

Carotid artery occlusive disease:

- Stroke is the third most common cause of death following cardiovascular disease and cancer and is the most common cause of neurological disability. **70-85%** of stroke is **ischemic** and **20-30%** is due to **atherosclerosis of CCA**.
- Pathogenesis: endothelial injury or dysfunction- platelet aggregation and inward migration of mononuclear cells and lymphocytes-release of growth factors- migration and proliferation of smooth muscle cells. In addition deposition of LDLP at the site of injury and within the macrophages (foam cells). Smooth muscles, foam cells and inflammatory cells with connective tissue deposition lead to the formation of plaque. The plaque can ulcerate and rupture exposing the underlying thrombogenic subendothelial surface which can lead to thrombosis and embolisation. Three types of ulcers have been described (type A-small, type B-large and type C-complex excavated. Type B and C ulcers are associated with higher incidence of stroke). Symptoms are produced by embolisation or decrease in blood flow due to arterial narrowing or thrombosis. Blood flow through ICA remains constant until the internal diameter is reduced by 70 % (critical stenosis).
- Natural history: A.NACET-the **3-year risk** of stroke in **asymptomatic** patients was 1.8% in 0-29% stenosis, 2.1% for 30-69% and 5.4% for 70-99% stenosis. For **symptomatic** patients the risk was 26% for 70-90% stenosis, 20% 50-70% and 19% for <50% stenosis.

B. ECST: for **asymptomatic** patients 4.5%, 8% and 14% and for **symptomatic** 17%, 10% and 6%. These two studies measured the degree of stenosis differently (50% stenosis in ECST =75% stenosis in NACET). In NACET the reference was CCA (distal ICA), while in ECST, the reference was the bulb region ???

- Clinical presentations:
 1. TIA either ischemic or retinal (transient neurological deficit lasting < 24hours). The risk of subsequent stroke is **36%** (consensus figure American heart association). TIA is due to distal embolisation and less likely to decrease in blood flow through the narrowed artery **60%** of patients with TIA has **IHD** and **30%** PVD.
 2. Bruit: **4% of people > 45 years of age have cervical bruit**. Cervical bruit is most commonly due CA disease, but in **12%** is due to cardiac disease. **Three** fold increase in the incidence of stroke in patients with bruit. In one study the risk of stroke was **1.7% per year**, but only in 40% the stroke was on the ipsilateral side of the bruit.
- Diagnosis: carotid duplex, angiography and MRA, CT and MRI looking for established stroke and other tests to identify increased risk of stroke (protein S, C antithrombin III, Lupus anticoagulant, homocystine etc..)
- Treatment:
 1. Medical treatment:
 - A. Correction of the risk factors for stroke **.Hypertension** is the most prevalent and correctable risk factor. 5-6 mm decrease in DBP reduces the risk of stroke by 42%. The aim is to keep **SBP<140 and DBP< 90**. Other factors include **DM, smoking, excessive alcohol intake, hypercholesterolemia and hyperhomocysteinemia** (risk factor for atherosclerosis and endothelial dysfunction vitamins B6, B12 and folate may reduce the level).

- B. Antiplatelets: **Aspirin** –irreversible inhibitor of cyclooxygenase and so prevents the formation of thromboxane A₂ “potent vasoconstrictor and platelet aggregator. FDA recommended dose is 50-325 mg /day. 25% reduction in risk of death from cardiac disease **Clopidogrel**-adenosine diphosphate receptor antagonist. Inhibits the adenosine phosphate pathway of platelet aggregation. Dose 75 mg/day. Similar effect to aspirin. **Dipyridamole**-phosphodiesterase inhibitor increases the level of c-AMP. Additive effect when combined with aspirin.(Aspirin+dipyridamole=clopidogrel)
- C. Warfarin is used in patients with nonvalvular AF.

2. Carotid endarterectomy:

- A. Symptomatic patients: **NACET**- 17% reduction in the absolute risk of stroke and death from stroke in the endarterectomy group in comparison with best medical treatment for symptomatic patients with > 70% stenosis. In moderate stenosis 50-69% the 5 year stroke in the surgery group was 15% in comparison to 22% in the medical group (statistically significant). **ECST**-6% reduction in stroke at 3 years in the endarterectomy group. Both studies are prospective randomised trials. So for symptomatic patients with > 70% stenosis there is class 1 evidence in favour of CE.
- B. Asymptomatic patients: Asymptomatic carotid atherosclerosis study and veterans administration asymptomatic stenosis trial demonstrated decreased risk of stroke in EA group in comparison with best medical treatment for patients with asymptomatic carotid stenosis > 50% and 60%. The difference was **not statistically difference**, so for patients with asymptomatic lesions > 60% surgery is beneficial in selected group of patients (ulcerated lesions, progressive stenosis on follow up).
- C. Controversies in CE: **tandem lesions** in the carotid siphon do not increase the risk of CE; however it is a predictor of the future development of coronary artery disease. The use of **cerebral protecting agents** such as barbiturate or etomidate may decrease the risk of ischemic injury from cross clamping and is safe (decrease the cerebral metabolic rate and O₂ consumption and CBF by 50% at a dose causing EEG burst suppression. Etomidate has less myocardial depressing effect. **The use of carotid patch graft** (saphenous, Dacron, PTFE) is controversial. Both primary closure and patch angioplasty have received support. Patch angioplasty is indicated in selected group of patients (recurrent stenosis, small diameter ICA “women”, patients who had cervical radiation, habitual smokers). The use of **intraoperative carotid shunt** is also controversial with some studies showing advantage in decreasing the risk of peri operative stroke and others showing no effect and potential harm “intimal injury” and increasing the risk of embolisation. It is believed that most perioperative strokes are embolic rather than hemodynamic. Shunt may be used selectively in patients who demonstrate the following:
 1. MCA velocity decreases by 60%
 2. EEG changes not responding to hypertension
 3. Carotid stump MAP<25mm Hg. Operative microscope is

useful in removing the last bits of the plaque and closing the carotid incision.

- D. Complications: 1. **Embolisation** of thrombotic material, plaque and air is the most common cause of perioperative stroke it can happen during skin preparation, dissection of ICA and removing of clamps. Heparin, careful dissection and removal of ICA clamp last can reduce the risk 2. **Thrombosis** : the risk can be reduced by giving intraoperative heparin before opening the ICA and by giving postoperative aspirin +- dipyridamole 3. **Intracerebral haemorrhage and hyperperfusion syndrome**(headaches, facial pain, confusion and seizures : <1%. Due to increased perfusion of vessels that are maximally dilated and lost autoregulation. Similar to NPPB syndrome after resection of AVM. The postoperative blood pressure should be kept at lower normal level. The incidence of ICH is higher in patients with previous infarction. 4. **Myocardial infarction**: occurs in 3% and accounts for 50% of late deaths. Patient's cardiac function should be thoroughly assessed and patients should have preoperative cardiac consultation 5. **Wound haematoma**: the risk is higher for redo cases 4% 6. **Nerve injury**: risk is higher for redo cases 0-20%(vagus, recurrent laryngeal, hypoglossal, transverse cervical and supraclavicular, sympathetic chain)
- E. Technical aspects: Nerves at risk during the procedure are greater auricular, lesser occipital, transverse cervical, cervical and mandibular branches of facia nerve, XI, vagus, superior laryngeal (when clamping superior thyroidal artery), hypoglossal at the bifurcation (dissection should be lateral and superior to the hypoglossal artery) . For operative anatomy and technique look page 1631.

3. **Carotid angioplasty and stenting**: The efficacy of percutaneous angioplasty and stenting in preventing stroke remains undetermined. **CREST** study comparing **EA** with **angioplasty** is underway currently. A number of **retrospective studies** of percutaneous angioplasty and stenting have reported comparable results to CE. Currently carotid angioplasty and stenting is indicated for selective group of patients
- A. Patients with **recurrent stenosis**: incidence is 1.3-49% clinically significant recurrence occurs in 1-4%. Recurrence can be early in the first 2 years and usually due to myointimal hyperplasia and late (more than 2 years) due to atherosclerosis. Early recurrence tends to be less symptomatic and potentially reversible due to remodelling of the arterial wall or to resolution of the mural thrombus.. Factors associated with increased recurrence are smoking, younger age group<55, female sex(small artery), DM, hyperlipidemia and surgical factors (narrowing the artery during closure , incomplete excision of the plaque) **Redo surgery** carries high risk 10% risk of major complications. Angioplasty is an alternative for patients with symptomatic recurrence.
- B. Patients with **high cervical lesions** near the base of skull. Surgery for these lesions requires splitting the mandible and carries high risk of cranial nerve injury 7-27%.

- C. History of **neck dissection and radiation for malignancy**: radiation can cause carotid stenosis 2-50 years after the radiation. The stenotic segment tends to be longer.
- D. Patients with **contralateral occlusion of ICA**. NACET reported **14%** 30 day mortality in this group.
- E. Angioplasty and stenting may be used to treat **traumatic and spontaneous carotid dissections**.

Complications are comparable to CE and include embolisation 1%, thrombosis, ICH, **carotid dissection** due to intimal fracture develops in up to **25%** **stenting prevents acute occlusion**., other complications include groin haematoma and femoral pseudoaneurysm, contrast induced renal failure, bradycardia and asystole from carotid bulb compression. Restenosis develops in **7-16%**. Advantage to angioplasty is that it can be done under local anaesthesia, so the patient's neurological status can be monitored.

Other carotid artery diseases:

1. Carotid artery trauma:

- Mostly due to **penetrating injury in >80%** of cases (gun shots, stab wounds, iatrogenic needle punctures, neck surgery). Penetrating injury can lead to complete or partial disruption of vessel wall, pseudoaneurysm, AV F and local haemorrhage. Less commonly due to blunt trauma (MVA, falls). Different mechanisms of blunt injury have been described (hyperextension and rotation or lateral flexion stretch the cervical ICA against transverse processes. **Blunt injury** usually causes **dissection of the ICA** (intimal tear with the formation of pseudo lumen which can expand inwards and cause narrowing or obstruction of the artery lumen or can expand outwards and cause pseudoaneurysm. The false lumen can be subintimal or subadventitial.
- Clinical manifestations: **high index of suspicion** is necessary to diagnose carotid injuries due to blunt trauma because of the absent external signs of trauma and the **delayed development of neurological signs in > 50%** of patients. Patients may present with TIA, stroke not explained by early CT scan, Horner's syndrome. **MRA or angio should be obtained on patients with trauma who develop neurological symptoms that can't be explained by CT head**. Regarding patients with penetrating injuries, neck has been divided into 3 zones. Injury to zone 1 (below the cricoid cartilage)- if the patient is haemodynamically unstable –exploration, if stable –carotid angio, bronchoscopy and esophagoscopy and explore if these tests are positive,. Zone 2 (between cricoid and angle of mandible)- unstable-explore, stable-observe. Zone 3- above the angle of the mandible-unstable explore, stable get carotid and vertebral angiograms and explore if there are injuries.
- Diagnostic methods: **MRI/MRA**- TI fat suppression is the diagnostic method of choice for carotid dissection. **Cerebral angiogram** is the gold standard for penetrating injuries. **Carotid duplex** can diagnose carotid dissection but is not sensitive for high ICA injuries or proximal CCA injuries. CT and MRI head-looking for infarction. CT neck for fractures of transverse processes and lateral masses.
- Treatment: the treatment of carotid dissection has been **controversial** (observation vs. treatment, anticoagulation vs. angioplasty or surgery,

Heparin/warfarin vs. antiplatelets) Although there is no class 1, 2 evidence most centres recommend anticoagulation with heparin then warfarin for 3 months and follow up MRA looking for recanalisation. If MRA shows recanalisation antiplatelets are given for 6 months or for life. If no recanalisation anticoagulation is continued for another 3 months, however if the patient continues to have ischemic symptoms despite being on anticoagulation, transluminal angioplasty and stenting is a viable option. Surgery is indicated for penetrating injuries. Surgical options include direct repair, vessel reconstruction, ligation, trapping with or without revascularisation procedures (cervical petrous, petrous supraclinoid ICA bypass using saphenous vein, STA/MCA bypass). Surgery for blunt trauma is rarely indicated and should be done by vascular neurosurgeon with intraoperative cerebral protection, EEG monitoring.

2. Carotid body tumour:

- Carotid body is 7 X 4X 1.5 mm wheat size organ attached to the dorsal aspect of carotid bifurcation by fibrovascular ligament (Meyer's) and innervated by carotid sinus branch of glossopharyngeal nerve (Hering's). It functions as chemo- receptor. This is a very vascular organ supplied mainly by AP branch of ECA, STA, but can be supplied by ICA, VA, TCT .Histologically is composed of chromaffin cells similar to other paraganglia.
- Carotid body tumours are rare. Histologically consist of epithelial cells grouped in cords or clusters Zellballen. They resemble other paragangliomas with which they may coexist (glomus jugulare, vagale, tympanicum and pheochromocytoma). The majority are hormonally inactive. Some tumours can produce noradrenaline and dopamine. The majority are benign. 6% malignancy rate with metastasis.
- Clinically: pulsatile mass in the neck. If large they can cause hoarseness of voice, hemi tongue atrophy, Horner's syndrome. Investigations _ MRI with contrast shows vividly enhancing tumour in carotid bifurcation, Angio- highly vascular tumour, and balloon compression test helps in intraoperative decision making, embolisation should be considered for large tumours. 24 hour urine for catecholamines and s 5 HMA.
- Treatment is surgical excision with preoperative embolisation, intraoperative cerebral protection and EEG monitoring. The role of radiotherapy remains unclear. It is indicated for residual and recurrent tumours.

3. Fibromuscular dysplasia:

- This is an arteriopathy of unknown origin that affects medium and large sized vessels and characterised by variable degree of replacement of the media/muscularis layer with fibrous tissue. It can be unifocal and multifocal. The most commonly affected artery is the renal artery. F: M ratio is 9:1.
- The cause is unknown. Estrogens and progesterone may play a role, some cases are familial with autosome dominant inheritance and limited penetrance
- Clinical presentations: patients may be asymptomatic. 2/3 of symptomatic patients have cervical bruit, symptoms of cerebral ischemia have been reported in 20-50%. FMD has been associated with spontaneous dissection, aneurysm formation and spontaneous carotico-cavernous fistulas.

- Radiologically three patterns 1. **String of beads**: 80% of cases areas of stricture irregularly spaced separated by dilated segments 2. **Concentric tubular stenosis** 3. **Outpouching** due to focal arterial weakness.
- Treatment: asymptomatic patients are observed and followed up by MRA and Duplex U/S. Patients with embolic symptoms are treated with antiplatelets. If symptoms continue despite antiplatelet therapy, one should consider angioplasty and stenting.

4. **Spontaneous carotid artery dissection:**

- Spontaneous carotid artery dissection has been reported in association with FMD, medial cystic necrosis and Marfan's syndrome; however the cause in the majority is unknown.
- Patients present with headaches 83%, neck pain 20%, TIA and stroke 60% and ptosis and miosis 50 % (**fibres to sweat glands travel along ECA**). Diagnosis is by MRA T1 fat suppression or carotid angio which can demonstrate long tapered narrowing, pseudoaneurysm or occlusion.
- Treatment is controversial, but most centers recommend anticoagulation as first line of treatment and angioplasty with stenting if patients continue to have ischemic symptoms despite anticoagulation.

5. **Carotid stenosis due to radiation:**

- Radiation treatment for cervical cancers/lymphomas can cause endothelial damage and accelerate atherosclerotic changes in CCA, ICA and ECA. Stenosis can develop 2-50 years after radiation and characterised by involving long segments, areas not usually involved in atherosclerosis such as CCA, the arterial wall is weak which makes endarterectomy more dangerous. Patients present similar to others with occlusive carotid disease and angioplasty and stenting may be preferable to endarterectomy in this group although this is debatable.

6. **Extracranial carotid artery aneurysms:**

- Rare, mostly pseudoaneurysms due to trauma or infection. Very rarely true aneurysms due to atherosclerosis. Larger aneurysms can present with pulsatile cervical mass, rarely they can present with neck haematoma or epistaxis due to rupture. Some patients present with TIAs. The goals of treatment are to exclude the aneurysm from circulation and to preserve adequate cerebral blood flow. Historically these lesions were treated with Hunterian ligation which does not address the second goal. Surgically accessible aneurysms in lower and midcervical region are treated with excision and primary repair or repair with saphenous or Dacron graft under cerebral protection and EEG. High cervical lesions are treated with trapping +/- bypass depending on balloon occlusion test results and cerebral blood flow assessment. Other option is transluminal stenting in the absence of infection.

Extracranial vertebral artery disease:

- **Anatomy of extracranial vertebral artery:** vertebral artery is divided into 3 segments. The blood flow through vertebral artery is about 120 ml /min.

1. Proximal : From the origin(SCA sometimes aorta and rarely CCA) to entry through the transverse foramen of C6
2. Middle segment :from C6-C2
3. Distal segment: from C2 it ascends laterally to transverse foramen of C1 and then passes posterior to atlanto occipital joint to lay on the upper surface of the posterior arch of C1 about 2cm off midline and then enters the dura.
 - Vertebrobasilar insufficiency (VBI) is a syndrome characterised by many non-specific symptoms including (dysphagia, dysphonia, ataxia, motor and sensory symptoms, hemianopsia, dizziness, vertigo and cranial nerves palsy). These symptoms may result from haemodynamic insufficiency or emboli into VB system. Many of these symptoms occur in Meniere's disease, vestibulitis, demyelinating diseases, C-P angle tumours etc...
 - Haemodynamic insufficiency may result from cardiac causes (heart failure, arrhythmia, postural hypotension) and from stenosis of vertebral or basilar arteries due to :
 1. Atherosclerosis: most commonly affects the origin of vertebral artery. Critical stenosis is not known. Stenosis per se does not always produce symptoms (85% stenosis produces 25% decrease in blood flow.
 2. Traumatic or spontaneous dissection
 3. Subclavian steal: proximal SCA stenosis-retrograde flow through VA during arm exercise.
 4. compression of vertebral by anterior scalene (rare)
 - Cerebral angiogram which is the gold standard test carries 1% risk of neurological deficit and up to 0.5% risk of permanent deficit, hence it is very important to exclude cardiac and ear causes of the symptoms before embarking on invasive investigations (Holter monitor, cardiac echo, ENT consult with audiogram and vestibular tests).CT scan to exclude mass lesions and haemorrhage, MRI-mass lesions, demyelination, infarctions (DWI), perfusion (PWI). MRA + MRI (T1 fat suppression) is the diagnostic method of choice for dissection. The status of cerebral blood flow can be assessed using SPECT, PET, Xenon CT. Cerebral angiogram remains the gold standard test, but it is invasive and carries a small risk of causing deficit.
 - Once the diagnosis of VBI is made there are three treatment options depending on the cause:
 1. Medical treatment: A. Embolic causes (arrhythmias, SBE, valve disease and emboli from atherosclerotic plaque): antiplatelets (aspirin, dipyridamole, Clopidogrel) +-anticoagulation (brain stem infarction decreased from 35% to 15% with the use of oral anticoagulants. Low dose aspirin reduces the risk of death from infarction and stroke by 25%. B. For dissection: anticoagulation and antiplatelets. C. Treatment of postural hypotension cardiac failure etc...
 2. Endovascular treatment: Balloon angioplasty +- stenting for atherosclerotic narrowing and carotid dissection in patients not responding to medical therapy, embolisation of fistulas is the first line of treatment. The largest series of 46 patients with vertebral AVF treated with endovascular embolisation (90% complete occlusion, 10% partial occlusion) no complications.
 3. Surgical: contrary to carotid artery disease there are no prospective randomised studies comparing surgery with best medical treatment. **Surgery is used in highly selected group of patients who do not respond to medical treatment and fail endovascular treatment.** In a series of 230 patients mortality

was 1%, symptoms resolved in 83% and the 10 year potency of the graft was 91%. Surgical options include.

- A. Proximal V A: (transposition of VA to CCA, venous graft VA-CCA, vein graft VA-cervicothyroid trunk endarterectomy). Supraclavicular incision with division of the clavicular head of sternocleidomastoid muscle and omohyoid muscle, retraction of CCA and vagus nerve medially.
- B. Middle third: (Drilling of the transverse foramen of C6 and removal of osteophytes, rarely venous bypass graft VA-CCA or transposition of VA into CCA)
- C. Distal VA: (CCA-VA venous bypass, ECA –distal VA venous bypass, transposition of occipital artery to VA). (Page 1708 for details).