Anaesthesia for interventional neuroradiology

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Abstract

The volume and range of procedures undertaken by interventional neuroradiologists continues to expand. They are now treating many conditions previously considered untreatable or only amenable to open surgical techniques. To facilitate the close cooperation required between radiologists and anaesthetists necessary for the successful outcome of these complex and lengthy procedures, it is important for the anaesthetist to have an appreciation of the pathophysiology, potential multisystem effects of the underlying disease, cerebral protection strategies and the potential pitfalls of each procedural technique. Maintaining vigilance during the post-procedural monitoring phase is essential for the early recognition of potential complications, such as bleeding or vessel occlusion, which may warrant further emergency radiological or neurosurgical interventions.

Keywords Acute ischaemic stroke; anaesthesia; arteriovenous malformations; balloon test occlusion; embolization of intracranial tumours; endovascular management of aneurysmal disease; imaging technology; neuroradiology; subarachnoid haemorrhage; thrombectomy

Royal College of Anaesthetists CPD Matrix: 3F00

Learning objectives

After reading this article, you should be able to:

- summarize the principles of anaesthesia for interventional neuroradiology, including the rationale for local or general anaesthesia
- categorize the range of conditions amenable to radiological intervention, including their physiopathology and multisystem effects
- identify the hazards of remote site anaesthesia, contrast and ionizing radiation
- explain the importance of close monitoring in the post-procedural period for the early detection of potentially rapidly evolving neurological deficits and other complications

General considerations for anaesthesia

While many neuroradiological procedures can be carried out in the awake patient, general anaesthesia (GA) may be required because:

- Procedures can be technically challenging and long periods on the angiography table may be uncomfortable and stressful.
- High-quality images are more readily achieved in a motionless and intermittently apnoeic patient.
- GA aids the provision of a physiologically stable patient where arterial pressure, ventilation and ICP can be manipulated.
- Complications may occur rapidly and GA aids urgent transfer to a neurosurgical theatre

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Some procedures such as mechanical clot retrieval and balloon test occlusion can be carried out on an awake patient, but may still require an anaesthetic presence if analgesia, sedation, blood pressure manipulation or rapid conversion to GA becomes necessary.

Furthermore, the patient's presenting neurological condition may result in confusion, pain, lack of cooperation, involuntary movements or a reduced level of consciousness requiring emergency airway management and resuscitation.

Patient assessment

In addition to the standard assessment, patients should have a documented assessment of their baseline neurological state (Glasgow Coma Score, pupil size and reactivity, and focal neurological deficits) and the underlying pathology.

It is important to identify patients who may be at high risk from contrast-induced nephropathy (Box 1).

Drug history should specifically include drugs affecting coagulation, and allergy history should cover iodine, shellfish and contrast in particular. Due to the high dose of ionizing radiation involved in treatment, radiological precautions should minimize the risk to women of child-bearing age.

All patients should have preoperative blood tests: full blood count, urea and electrolytes, estimated glomerular filtration rate (eGFR), coagulation screen, a valid group and save sample and review of their imaging.

Induction

General anaesthetic techniques should aim to maintain cerebral perfusion pressure and avoid extremes of blood pressure and facilitate rapid emergence and neurological assessment. If a rapid

Risk factors for contrast-induced nephropathy

- Age >75 years
- Pre-existing renal impairment
- Hypertension
- Diabetes mellitus (esp. with metformin use)
- Dehydration
- Co-administration of nephrotoxic drugs (e.g. aminoglycosides, non-steroidal anti-inflammatory drugs)

Box 1

sequence induction is required techniques aiming to minimize any increase in ICP should be employed, such as high-dose opioids or alternatives such as intravenous lidocaine (1.5 mg/kg) or labetalol (20–50 mg).

Airway and equipment

Restricted access to the patient is common within the neuroradiology suite. The patient's head is usually located at the opposite end to the anaesthetic machine and a reinforced tracheal tube or south-facing RAE™ is used to prevent kinking or displacement. Intravenous access should be securely fixed and extensions on the breathing circuit, capnography and intravenous tubing should accommodate table movement.

With potentially large volumes of endovascular catheter flush (up to 2 litres), intravenous fluids and the diuretic effect of contrast, a urinary catheter should be considered. A nasogastric (NG) tube may need to be inserted, as some procedures require the intraoperative administration of loading doses of aspirin 300 mg and/or clopidogrel 300 mg at the radiologist's request (an intravenous preparation of aspirin is available). The position of the NG tube can be checked by the radiologist and should be documented to allow immediate use if retained post-procedure.

Monitoring

In addition to the essential standard monitoring (ECG, NIBP, SpO_2, $ETCO_2$, ETAA), invasive arterial monitoring is necessary during most interventional procedures to allow for accurate blood pressure monitoring and management. This may be achieved by sharing a port of the radiologist's arterial endovascular access but this precludes access for sampling (coagulation monitoring, blood gas analysis) and for continuing monitoring in the post-procedure period. Temperature monitoring and patient warming are important as angiography suites are typically cold and procedures may be prolonged.

Maintenance

Both inhalational and total intravenous anaesthesia (TIVA) can be used for maintenance. Providing a motionless patient and episodes of controlled apnoea can be achieved using a remifentanil infusion supplemented by intermittent boluses of neuromuscular blocking agent if required.

Nitrous oxide should be avoided as it may cause expansion of micro air bubbles inadvertently introduced via the radiologist's catheters.

Analgesia

Interventional neuroradiological procedures are rarely painful, except for extracranial procedures or where dural stimulation occurs during tumour embolization. These procedures are usually managed using a remifentanil infusion or boluses of short-acting opioids such as fentanyl or alfentanil to facilitate reliable neurological assessment in the post-operative period.

Extubation

A rapid but controlled emergence is desirable for early neurological assessment with a smooth transition to avoid coughing which may lead to raised ICP and re-bleeding, particularly from groin vessels.

Special considerations

Remote site anaesthesia and transfer

Angiography suites are often remote from the main operating theatre complex and easily available emergency support. Anaesthetists should therefore seek to familiarize themselves with this isolated environment, the available equipment and the procedure being undertaken, and should ensure appropriate support is available. Provisions need to be made before the case is started for the safe intra-hospital transfer of the patient to recovery or the intensive care unit (ICU) for appropriate post-procedure monitoring. Patients originating from ICU may require careful management of external ventricular drains and intracranial pressure (ICP) monitoring devices in transit. Guidance on remote site anaesthesia is available from the Royal College of Anaesthetists.

Radiation safety

Patients and staff are exposed to high-dose ionizing radiation from three sources: direct radiation from the X-ray tube; leakage through the collimators' protective shielding; and scatter radiation from the patient's body (Table 1).

Despite the dose of radiation decreasing exponentially with the distance from the source, maximizing one's distance from the source may be difficult in a confined space. Therefore, adherence to radiation safety guidelines is vital.

Staff should minimize their exposure by combining various types of shielding. This includes the wearing of lead aprons (>0.5 mm thickness) and thyroid collars and using glass lead screens. Protective eyewear should also be considered to reduce the risk of radiation-associated cataract formation.

Contrast nephropathy and other reactions

Patients can receive significant amounts of contrast agent (up to 300 ml). All patients are at risk of acute contrast-induced nephropathy, with some risk-factors increasing it further (Box 1).

Limiting the dose of contrast agent and optimal hydration reduces the risk of acute kidney injury. Patients should have their renal function monitored for 72 hours post-procedure, and renal replacement therapy may be required if renal function significantly deteriorates. If eGFR is <60 ml min^{-1}, then post-contrast metformin should be withheld for 48 hours and reinstituted after renal function has been re-evaluated.

There is insufficient evidence to support the preventative use of either *N*-acetyl cysteine or IV sodium bicarbonate. Other contrast reactions can also occur, such as anaphylaxis, direct cardiac toxicity or effects linked to hypertonicity of the contrast agent.

Radiation doses associated with radiological procedures

Chest X-ray	0.02 mSv	1 CXR equivalent
Abdominal X-ray	0.06 mSv	3 CXR
CT scan of head	1.4–2 mSv	100 CXR
Cerebral angiogram	5 mSv	250 CXR
CT scan of chest	6.6 mSv	300 CXR
Interventional cerebral angiogram	7–10 mSv	300-500CXR

Table 1

Anticoagulation and major blood loss

Endovascular procedures carry a risk of thromboembolic complications. At the beginning of every procedure a baseline activated clotting time (ACT) is obtained (normal range 90–130 seconds) and the radiologist often requests the administration of IV heparin (70–100 units/kg) to prevent vessel occlusion. Aiming to maintain a target of two to three times baseline ACT, further doses of IV heparin may need to be given and rechecked regularly during long procedures. Aspirin (NG or IV) and clopidogrel or prasugrel may also be required. In difficult cases, abciximab (a potent glycoprotein IIb/IIIa inhibitor) may be effective intra-arterially for the treatment of procedure related thrombotic complications. Although it is rare, damage to major vessels or spontaneous bleeding can occur and must be recognized by the anaesthetist, and provisions made to manage major blood loss. Vigilance should continue post-procedure as bleeding from the arterial access site may occur occultly, for example into the retroperitoneal space or soft tissue compartments of the thigh.

Imaging technology

High-speed digital subtraction angiography (DSA) remains the gold standard for interventional neuroradiology. This involves taking a pre-contrast mask picture (a plain X-ray) followed by fluoroscopy screening. All stable structures common to both images (i.e. bone shadows and other non-vascular structures) are subtracted digitally from the mask image. Simultaneously, angiography is performed by injecting a small amount of contrast medium into the circulation. As the contrast is not on the mask image, it is not subtracted, leaving an image 'road map' of the blood vessel or lesion (i.e. visualizing a cerebral aneurysm). In order to allow the radiologist to follow the radiopaque microcatheter tip through the vascular circulation, the real-time image of the micro-catheter or any items (e.g. stents or coils) is superimposed onto the road map so they are clearly visible.

Rotational angiography (Dyna CT™) is an X-ray technique that allows the acquisition of CT-like 3D images with a fixed C-arm. The C-arm rotates (200–360°) around the isocentre of the body part in question over 5–20 seconds, acquiring a few hundred 2D images. Software then performs a cone beam reconstruction, which allows a multiplanar 3D volume to be rotated and zoomed into (Figure 1).

CT angiography (CTA) combines traditional CT scanning with intravenous injection of contrast allowing the visualization of blood vessels and the qualitative assessment of blood flow within them. Although this helps to avoid invasive angiography it does not give any assessment of the adequacy of flow and its sensitivity for aneurysmal subarachnoid haemorrhage (aSAH) is lower than DSA.

CT perfusion and vascular MR studies are also used to identify vasospasm in aSAH and identify those stroke patients who may or may not benefit from mechanical clot retrieval.

Management of specific conditions

The range of commonly performed interventional neuroradiological procedures are listed in Box 2.

Classification of interventional neuroradiological procedures

Intracranial lesions

- Diagnostic angiography
- Coil embolization of cerebral aneurysms (elective and emergency)
- Stenting of aneurysms
- Venous stenting
- Transluminal balloon angioplasty for cerebral vasospasm
- Balloon angioplasty and stenting for carotid artery stenosis
- Test and therapeutic carotid occlusions for giant aneurysms and skull base tumours
- Thrombolysis and thrombectomy after stroke
- Glue embolization of cerebral arteriovenous malformation
- Embolization of carotid-cavernous fistula
- Embolization of intracranial tumours

Extracranial lesions

- Embolization of dural AV malformations, fistulae, and spinal AV malformations
- Vertebral artery stenting
- Vertebroplasty and kyphoplasty

Box 2

Subarachnoid haemorrhage

Subarachnoid haemorrhage (SAH) accounts for about 5% of all cerebral vascular events in the UK. Eighty-five per cent of non-traumatic SAHs are caused by aneurysmal SAH (aSAH.)

The prevalence of cerebral aneurysms is significant, affecting 3.6–6% of the population, and the annual incidence of aSAH is 8–12/100,000. Often occurring in patients of relatively young age (half are younger than 60 years), unfortunately the outcome of aSAH is generally poor, with 50% mortality within a month and 50% of the surviving patients suffering from significant neurological sequelae. Aneurysms usually develop at points of vessel branching on the circle of Willis and are classified as small <12 mm, large 12–24 mm, and giant >24 mm. The risk of rupture is directly related to aneurysm size.

Management of SAH therefore requires a multidisciplinary approach at a dedicated neuroscience center. Patients suspected of SAH should have an urgent non-contrast CT scan (sensitivity of 95–100% on day 1), but if negative, may require a lumbar puncture 12 hours post-ictus.

The gold standard for the detection of intracranial aneurysms is four-vessel DSA. CTA is readily accessible and rapid, but has lower sensitivity and specificity for smaller aneurysms (<5 mm). Magnetic resonance angiogram (MRA) can give more information regarding the cause of the intracranial bleed, but may not be available 24/7, especially for patients requiring a GA. Treatment options for aneurysmal disease include endovascular treatment of the aneurysm or open surgical clipping. The consensus view in the UK is that coiling is the preferred treatment in the majority of aneurysms, especially aneurysms in the posterior circulation. If

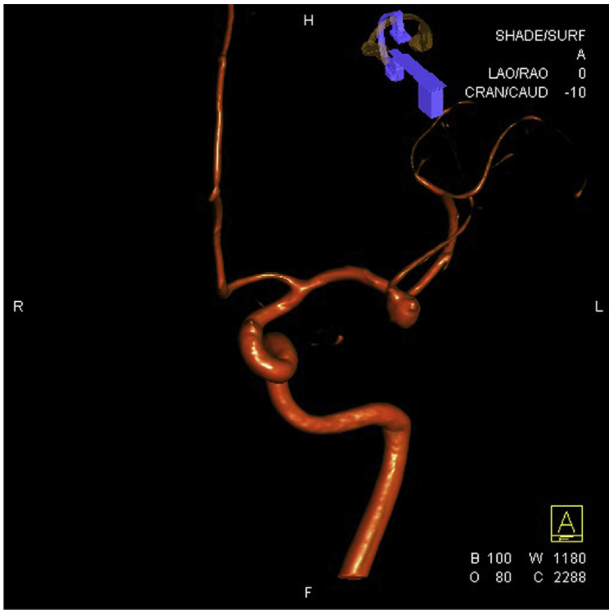

Figure 1 Dyna CT™ reconstruction showing left middle cerebral artery aneurysm.

the aneurysm has difficult anatomy such as a wide neck, difficult angiographic arterial access or coiling fails, then clipping may be required.

Endovascular management of aneurysmal disease

Endovascular management is achieved by a number of approaches:

- Obliteration of the aneurysmal sac using coils with or without stents.
- Occlusion of the proximal parent arteries feeding the aneurysm.
- Placement of a flow disrupting device at the aneurysm neck.
- More rarely, embolization using the injection of a 'glue' substance such as ethylene vinyl alcohol co-polymer (Onyx™).

Coil insertion is achieved by navigating a catheter into the carotid or vertebral artery via the insertion of a femoral arterial sheath. Through this a microcatheter is introduced into the cerebral circulation deploying coils into the sac of the aneurysm until occlusion is achieved (Figure 2). Traditionally, these are platinum coils but newer technology includes:

- Hydrocoils; platinum coils coated with synthetic polyalcohol, which expand within minutes after contact with blood, achieving good volumetric packing.
- Bioactive coils; prevent re-bleeding and re-growth by producing an enhanced cellular response stimulating neointima formation across the aneurysm neck.

Stents (metal mesh devices in the shape of a vessel) and balloons can also be used to facilitate aneurysmal occlusion:

- Stents deployed inside the parent artery at the site of the aneurysm to cover the neck of the aneurysm.
- Flow-diverting stents divert blood flow within an artery, effectively decreasing the flow within an aneurysm and ultimately leading to occlusion.
- High strut density stents result in spontaneous thrombosis of the aneurysm, without occluding the parent vessel.
- Balloon-expandable stents assist coil embolization of difficult lesions unsuitable for simple coiling (e.g. dissecting, fusiform and wide-necked aneurysms).
- Balloon trapping involves balloons being placed intravascularly above and below a giant aneurysm.

Flow disruption devices are a more recent development which allow the neuroradiologist to treat wider necked aneurysms, which were previously less amenable to endovascular approaches.

- A cage placed within the aneurysm sac causes disruption to blood flow across the neck of the aneurysm. As with a flow diverting stent, this leads to thrombosis of the aneurysm sac.
- Devices include the Woven EndoBridge (WEB)™.

More commonly employed in the treatment of arteriovenous malformations (AVMs), glue-like substances can be injected into the aneurysm sac, causing physical obliteration. These agents carry the risk of vessel occlusion, and are reserved for aneurysms which are more difficult to treat with other modalities.

With regard to adverse events, stents carry a risk of arterial thrombosis, and adequate anticoagulation must be achieved. Distal thromboembolism and rupture resulting from manipulation of the aneurysm sac can clinically present in the anaesthetized patient as sudden onset hypertension and/or bradycardia, as a result of raised intracranial pressure (ICP). Contrast extravasation may also be seen on the screen.

Management of these events includes:

- Arterial pressure control by deepening anaesthesia, or with intravenous antihypertensives, e.g. labetalol.
- Reversal of heparin with protamine (1 mg protamine per 100 units heparin administered), if requested by the radiologist who must also gain control of the leak.
- High extravasated blood load risks the development of obstructive hydrocephalus, potentially requiring a CT scan and emergency insertion of an external ventricular drain (EVD).
- Craniotomy for intracranial haematoma evacuation and surgical clipping of the aneurysm.

Management of vascular occlusion secondary to arterial thrombus, emboli, vasospasm, or misplaced catheter or coils involves:

- Increasing collateral flow by increasing arterial pressure 30–40% above baseline, with or without direct intra-arterial thrombolysis with abciximab.
- Intravenous aspirin and heparin, and abciximab are administered pre-, intra-, and post-procedure at the request of the radiologist.
- The misplaced catheter/coils are removed, followed by thrombectomy if indicated.

Post-procedure anti-platelet medication will normally continue with an individualized approach depending upon whether coils, coils plus stent or flow-diverting stents have been used and may involve dual therapy for weeks or months and potentially lifelong aspirin.

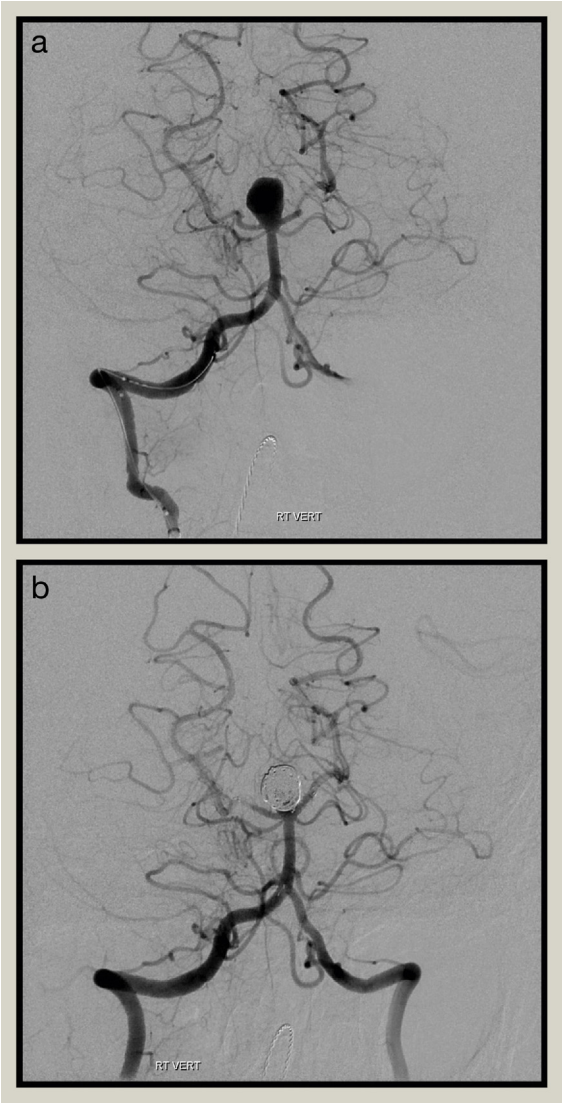

Figure 2 Basilar artery aneurysm: **(a)** pre-coiling, and **(b)** post-coiling.

Vasospasm

Following aneurysmal subarachnoid haemorrhage (aSAH) the leading cause of death and morbidity is delayed cerebral ischaemia (DCI), and vasospasm of cerebral arteries is one component of this pathophysiological phenomenon. The highest risk period for DCI is 2–14 days following aneurysm rupture, and it presents as either a global decrease in conscious level or as a focal deficit such as new motor weakness, dysphasia or aphasia. Presentation may even be as subtle as spontaneous systemic hypertension. Affected patients require neuroradiology input for diagnosis and/or the management of vasospasm.

- CTA may demonstrate reduced caliber of the cerebral arteries.
- Plain CT of the brain will demonstrate areas of established cerebral infarct or hypoperfusion, but a CT perfusion scan may be informative.
- Cerebral angiography is the most specific investigation for demonstrating vasospasm of the cerebral arteries, and also allows for direct treatment.
    - o Calcium-channel antagonists such as verapamil or nimodipine may be injected directly into the constricted arteries, though the increase in vessel calibre is usually temporary.
    - o Mechanical balloon dilatation can be performed to open up the vessel.
    - o A stent can be placed to more permanently improve patency of the affected cerebral arteries. This will mandate anti-platelet therapy to prevent in-stent thrombosis.

Arteriovenous malformations

Arteriovenous malformations (AVMs) are congenital abnormalities consisting of abnormally large vessels and complex fistulae. They can bleed and patients present with headaches, intracranial haemorrhage and seizures. Treatment options include open surgery, glue embolization of fistulae and feeding arteries, or gamma knife radiotherapy alone or in combination. The aim of embolization is to obliterate as many of the fistulae and feeding arteries as possible by injecting 'glue' or coils into the nidus of the AVM. Types of 'glue' include:

- Cyanoacrylate adhesive (Glubran™) a polymerizing adhesive that solidifies on contact with ionic solutions, i.e. blood.
- Ethylene vinyl alcohol co-polymer (Onyx™), a non-adhesive polymer that solidifies through the process of precipitation, allowing for controlled filling of the vascular abnormality over several minutes.

Caution must be exercised when treating the AVM to prevent overwhelming the cerebral autoregulatory capacity of a chronically hypotensive vascular bed. Therefore, in order to prevent parenchymal haemorrhage or swelling, the mean arterial pressure should be kept to 20% below baseline following embolization.

Other complications may include cerebral haemorrhage and embolization of glue into the pulmonary circulation, normal brain arteries and draining veins, thereby causing venous outflow obstruction. Severe post-procedural headache may be indicative of bleeding and should warrant an urgent CT head scan.

Steroids may be administered prophylactically post-procedure to reduce the incidence of perinidus oedema. These patients often need to have multiple procedures to achieve complete obliteration of the AVM.

Acute ischaemic stroke

Stroke is the leading cause of neurodisability and the third most common cause of death in the UK and Europe. Eighty per cent of strokes are caused by ischaemia due to thromboembolic occlusion, commonly of larger, proximal vessels such as the internal carotid or middle cerebral arteries. Rapid diagnosis and treatment is of the essence to reduce the burden of death and disability from this disease. In the past decade mechanical clot retrieval has demonstrated its superiority over intravenous recombinant tissue plasminogen activator (rTPA) alone as the most effective treatment for acute ischaemic stroke, with a number to treat of 2.6 to achieve post-treatment improvement in functional outcome, as measured by the modified Rankin Scale (mRS).

Anaesthetic management of endovascular treatment of acute ischaemic stroke

- Delays have a detrimental effect on patient outcome, preopera tive assessment should be performed as quickly as possible
- In cooperative patients, local anaesthesia should be aimed for
- If conscious sedation is performed, provisions should be made for rapid conversion to general anaesthesia if necessary
- GA is preferred in uncooperative or confused patients and tracheal intubation is recommended
- Under GA systolic arterial pressure should be maintained between 140 and 220 mmHg (<180 mmHg in patients given rtPA)
- Patients should be extubated early, and have full neurological assessment. They should be monitored post-procedure in a high dependency environment

Box 3

The European Stroke Organisation (ESO) released a consensus statement in 2014 making recommendations on the use of endovascular treatment for acute ischaemic stroke, followed by standards published in 2015 by the British Association of Stroke Physicians, British Society of Neuroradiologists and Neuro Anesthesia and Critical Care Society for providing a safe acute ischaemic stroke service (Box 3). The National Institute for Health and Care Excellence's 2016 guidance confirmed that mechanical clot retrieval is both safe and effective.

Current recommendations are that mechanical clot-retrieval should be offered to patients with ischaemic stroke if:

- the occlusion is in a large, proximal cerebral artery, and
- they have significant neurological impairment, defined as a National Institutes of Health Stroke Scale (NIHSS) score of 6 or greater, and
- the procedure can begin within 5 hours of symptom onset.

Time from symptom onset to arterial puncture can be extended to 12 hours in patients where imaging suggests that viable cerebral tissue can still be salvaged. This may be calculated from the Alberta Stroke Programme Early CT score (ASPECTS), or from a CT perfusion or MRI scan. In those with posterior circulation large vessel infarcts, time to arterial puncture can be extended to 24 hours.

Intravenous rTPA should be given prior to clot retrieval (within 4.5 hours of symptom onset), unless there are specific contraindications.

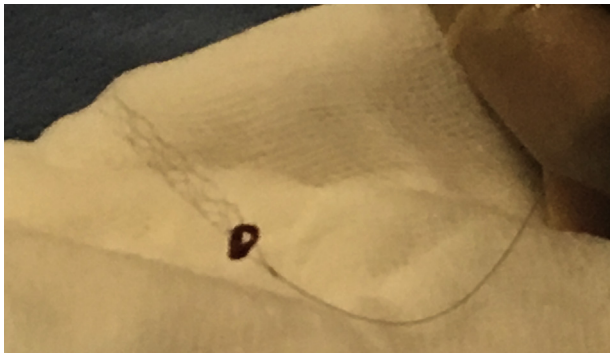

Figure 3 Thrombus removed during mechanical clot retrieval.

The procedure is usually performed via the femoral artery route, through which a guide catheter is maneuvered into the internal carotid artery. The guide catheter contains an intermediate catheter which is advanced to the circle of Willis, and a microcatheter which is directed towards the clot over a microguidewire. Once the microcatheter is in position, its guidewire is removed and the clot retrieval device advanced through the microcatheter to be opened within the clot, ensnaring it within a stent-like structure (Figure 3). The retrieval device is then withdrawn back into the intermediate catheter, while negative pressure is applied either manually or with a mechanical pump to create a suction effect. A balloon guide which acts as a cuff around the guide catheter can be inflated during clot retrieval to temporarily occlude forward blood flow, with the aim of preventing distal embolization of clot fragments. Attempts can be made to retrieve the clot using a suction technique alone, if an intermediate catheter with an external lumen similar in size to the blocked vessel is used. Additional procedures may be required before or after removal of the thrombus, such as angioplasty or stent insertion in carotid or other cerebral vessels with stenosis and/or atherosclerotic plaque.

Risks associated with mechanical clot retrieval are broadly similar to other interventional neuroradiological procedures — procedural failure, contrast reactions, femoral artery injury and retroperitoneal haematoma, carotid or cerebral vessel perforation or dissection, vasospasm, intracranial or subarachnoid haemorrhage, and distal embolization of clot fragments.

As mechanical clot retrieval has evolved, so has the accompanying debate as to whether general anaesthesia or local anaesthesia with sedation is the safer technique. General anaesthesia with endotracheal intubation offers the familiar advantages of a still patient in whom cardiovascular and respiratory physiology can be manipulated; however, GA can provoke deleterious hypotension, and may slow down time to arterial puncture. Local anaesthesia has the benefits of keeping the patient awake to monitor for neurological changes, but if the procedure is lengthy the patient may become uncomfortable and uncooperative, increasing the time taken to complete the procedure and the risk of intravascular complications or failure of the procedure. A fall in conscious level may lead to loss of the airway mid procedure, which can be a logistical challenge to manage in the interventional suite.

Early observational studies suggested poorer outcomes in patients who had GA; however, these studies were not designed to examine the effect of anaesthetic technique and were confounded by selection bias and heterogeneity. More recent randomized control trials (GOLIATH, ANSTROKE and SIESTA) have shown that neither GA nor conscious sedation with local anaesthesia is inferior in terms of post-procedure functional or radiological outcomes. A decision on how best to proceed can be agreed case-by-case between the anaesthetist and radiologist, depending on stroke severity, comorbidities, ability of the patient to communicate and co-operate, and anticipated technical difficulty of the retrieval procedure.

Expediency in the anaesthetic room is important — general anaesthetic technique should follow the principles outlined above, but consider delaying the insertion of arterial lines and urinary catheters where practical until the end of the case. Rapid sequence induction may be indicated depending on fasting time

or the presence of bulbar dysfunction. Blood pressure control is important to maintain cerebral perfusion to the ischaemic penumbra, and a peripheral infusion of a vasopressor such as metaraminol at a rate of 0.5–10 mg/hour is useful to achieve this, aiming for a systolic blood pressure of at least 140 mmHg.

A discussion should be had at the end of the procedure with the radiologist about blood pressure targets and the need to commence anti-platelet therapy (often delayed for 24 hours post rTPA.)

Patients need close neuromonitoring post mechanical clot retrieval, which may be offered in a high dependency or specialized acute stroke unit. Rapid access to neurosurgical services is crucial to deal with complications such as cerebral vessel rupture which can't be controlled radiologically, or to offer surgical decompression in certain cases such as haemorrhagic transformation or malignant MCA syndrome. These factors need to be considered by local stroke networks who wish to introduce or widen access to this neuroradiological treatment of ischaemic stroke. Currently, a nation-wide shortage of interventional radiologists is a rate limiting step in offering mechanical clot retrieval 24/7 across the UK.

Embolization of intracranial tumours

To reduce tumour vascularity and facilitate surgical excision, tumour embolization is performed before open surgery. Steroids are usually prescribed in the interval between embolization and surgery to minimize significant post embolization tumour swelling. Severe post-procedural pain may occur if dural vessels are embolized.

Carotid artery balloon test occlusion (BTO)

Advances in skull base surgery now allow large-scale en bloc resections of neoplasms affecting deep structures such as the clivus and sphenoid wings, which frequently involve the internal carotid artery. BTO is used to access the adequacy of the cerebrovascular collateral circulation before electing to dissect or occlude the carotid artery. BTO is performed under local anaesthesia with anaesthetic support and continuous neurological assessment to prove the adequacy of collateral circulation. Optimal heparinization is essential to minimize the risk of clot formation from blood flow stasis distal to the point of BTO in the artery. Deliberate hypotension can be used to increase the sensitivity of the test and provide a guide to optimum blood pressure during surgery under GA. ◆

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