter, slightly stiffer than the Angled Taper but similar in shape. 4 or 5F Simmons 1, Spinal angiography. 4 or 5F Simmons 2 or 3, Left common carotid artery; bovine configuration; tortuous aortic arch; patient's age > 50. 5F CK-1 (aka HN-5), Left common carotid or right vertebral artery. 5F H1 (aka Headhunter), Right subclavian artery; right vertebral artery. 4 or 5F Newton, Tortuous anatomy, patients >65.(6)

**Injection with Hand**

A 10-mL syringe containing contrast should be attached to the catheter, and the syringe should be snapped with the middle finger several times to release bubbles stuck to the inside surface. The syringe should be held in a vertical position, with the plunger directed upward, to allow bubbles to rise away from the catheter(Fig. 11)

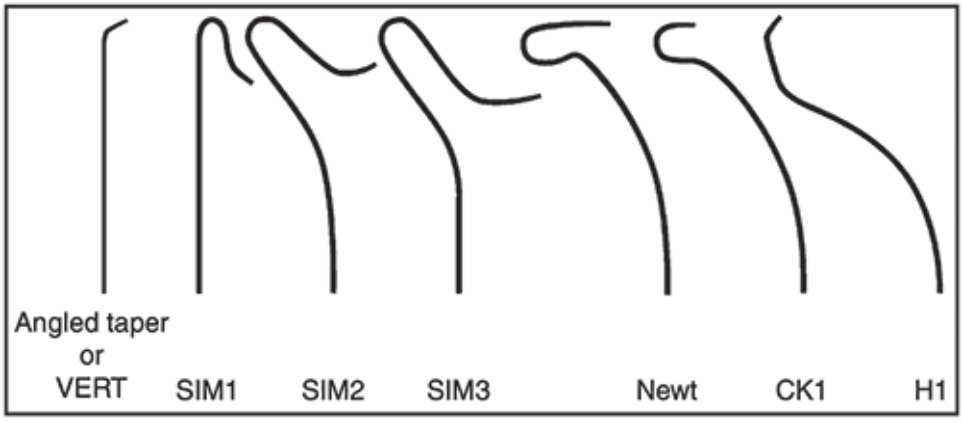


**Fig.-10:** *Different types of catheter*

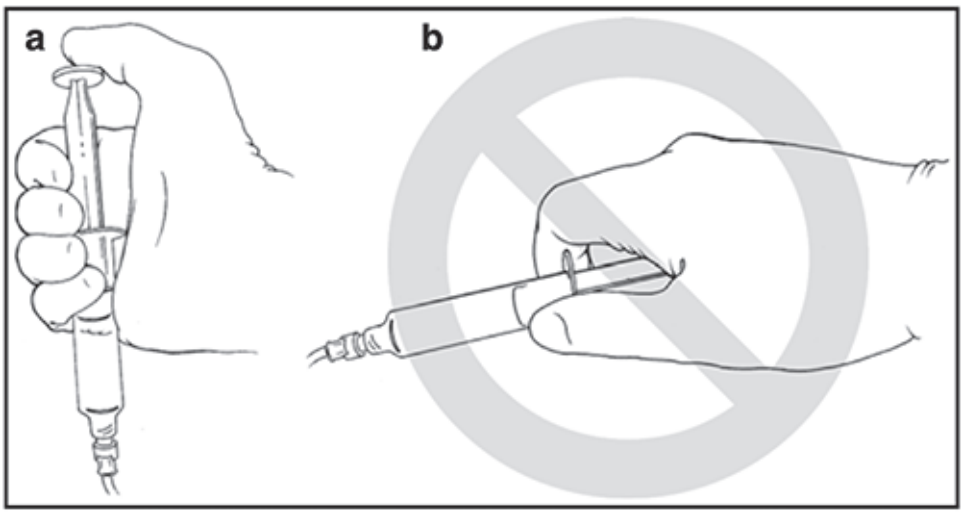


**Fig.-11:** *Injection technique*

Figure 11 : Syringe holding method for hand injections. Correct method (a): the syringe is grasped in the palm of the hand when it is attached to the catheter; this position places the plunger in an upright position to allow bubbles to rise away from the attachment to the catheter. Incorrect method (b): the syringe is held in a horizontal position, like a weapon. Bubbles can go any which way.(6)

**Hand Injection Method**

- Use meticulous technique for flushing and contrast injections (see above).
- Whenever possible, flush the catheter in the descending aorta to keep bubbles away from the cerebral circulation.
- After filling a syringe, allowing it to sit for a few minutes before injection will allow bubbles to come out of suspension and become visible.(6,9)
- A slower flush is less likely to cause bubbles than a rapid flush.(6,9)

**Femoral Artery Puncture Site Management**

The "gold standard" for management of the arteriotomy after an angiogram is manual compression.

- Remove the sheath and apply pressure to the groin 1–2 cm superior to the skin incision.Apply pressure for 15 min: usually 5 min of occlusive pressure, followed by 10 min of lesser pressure.For patients on aspirin and/or clopidogrel, a longer time is required, usually 40 min.
- At the end of the time period, release pressure on the groin slowly and apply a pressure dressing.
- After compression, the patient should remain supine for 5 h, then be allowed to ambulate but remain under nursing observation for one more hour prior to discharge.(6,10)
- Early mobilization even as early as 1.5 h after hemostasis does not significantly increase the incidence of hematomas but definitely reduces complaints of back pain.(6,11)

**Post-angiogram Orders (6)**

- Bed rest with the accessed leg extended, head of bed £30°, for 5 h, then out of bed for 1 h. (If a closure device is used, bed rest, with head of bed elevated 30°, for 1 h, then out of bed for 1 h.
- Vital signs: Check on arrival in the recovery room, then Q 1 h until discharge. Call a physician for SBP <90 mmHg or decrease 25 mmHg; pulse >120.
- Check the puncture site and distal pulses upon arrival in the recovery room, then Q 15 min×4, Q 30 min×2, then Q 1 h until discharge. Call physician if:
  - Bleeding or hematoma develops at the puncture site.
  - Distal pulse is not palpable beyond the puncture site.
  - Extremity is blue or cold.
  - Check the puncture site after ambulation.
- IVF: 0.9N.S. at a maintenance rate until the patient is ambulatory.

- Resume pre-angiogram diet.
- Resume routine medications.
- PO fluids 400 mL.
- D/C IV prior to discharge.

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