Carotid endarterectomy as complex intraoperative monitoring

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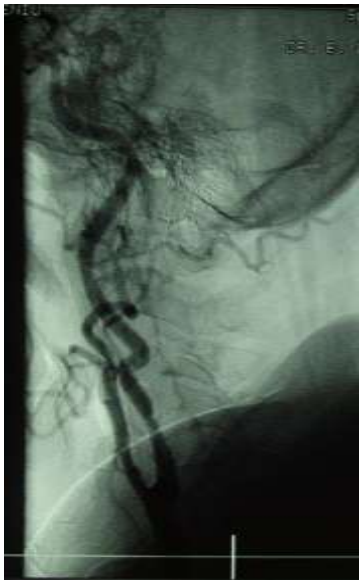
History of Carotid Disease

Sir William Richard Gowers (British neurologist)

First to link stroke with extracranial vascular disease in 1875

The first surgical intervention to relieve atherosclerotic obstruction of the carotid arteries was successfully performed by Dr. Michael DeBakey in 1953 for the first time, at the Methodist Hospital in Houston



Dr. Egas Moni, portuguese neurologist and the developer of cerebral angiography (Nobel Prize in 1949)

STROKE

Table B. Deaths and death rates for 2011 and age-adjusted death rates and percentage changes in age-adjusted rates from 2010 to 2011 for the 15 leading causes of death in 2011: United States, final 2010 and preliminary 2011

[Data are based on a continuous file of records received from the states. Rates are per 100,000 population; age-adjusted rates per 100,000 U.S. standard population based on the year 2000 standard; see Technical Notes. For explanation of asterisks (*) preceding cause-of-death codes, see Technical Notes. Figures for 2011 are based on weighted data rounded to the nearest individual, so categories may not add to totals]

Rank[1]	Cause of death (based on the *International Classification of Diseases, Tenth Revision*, 2008 Edition, 2009)	Number	Death rate	Age-adjusted death rate		
				2011	2010	Percent change
...	All causes	2,512,873	806.5	740.6	747.0	-0.9
1	Diseases of heart (I00–I09,I11,I13,I20–I51)	596,339	191.4	173.7	179.1	–3.0
2	Malignant neoplasms (C00–C97)	575,313	184.6	168.6	172.8	–2.4
3	Chronic lower respiratory diseases (J40–J47)	143,382	46.0	42.7	42.2	1.2
4	Cerebrovascular diseases (I60–I69)	128,931	41.4	37.9	39.1	–3.1
5	Accidents (unintentional injuries) (V01–X59,Y85–Y86)[2,3]	122,777	39.4	38.0	38.0	0.0
6	Alzheimer's disease (G30)	84,691	27.2	24.6	25.1	–2.0
7	Diabetes mellitus (E10–E14)	73,282	23.5	21.5	20.8	3.4
8	Influenza and pneumonia (J09–J18)[4]	53,667	17.2	15.7	15.1	4.0
9	Nephritis, nephrotic syndrome and nephrosis (N00–N07,N17–N19,N25–N27)[5]	45,731	14.7	13.4	15.3	–12.4
10	Intentional self-harm (suicide) (*U03,X60–X84,Y87.0)[2]	38,285	12.3	12.0	12.1	–0.8
11	Septicemia (A40–A41)	35,539	11.4	10.5	10.6	–0.9
12	Chronic liver disease and cirrhosis (K70,K73–K74)	33,539	10.8	9.7	9.4	3.2
13	Essential hypertension and hypertensive renal disease (I10,I12,I15)	27,477	8.8	8.0	8.0	0.0
14	Parkinson's disease (G20–G21)[6]	23,107	7.4	7.0	6.8	2.9
15	Pneumonitis due to solids and liquids (J69)	18,090	5.8	5.3	5.1	3.9
...	All other causes (residual)	512,723	164.6	...	...	...

16 Deaths from stroke

Stroke carries a high risk of death. Survivors can experience loss of vision and/or speech, paralysis, and confusion. Historically called "apoplexy", "stroke" is so called because of the way it strikes people down.

Previous stroke significantly increases risk of further episodes. Certain racial, ethnic and socioeconomic groups are also at greater risk of stroke. The most important modifiable cause of stroke is high blood pressure; for every ten people who die of stroke, four could have been saved if their blood pressure had been regulated. Among those aged under 65, two-fifths of deaths from stroke are linked to smoking. Other modifiable risk factors include unhealthy diet, high salt intake, underlying heart disease, diabetes and high blood lipids.

The risk of death depends on the type of stroke. Transient ischaemic attack or TIA – where symptoms resolve in less than 24 hours – has the best outcome, followed by stroke caused by carotid stenosis (narrowing of the artery in the neck that supplies blood to the brain). Blockage of an artery is more dangerous, with rupture of a cerebral blood vessel the most dangerous of all.

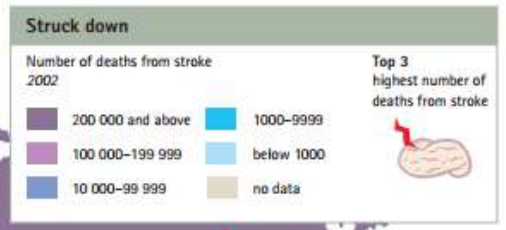
Even where advanced technology and facilities are available, 60% of those who suffer a stroke die or become dependent. Given these dismal statistics and the high cost of treatment of stroke, high priority should be accorded to preventive strategies.

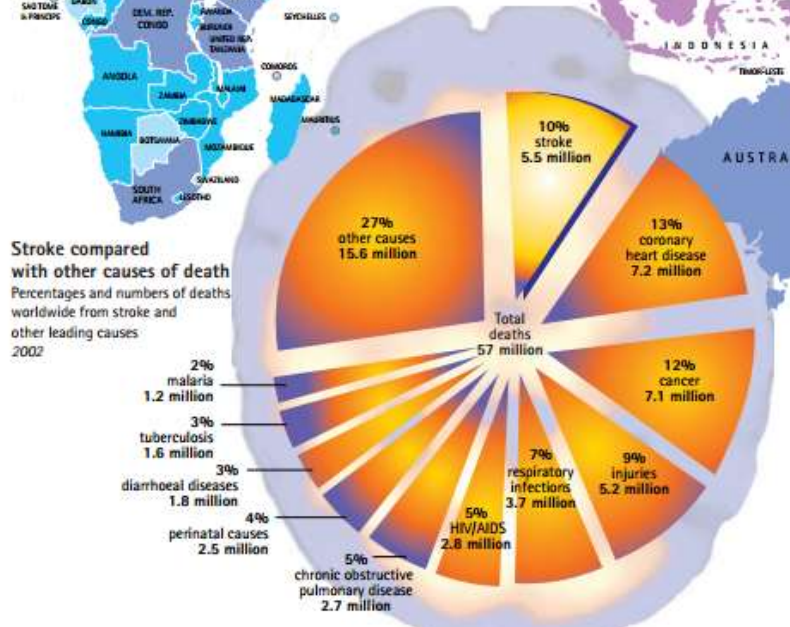
Stroke is the second leading cause of death above the age of 60 years, and the fifth leading cause in people aged 15 to 59 years old.

In the USA, someone dies of a stroke every three minutes.

Worldwide, 3 million women and 2.5 million men die from stroke every year.

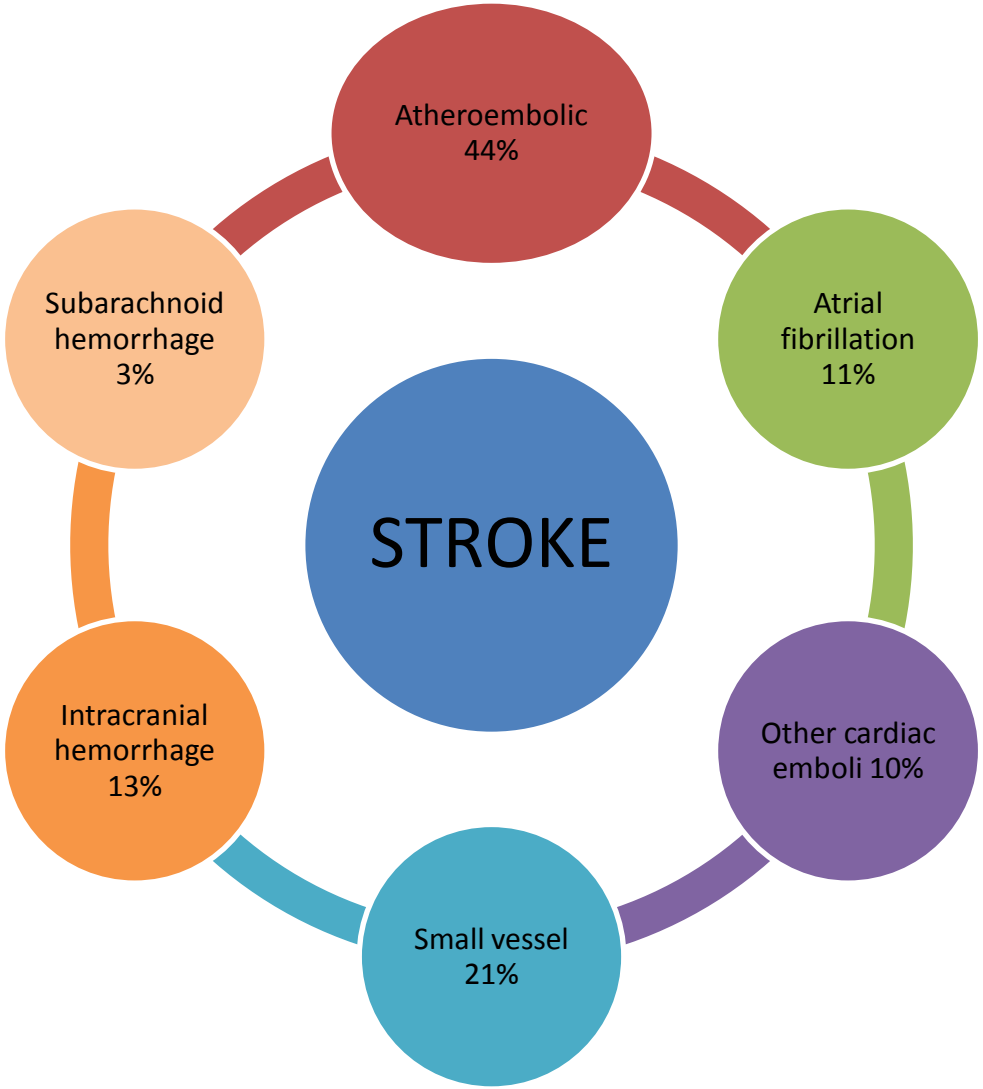
Stroke is the third most common cause of death in developed countries, exceeded only by coronary heart disease and cancer.

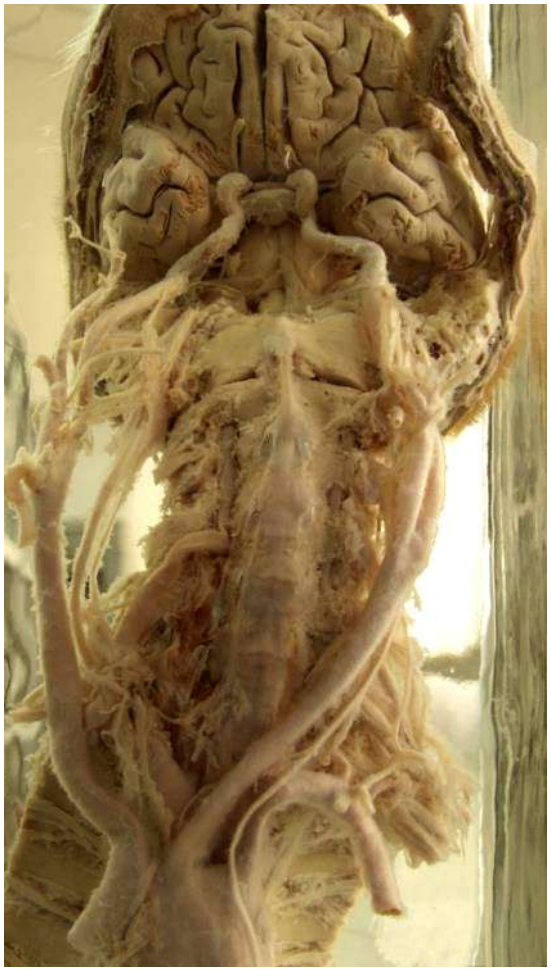




http://www.who.int/cardiovascular_diseases/en/cvd_atlas_16_death_from_stroke.pdf

Incidence of the Various Causes of Stroke





Evaluation of carotid artery stenosis

Carotid doppler ultrasonography

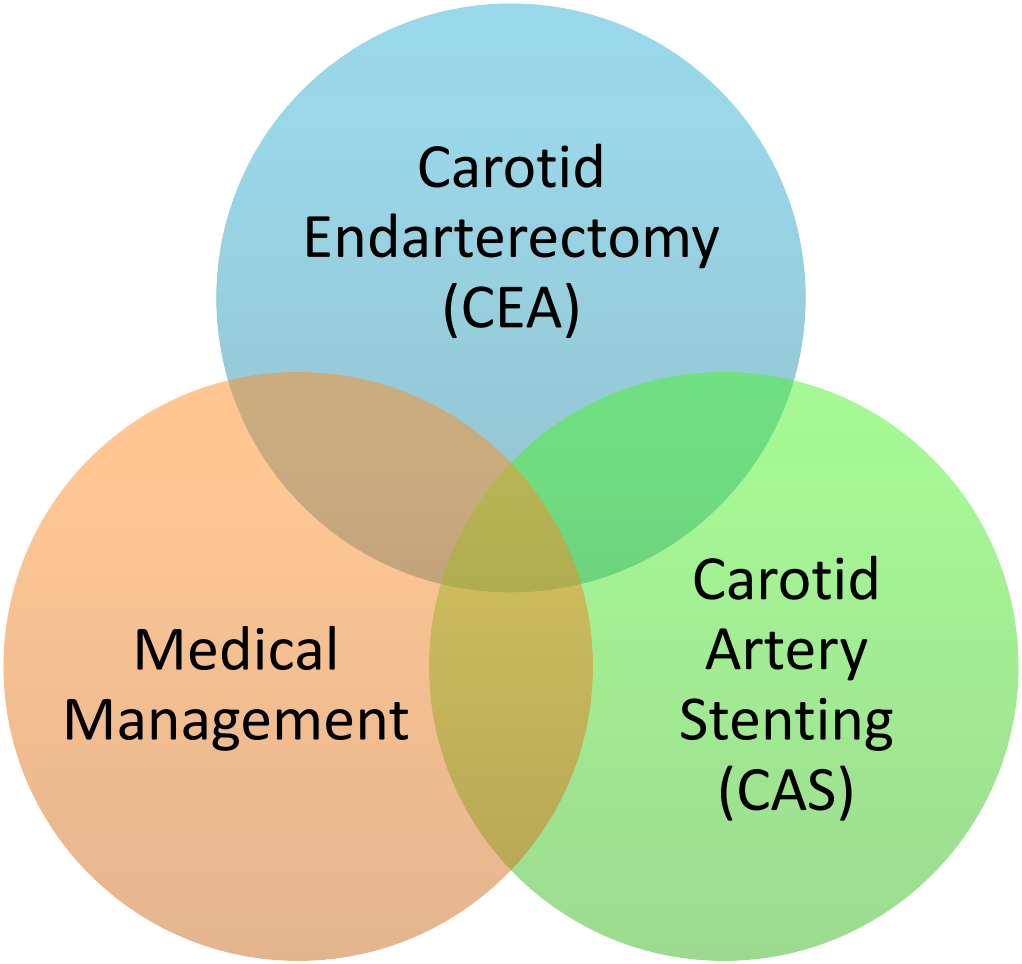
Transcranial doppler

Computed tomographic angiography

Magnetic resonance angiography (MRA)

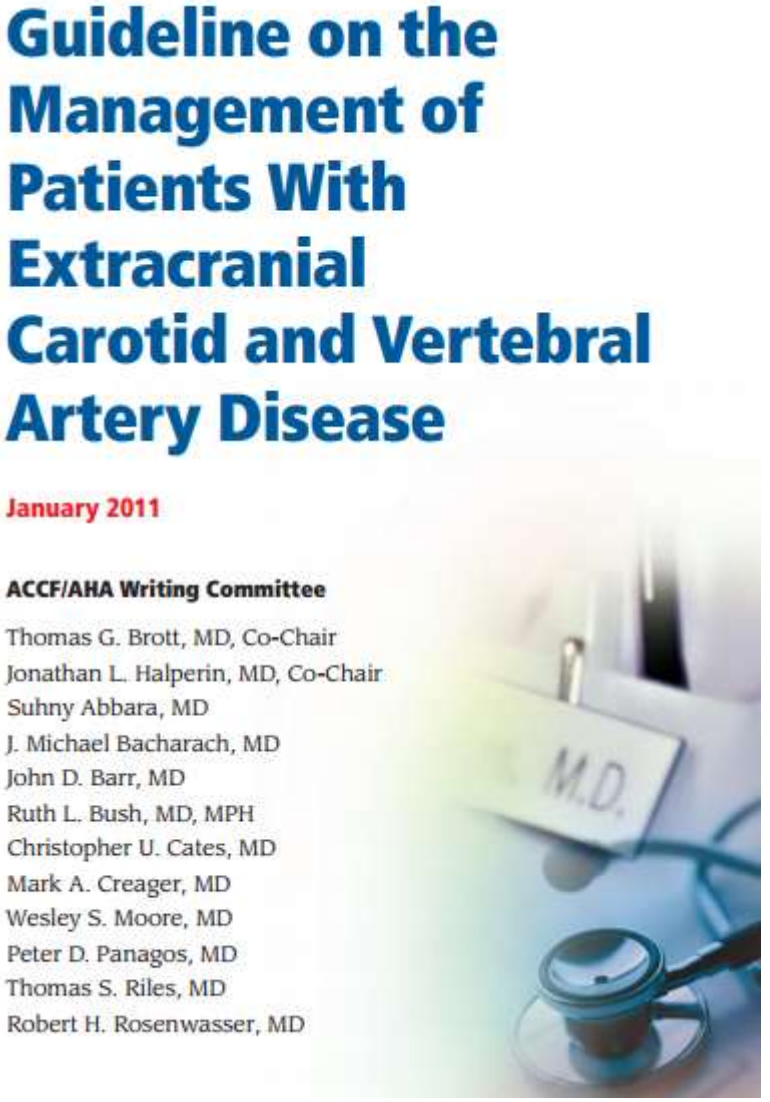
Carotid angiography (the gold standard)

Treatment Options



Medical Management

- Treatment of Hypertension
- Cessation of Tobacco Smoking
- Control of Hyperlipidemia
- Management of Diabetes Mellitus
- Antithrombotic Therapy



Facts

- 33% of TIA patients will suffer a stroke within 5 years, 17% within 1 year
- With ≥ 75% asymptomatic stenosis, 22% of patients will have an ischemic cerebrovascular event at 2 years
- CEA reduces the risk of any stroke from 25% to 10% at two years in patients with symptomatic stenosis of ≥ 70% (NASCET)
- CEA reduces the risk of any stroke or death from 11% to 5% at five years in patients with asymptomatic stenosis of ≥ 60% (ACAS)
- Large series of CAS have shown that stenting can be performed with an acceptable complication rate

Stenting equivalent to CEA?

Studies

- NASCET 1991 - North American Symptomatic Carotid Endarterectomy Trial (50 centers in US and Canada) - Stratified patients according to the degree of stenosis
- NASCET 1998 - Patients with ≥70% stenosis had durable benefit at eight years.
- Veterans Affairs Trial, 1993 - Asymptomatic Carotid Stenosis Veterans Administration Study - Randomized to optimal medical treatment alone vs. optimal medical treatment plus carotid endarterectomy
- ACAS, 1995 - Asymptomatic Carotid Artery Study Prospective randomized trial - medical vs. carotid endarterectomy
- CAVATAS, 2001 - Endovascular versus surgical treatment in patients with carotid stenosis in the Carotid and Vertebral Artery Transluminal Angioplasty Study - no difference in the major risks of endovascular treatment compared with carotid surgery
- CARESS, 2003 - CEA vs. CAS with embolic protection
- SAPPHIRE, 2004 - Stenting and Angioplasty with Protection for Patients at High Risk for Endarterectomy (SAPPHIRE) trial
- SAPPHIRE, 2008 - no difference in long-term outcome

Studies

- EVA-3S, 2006 - Endarterectomy vs. Angioplasty in Patients with Symptomatic Severe carotid Stenosis - the excess of primary outcome events after stenting was considered large enough for the safety committee to recommend stopping the trial
- SPACE, 2006 - Stent-Supported Percutaneous Angioplasty of the Carotid Artery vs. Endarterectomy (SPACE) collaborative group - failed to prove non-inferiority of CAS vs CEA
- CREST - Carotid Revascularization Endarterectomy Versus Stenting Trial
  - 2004
    - 30 day stroke/death rate higher with age ≥ 80 years
      - 12.1% in patients ≥ 80 years
      - 3.2% in patients < 80 years
  - 2010
    - Peri-procedural rate of stroke and death was significantly higher in CAS versus CEA for symptomatic patients (6.0% versus 3.2%) but not for asymptomatic patients (2.5% versus 1.4%)
    - Peri-procedural rate of MI was lower after CAS versus CEA for symptomatic patients (1.0% versus 2.3%) and for asymptomatic patients (1.2% versus 2.2%), however, this was not statistically significant.

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Stenting versus Endarterectomy for Treatment of Carotid-Artery Stenosis

Thomas G. Brott, M.D., Robert W. Hobson, II, M.D.,* George Howard, Dr.P.H., Gary S. Roubin, M.D., Ph.D., Wayne M. Clark, M.D., William Brooks, M.D., Ariane Mackey, M.D., Michael D. Hill, M.D., Pierre P. Leimgruber, M.D., Alice J. Sheffet, Ph.D., Virginia J. Howard, Ph.D., Wesley S. Moore, M.D., Jenifer H. Voeks, Ph.D., L. Nelson Hopkins, M.D., Donald E. Cutlip, M.D., David J. Cohen, M.D., Robert D. Ferguson, M.D., Stanley N. Cohen, M.D., Joseph L. Blackshear, M J.P. Mohr, M.D., Brajesh K. Lal, M.D., and James F. Meschia, M.D., for the

Study results ???

CREST 2010

In conclusion, carotid revascularization performed by highly qualified surgeons and interventionists is effective and safe. Stroke was more likely after carotid-artery stenting. Myocardial infarction was more likely after carotid endarterectomy, but the effect on the quality of life was less than the effect of stroke. Younger patients had slightly fewer events after carotid-artery stenting than after carotid endarterectomy; older patients had fewer events after carotid endarterectomy. The low absolute risk of recurrent stroke suggests that both carotid-artery stenting and carotid endarterectomy are clinically durable and may also reflect advances in medical therapy.

Consensus Guidelines 2011

PRACTICE GUIDELINES

2011 ASA/ACCF/AHA/AANN/AANS/ACR/ASNR/CNS/SAIP/SCAI/SIR/SNIS/SVM/SVS Guideline on the Management of Patients With Extracranial Carotid and Vertebral Artery Disease: Executive Summary

A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, and the American Stroke Association, American Association of Neuroscience Nurses, American Association of Neurological Surgeons, American College of Radiology, American Society of Neuroradiology, Congress of Neurological Surgeons, Society of Atherosclerosis Imaging and Prevention, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of NeuroInterventional Surgery, Society for Vascular Medicine, and Society for Vascular Surgery

Developed in Collaboration With the American Academy of Neurology and Society of Cardiovascular Computed Tomography

Consensus Guidelines 2011

Table 7. Summary of Recommendations Regarding the Selection of Revascularization Techniques for Patients With Carotid Artery Stenosis

	Symptomatic Patients		Asymptomatic Patients
	50% to 69% Stenosis	70% to 99% Stenosis*	70% to 99% Stenosis*
Endarterectomy	Class I LOE: B	Class I LOE: A	Class IIa LOE: A
Stenting	Class I LOE: B	Class I LOE: B	Class IIb LOE: B

The severity of stenosis is defined according to angiographic criteria by the method used in NASCET (37) but generally corresponds as well to assessment by sonography (112) and other accepted methods of measurement. See Sections 7.2 to 7.4.4 for details.

LOE indicates level of evidence.

Consensus Guidelines 2011

Class III: No Benefit

1. Except in extraordinary circumstances, carotid revascularization by either CEA or CAS is not recommended

- when atherosclerosis narrows the lumen by less than 50%. (Level of Evidence: A)
- for patients with chronic total occlusion of the targeted carotid artery. (Level of Evidence: C)
- for patients with severe disability[6] caused by cerebral infarction that precludes preservation of useful function. (Level of Evidence: C)

SVS Guidelines 2011

J Vasc Surg. 2011 Sep;54(3):832-6. doi: 10.1016/j.jvs.2011.07.004.

Updated Society for Vascular Surgery guidelines for management of extracranial carotid disease: executive summary.

Ricotta JJ, Aburahma A, Ascher E, Eskandari M, Faries P, Lal BK; Society for Vascular Surgery.

Washington Hospital Center, Georgetown University School of Medicine, Washington, DC 20010, USA. John.J.Ricotta@medstar.net

Erratum in

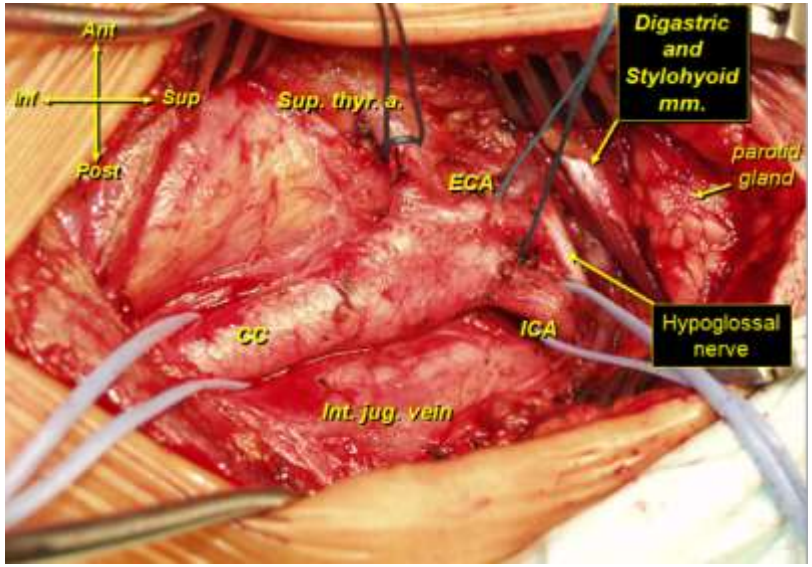
J Vasc Surg. 2012 Mar;55(3):894.

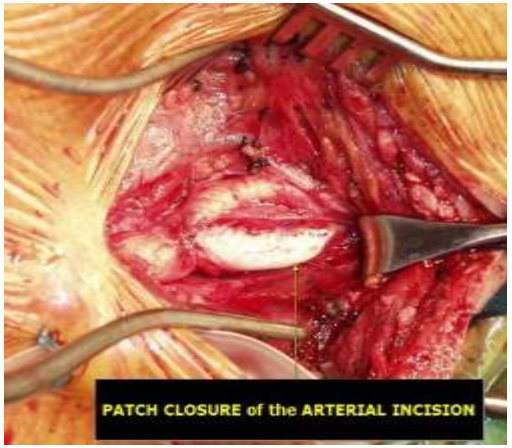
Abstract

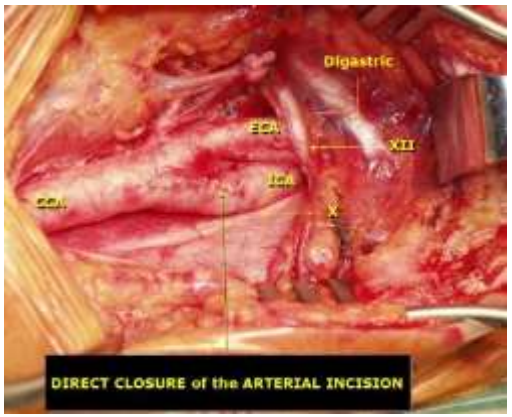
In 2008, the Society for Vascular Surgery published guidelines for the treatment of carotid bifurcation stenosis. Since that time, a number of prospective randomized trials have been completed and have shed additional light on the best treatment of extracranial carotid disease. This has prompted the Society for Vascular Surgery to form a committee to update and expand guidelines in this area. The review was done using the GRADE methodology.[corrected] The perioperative risk of stroke and death in asymptomatic patients must be below 3% to ensure benefit for the patient. Carotid artery stenting (CAS) should be reserved for symptomatic patients with stenosis 50% to 99% at high risk for CEA for anatomic or medical reasons. CAS is not recommended for asymptomatic patients at this time. Asymptomatic patients at high risk for intervention or with <3 years life expectancy should be considered for medical management as first line therapy. In this Executive Summary, we only outline the specifics of the recommendations made in the six areas evaluated. The full text of these guidelines can be found on the on-line version of the Journal of Vascular Surgery at http://journals.elsevierhealth.com/periodicals/ymva.

Carotid Endarterectomy

- Surgical removal of the inner layer of the carotid artery when narrowed by atheromatous intimal plaques







Complications

- The perioperative mortality ranges from <0.5 to 3%
- Cardiac complications (myocardial infarction)
- Stroke is the second most common cause of mortality
- Stroke rates range from < 0.25 to 3%
- Causes of perioperative stroke: embolic, ischemic, hyperemic
- Nerve injury – Vagus nerve, recurrent laryngeal nerve, facial nerve, hypoglossal nerve, glossopharyngeal nerve
- Bleeding resulting in neck hematoma
- Infection
- Restenosis which occurs in up to 20% of patients

General Anesthesia versus Regional/Local Anesthesia

Cochrane Database Syst Rev. 2008 Oct 8;(4):CD000126. doi: 10.1002/14651858.CD000126.pub3.

Local versus general anaesthesia for carotid endarterectomy.

Rerkasem K, Rothwell PM.

Department of Surgery, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand, 50200.

Abstract

BACKGROUND: Carotid endarterectomy reduces the risk of stroke in people with recently symptomatic, severe carotid artery stenosis. However, there are significant perioperative risks which may be lessened by performing the operation under local rather than general anaesthetic. This is an update of a Cochrane review first published in 1996, and previously updated in 2004.

OBJECTIVES: To assess the risks of endarterectomy under local compared with general anaesthetic.

SEARCH STRATEGY: We searched the Cochrane Stroke Group Trials Register (last searched December 2007), MEDLINE (1966 to April 2007) EMBASE (1980 to April 2007) and Index to Scientific and Technical Proceedings (ISTP, 1980 to April 2007). We also handsearched six relevant journals to April 2007, and searched the reference lists of articles identified. For the previous version of this review we handsearched a further seven journals to 2002 and in August 2001 advertised the review in Vascular News, a newspaper for European vascular specialists.

SELECTION CRITERIA: Randomised trials and non-randomised studies comparing carotid endarterectomy under local versus general anaesthetic.

DATA COLLECTION AND ANALYSIS: Two review authors assessed trial quality and extracted the data independently.

MAIN RESULTS: Nine randomised trials involving 812 operations, and 47 non-randomised studies involving 24,181 operations were included. Meta-analysis of the randomised studies showed that there was no evidence of a reduction in the odds of operative stroke, but the use of local anaesthetic was associated with a significant reduction in local haemorrhage (odds ratio 0.30, 95% confidence interval 0.12 to 0.77) within 30 days of the operation. However, the randomised trials were too small to allow reliable conclusions to be drawn, and in some studies intention-to-treat analyses were not possible because of exclusions. Meta-analsis of the non-randomised studies showed that the use of local anaesthetic was associated with significant reductions in the odds of stroke (38 studies), death (42 studies), stroke or death (27 studies), myocardial infarction (27 studies), and pulmonary complications (seven studies), within 30 days of the operation. The methodological quality of the non-randomised trials was questionable. Thirteen of the non-randomised studies were prospective and 36 reported on a consecutive series of patients. In eleven non-randomised studies the number of arteries, as opposed to the number of patients, was unclear.

AUTHORS' CONCLUSIONS: There is insufficient evidence from randomised trials comparing carotid endarterectomy performed under local and general anaesthetic. Non-randomised studies suggest potential benefits with the use of local anaesthetic, but these studies may be biased.

General Anesthesia versus Regional/Local Anesthesia

Surgery. 2012 Sep;152(3):309-14. doi: 10.1016/j.surg.2012.05.008. Epub 2012 Jun 27.

Regional versus general anesthesia for carotid endarterectomy: the American College of Surgeons National Surgical Quality Improvement Program perspective.

Schechter MA, Shortell CK, Scarborough JE.

Department of Surgery, Duke University Medical Center, Durham, NC 27710, USA. matthew.schechter@duke.edu

Abstract

BACKGROUND: The ideal anesthetic technique for carotid endarterectomy remains a matter of debate. This study used the American College of Surgeons National Surgical Quality Improvement Program to evaluate the influence of anesthesia modality on outcomes after carotid endarterectomy.

METHODS: Postoperative outcomes were compared for American College of Surgeons National Surgical Quality Improvement Program patients undergoing carotid endarterectomy between 2005 and 2009 with either general or regional anesthesia. A separate analysis was performed on a subset of patients matched on propensity for undergoing carotid endarterectomy with regional anesthesia.

RESULTS: For the entire sample of 24,716 National Surgical Quality Improvement Program patients undergoing carotid endarterectomy and the propensity-matched cohort of 8,050 patients, there was no difference in the 30-day postoperative composite stroke/myocardial infarction/death rate based on anesthetic type. Within the matched cohort, the rate of other complications did not differ (2.8% regional vs. 3.6% general anesthesia; P = .07), but patients receiving regional anesthesia had shorter operative (99 ± 36 minutes vs 119 ± 53 minutes; P < .0001) and anesthesia times (52 ± 29 minutes vs. 64 ± 37 minutes; P < .0001) and were more likely to be discharged the next day (77.0% vs 64.4%; P < .0001).

CONCLUSION: Anesthesia technique does not impact patient outcomes after carotid endarterectomy, but may influence overall cost of care.

General Anesthesia

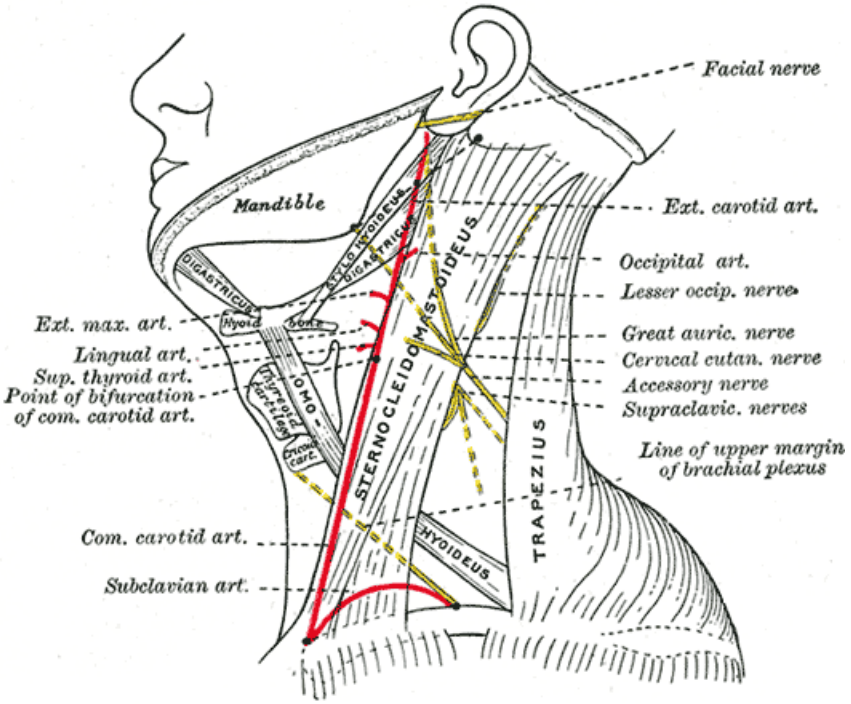
- Does not prevent hemodynamic response of manipulation of the carotid sinus (severe vagal response)
- Due to comorbidities (i.e. CAD, MI) it's important to avoid large BP swings especially upon intubation and emergence
- Maintenance of normocarbia
- Quick emergence
  - Important to quickly assess neurological function

Cervical Plexus Block

- Deep Cervical Plexus Block
  - Palpate the mastoid process behind the ear
  - Draw a line at the posterior border of the sternocleidomastoid muscle connecting the tip of the mastoid process and the Chassaignac tubercle (i.e. transverse process of C6)
  - 3 separate injections: at 2 cm below mastoid process there is the transverse process of C2; at 2 cm below C2 is C3 and another 2 cm below C3 is C4
  - 22 G needle x3 advanced perpendicular to the skin and slightly caudal until contacting the transverse process (depth about 1.5 to 3 cm)
  - Inject 3 to 4 ml of solution
  - Complications
    - Intravascular injection (Vertebral artery, Carotid artery, Internal jugular, External jugular)
    - Intrathecal injection (Epidural / Subarachnoid anesthetic)
    - Paralysis of the ipsilateral diaphragm (Partial phrenic nerve block)
    - Laryngeal block causing hoarseness, coughing and dysphagia

Cervical Plexus Block

- Superficial Cervical Plexus Block
  - Anesthetize C2 to C4 branches
  - Midpoint of the posterior border of the sternocleidomastoid muscle at the intersection with the internal jugular vein
  - 5ml local anesthetic injected subcutaneously posterior and immediately deep to SCM.
  - Redirect needle superiorly and inferiorly along the border of the SCM and inject 5ml at each site.
  - Aspirate frequently and with each redirection to detect intravascular injection.



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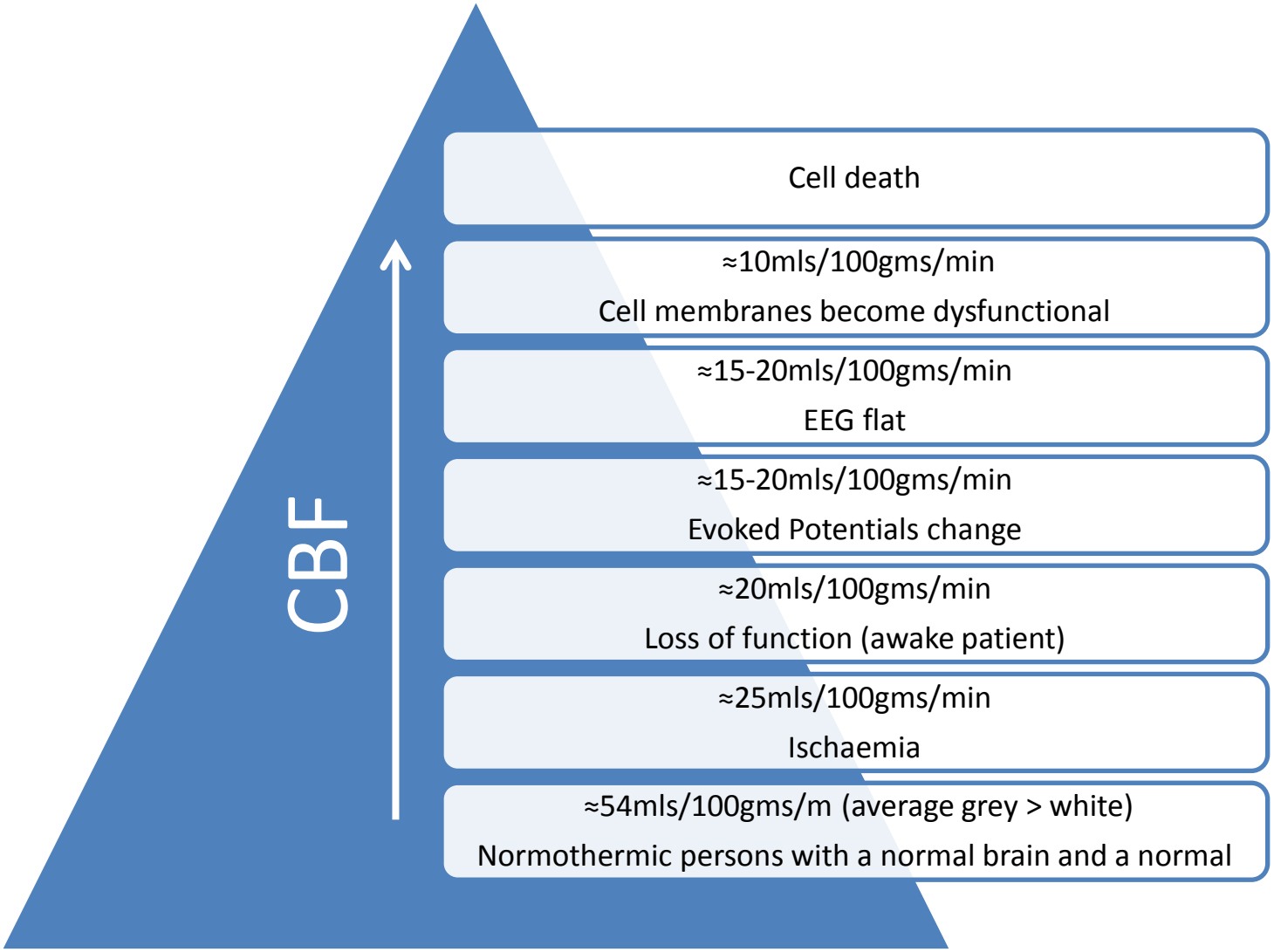
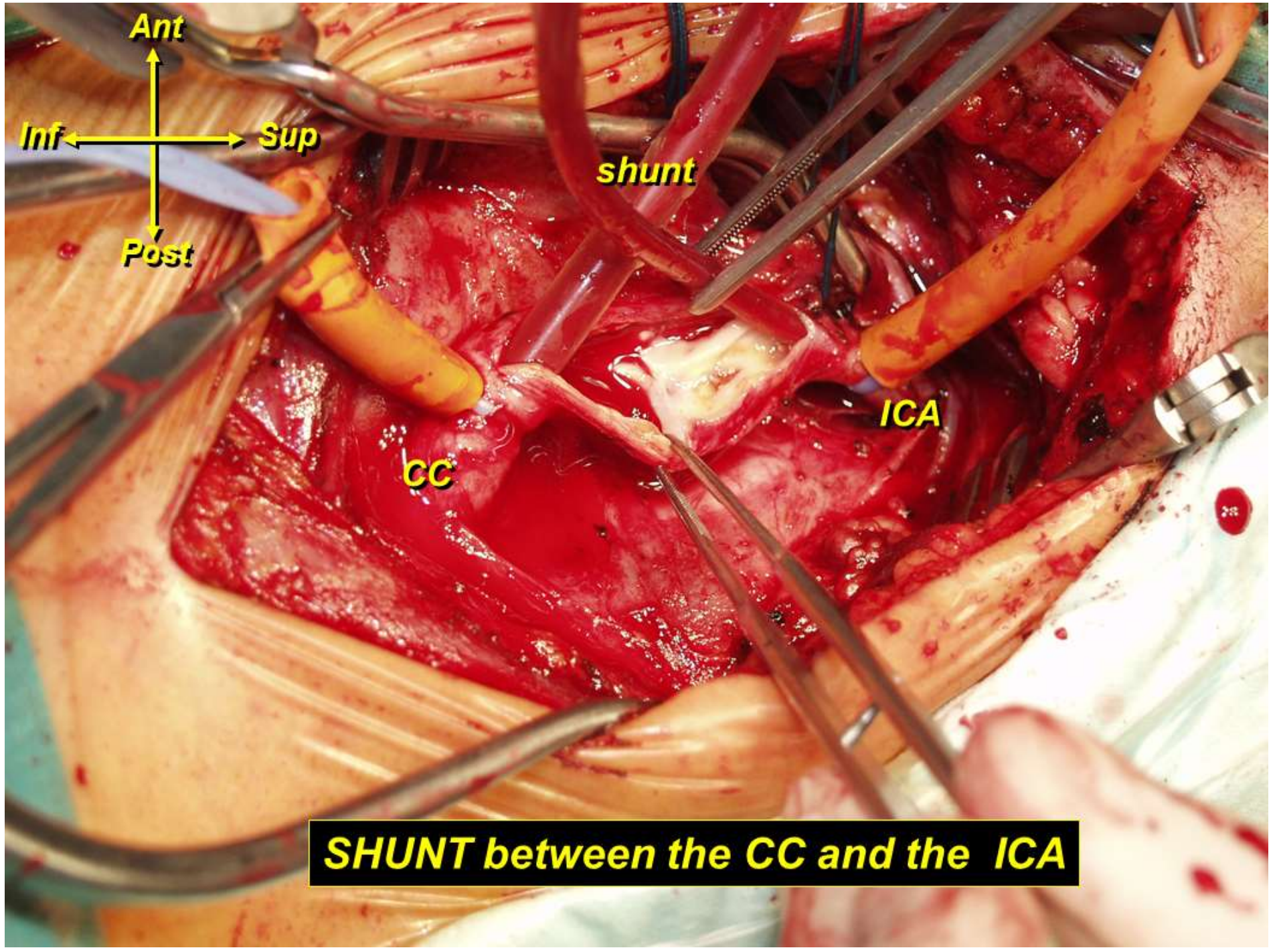
Cerebral Blood Flow



Cerebral Monitoring

- Why is it important?
  - Decreased cerebral blood flow determines / predicts the need for carotid shunt that may improve cerebral oxygen delivery
  - During carotid endarterectomy, the ischemic risk is correlated with the dependency between the cerebral circulation, the ipsilateral internal carotid artery, the cerebrovascular reserve of the contralateral cerebral hemisphere, as well as the presence and functioning of Willis polygon
- Why not shunt everyone?
  - Potential displacement of atheromatous debris, introduction of air embolism or thrombosis of shunt
  - Increases surgical time
  - Presence of shunt makes surgical field less than optimal
  - There are still 2 moments of low cerebral blood flow: placement and removal of the carotid shunt
  - 80-85% of patients tolerate well cross clamping of carotid artery, without requiring carotidian shunt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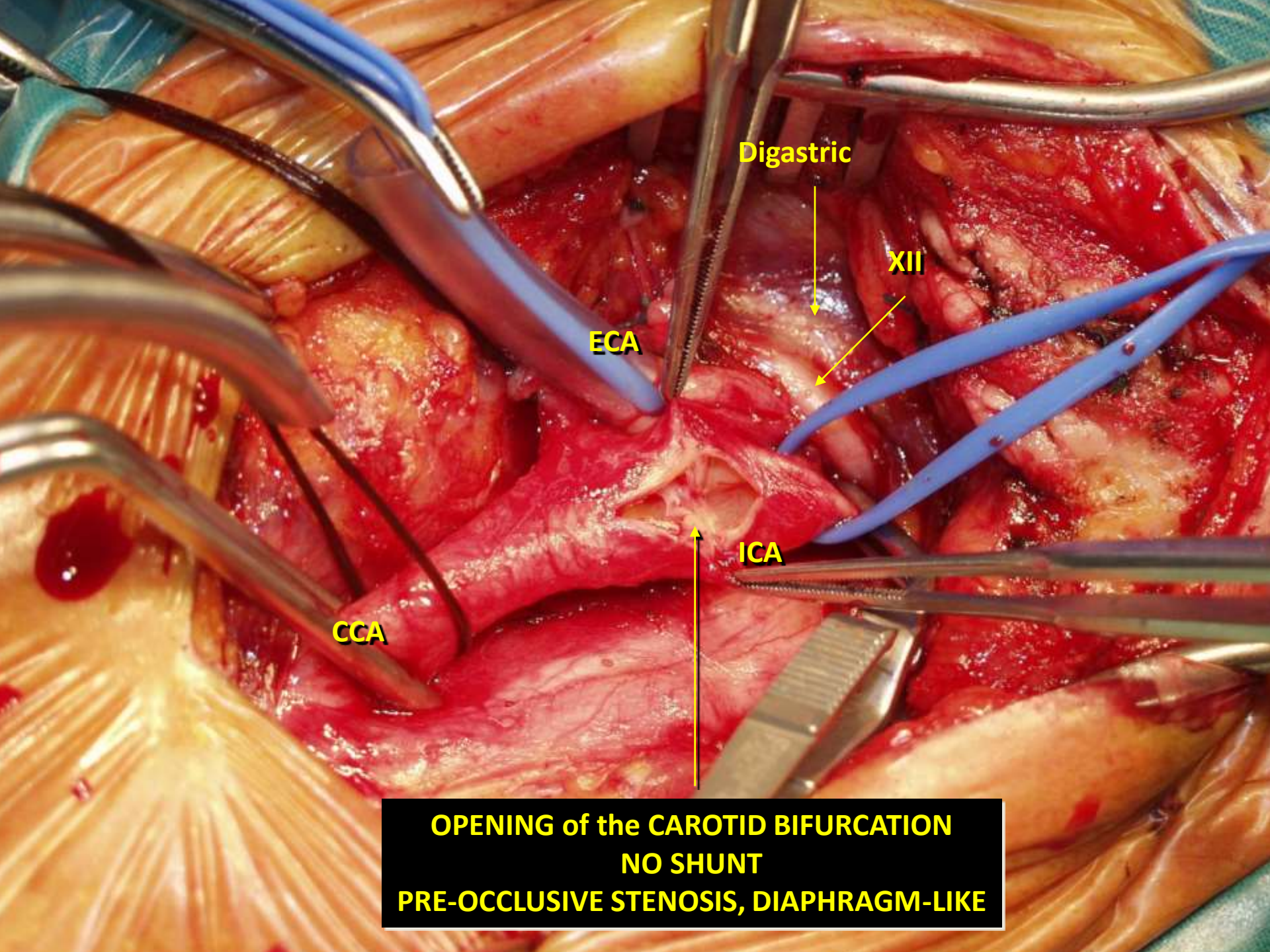


OPENING of the CAROTID BIFURCATION
NO SHUNT
PRE-OCCLUSIVE STENOSIS, DIAPHRAGM-LIKE

Cerebral Monitoring

Awake patient with locoregional anesthesia
Electroencephalography
Processed Electroencephalography (Bispectral Index)
Somatosensory Evoked Potentials
Transcranial Doppler Ultrasound
Carotid stump pressure
Jugular Oxygen Saturation
Conjunctival Oxygen Tension (pcj O2)
Cerebral Blood Flow Measurement with ^{133}Xe
Near Infrared Spectroscopy – Cerebral Oximetry

Awake patient - gold standard

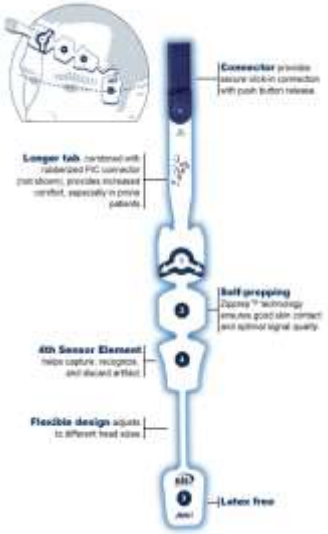
- Assessment of grip strength of the contralateral hand and responsive to verbal commands
- Disadvantages
  - low degree of patient comfort during surgery
  - sometimes it can convert to general anesthesia
- Neurological assessment is made early after surgery and throughout the ongoing surgical intervention especially during carotid clamping
- Indicators of the need for shunt placement or of the shunt malfunction:
  - Agitation, confusion
  - Drowsiness,
  - Seizures,
  - Muscle weakness in the extremities.

Electroencephalography

- Indirect method for determining the cerebral blood flow
- Limited sensitivity and specificity (respectively 69% and 89% in the study by Evans and respectively 73% and 92% in the study by Stoughton)
- EEG needs to be interpreted by neurologists, can have delays of 150“ before detecting ischemic phenomena - occurrence of cerebral ischemia is indicated by delta waves or disorganised rhythm
- EEG is influenced by diathermy, general anesthesia agents, $PaCO_2$, hypotension and previous ischemic phenomena
- Reflects ischemic impairments in the most superficial layer of cerebral cortex
- Laman et al (2005) clarified which EEG parameters are able to indicate the need for installing shunt
  - for anesthesia with isoflurane, SEF 90% is the best single parameter in order establish whether shunt is necessary or not and the 4 best derivations are F3-Cz, P4-Cz, C4-Cz and F7-Cz.
  - propofol sedation the best single parameter is the relative delta power and its 4 best derivation are F8-Cz, T4-Cz, C4-Cz and F4-Cz.

Process EEG – BIS, Entropy

- Bispectral Index / Cerebral Entropy
- Under general anesthesia, a suddenly modification of these scores after carotid clamping may be suggestive of cerebral ischemia
- Monitors only frontal lobes supplied by anterior communicating artery and can not estimate blood flow in the middle cerebral artery
- Is not a specific or sensitive method for detecting cerebral ischemia especially in patients with loco-regional anesthesia



Somatosensory Evoked Potentials

- Sensitivity on 60% and a specificity on 100%
- Exploring subcortical part of the brain but explores a more limited cortical territory than EEG
- Intraoperative strokes which occur outside the middle cerebral artery sometimes cannot be detected by SSEP
- Less reliable on patients with previous neurological deficit
- The parameter suggested by Haupt et al and subscribed by Rowed which best relates with the neurological outcome after CEA is a reduction of 50% of P25 width.

Transcranial Doppler Ultrasound

- Modality for measuring the ipsilateral mean middle cerebral artery velocity (VMCAi) during carotid endarterectomy
- Continuous and non-invasive measurement of cerebral blood flow - changes in velocity are proportional to cerebral blood flow changes based on the assumption that the vessel diameter (middle cerebral artery) and blood viscosity remain constant
- At carotid clamping is a initial decrease of the VCMAi followed by partial recovery in the next 15 seconds, the recovery that occurs due to brain self-regulation.
- A greater than 40% reduction of VMCAi determine the need for shunt placement.

Transcranial Doppler Ultrasound

- Benefits:
  - Allows the detection of embolic phenomena
  - Allows the detection of haemodynamic phenomena of hypo- or hyperperfusion and micro-embolisation phenomena
  - Identify the occurrence of the postoperative hyperperfusion syndrome with very good use for the immediate postoperative phase
- Disadvantages
  - Doppler signal is difficult to maintain during surgery
  - At 10% of patients skull conformation prevents transmission of ultrasound

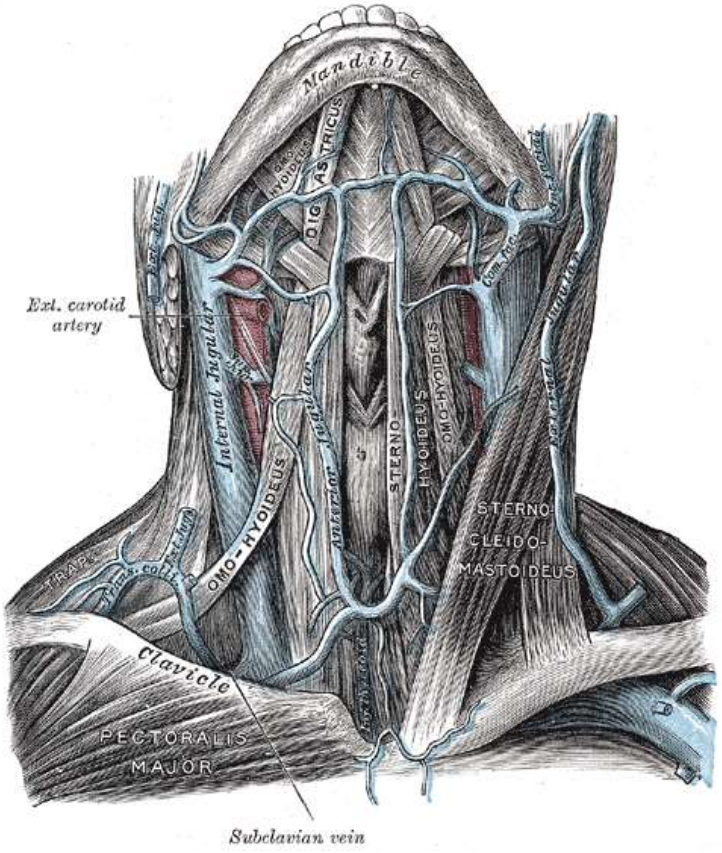
Carotid Artery Stump pressure

- Gives an estimate of collateral circulation above the crossclamp
- Carotid stump pressure tries to predict need for temporary shunt placement
  - > 50 mmHg adequate collateral circulation
  - < 40 mmHg need for temporary shunt placement
- PaCO2, body temperature and anesthetic agents influence vascular resistances
- Method used with caution in patients with preexisting ipsilateral stroke where there is a poor correlation between adequate perfusion pressure and cerebral ischemia

Kelly 1979 38% of pts with EEG changes had CSP >50mmHg
Kwan 1980 33% of pts who had LOC had CSP > 50mmHg
Mckay 1976 8% of pts with CSP > 50mmHg had rCBF < 18mls/100gm/m
Mcfarland 1988 CSP < 50mmHg 50% had no EEG changes
Brewster 1980 CSP < 50mmHg 53% had no EEG changes
Blackshear 1986 CSP < 25mmHg 77% had EEG changes but sensitivity only 40%
Harada 1995 CSP < 50mmHg 36% had EEG changes

Jugular Oxygen Saturation (SjO2)

- Very low sensitivity and specificity because venous blood may originate from different brain regions



http://en.wikipedia.org/wiki/File:Gray558.png

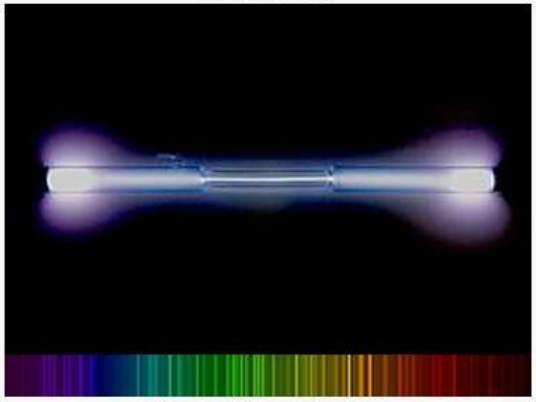
Conjunctival Oxygen Tension (pcj O2)

- Correlation between conjuctival oxygen tension and cortical oxygen tension
- Is not a specific or sensitive method for detecting cerebral ischemia

Cerebral Blood Flow Measurement with ^{133}Xe

- Three main limitations
  - Difficult to use routinely in the operating room
  - It has discontinuous feature
  - The inability of detecting the areas with low or absent flow because the detect or can only “see” the perfused tissue areas

colorless gas, exhibiting a blue glow when placed in a high voltage electric field



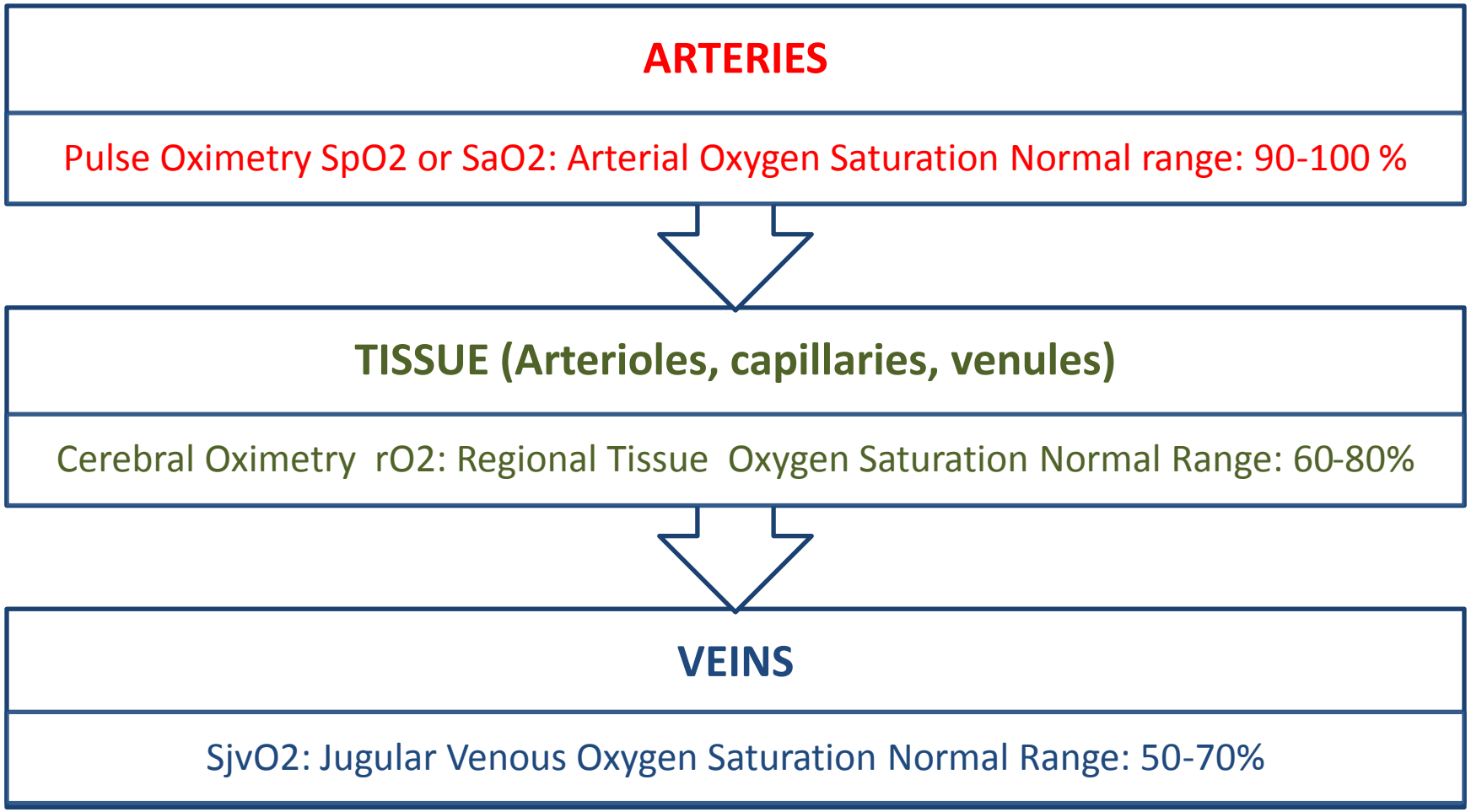
Spectral lines of xenon

http://en.wikipedia.org/wiki/Xenon

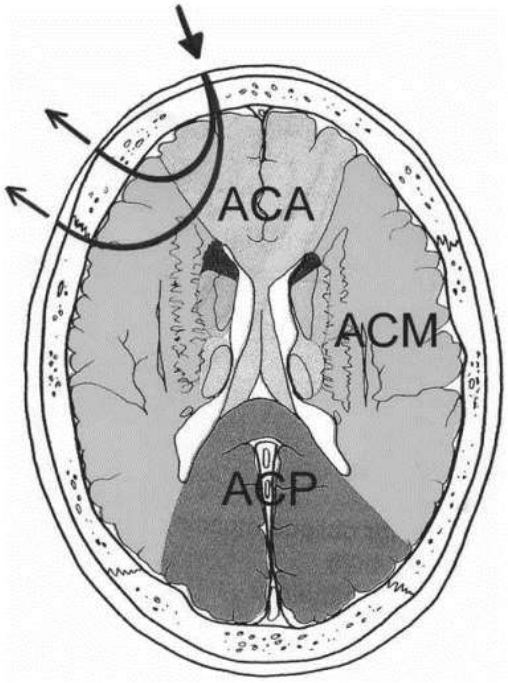
From Pulse Oximetry to Cerebral Oximetry

- Oxygen Saturation SO2= Oxy-Hemoglobin / (Total Hemoglobin) X100%
- Both are based on Beer-Lambert's Law that describes light absorption
- Pulse Oximetry: Two wavelengths. Using light loss (Systole – Diastole) to calculate only signals due to pulsation of arterial blood to derive arterial O2 saturation.
- Cerebral Oximetry: Looking into entire nonpulsating field to derive tissue O2 saturation. It requires precise light sources and more wavelengths to account for light lost from elements in addition to Oxy- and Deoxy-Hemoglobin.
- Cerebral oxygen saturation is biased toward venous oxygen saturation because on average, cerebral blood flow is com-posed of 75% venous and 25% arterial blood

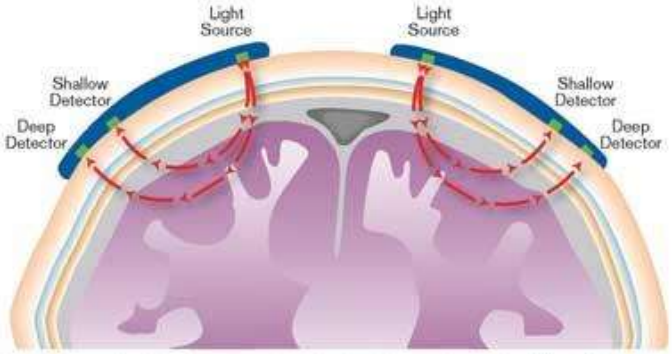
Transcranial Cerebral Oximetry



Transcranial Cerebral Oximetry



- Two sensors placed bilaterally on forehead - differentiates changes of non-ischemic source of rSO2 (low blood pressure that causes global hypoperfusion) from ischemic changes of rO2 during carotid clamping.
- Light from light source penetrates the scalp and the skull to reach the gray matter in the brain
- Closer detector collects reflected light from extracerebral tissue only
- Further detector collects reflected light from entire path.
- Patented algorithm solves the hemoglobin concentration while minimizing influence from extracerebral tissue.

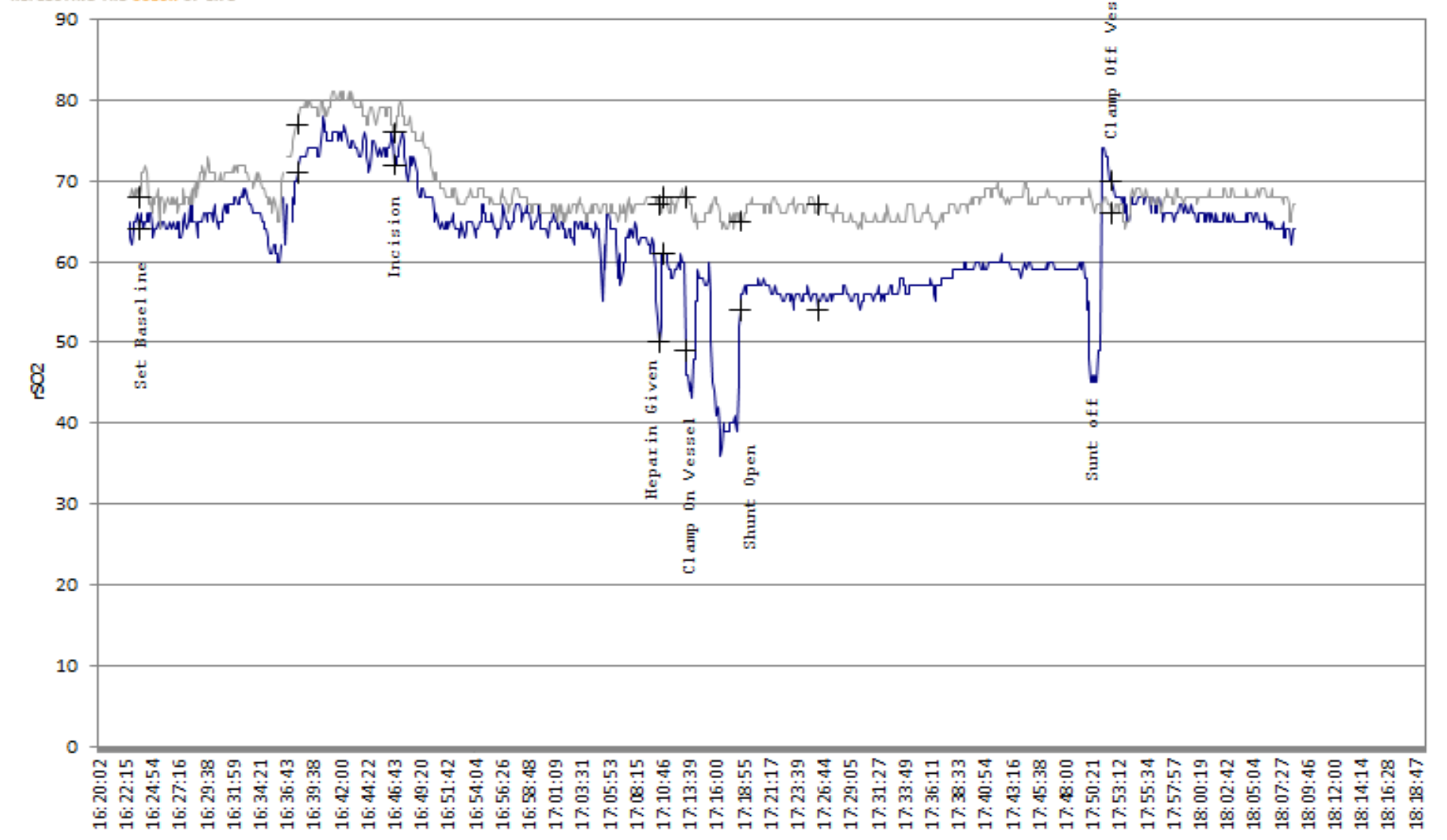


Transcranial Cerebral Oximetry

- INVOS measure the regional hemoglobin oxygen saturation of blood in the brain of an individual
- The sign of low cerebral blood flow is the decrease of rSO2 > 20% compared to the baseline value and not the decrease of rSO2 from a set value (e.g. rSO2 <60)
- Useful also in postoperative monitoring - decrease of rSO2 postoperatively immediately after carotid endarterectomy can demonstrate early carotid artery reocclusion

SOMANETICS
CEREBRAL/SOMATIC
INVOS OXIMETER
REFLECTING THE COLOR OF LIFE®

130409N_IVAN D - RealTime



Real Time Data from miercuri, septembrie 4, 2013

Version 3.3

L R .

Table 2. Cutoff Values

	100% Sensitivity			100% Specificity			Best Fit				
	Cutoff	Specificity	PLR	Cutoff	Sensitivity	NLR	Cutoff	Sensitivity	Specificity	PLR	NLR
TCD_{min}	25 cm/s	69%	3.22	6 cm/s	22%	0.78	25 cm/s	100%	69%	3.22	0.00
$TCD_{\%}$	48%	86%	7.25	70%	78%	0.22	48%	100%	86%	7.25	0.00
$NIRS_{min}$	59	47%	1.89	36	17%	0.83	59	100%	47%	1.89	0.00
$NIRS_{\%}$	13%	64%	2.77	34%	8%	0.22	20%	83%	83%	5.00	0.20
Stump pressure	40 mmHg	75%	4.0	33 mmHg	58%	0.42	40 mmHg	100%	75%	4.00	0.00
SEP	100%	0%	1.0	25%	18%	0.82	50%	82%	57%	1.91	0.32

Cutoff values and the corresponding sensitivity, specificity, negative likelihood ratio (NLR), and positive likelihood ratio (PLR) of the investigated monitoring parameters.

% = relative reduction compared with baseline; min = minimum during clamping; NIRS = near-infrared spectroscopy; SEP = somatosensory evoked potentials; TCD = transcranial Doppler sonography.

Anesthesiology 2007; 107:563–9

Accuracy of Cerebral Monitoring in Detecting Cerebral Ischemia during Carotid Endarterectomy

A Comparison of Transcranial Doppler Sonography, Near-infrared Spectroscopy, Stump Pressure, and Somatosensory Evoked Potentials

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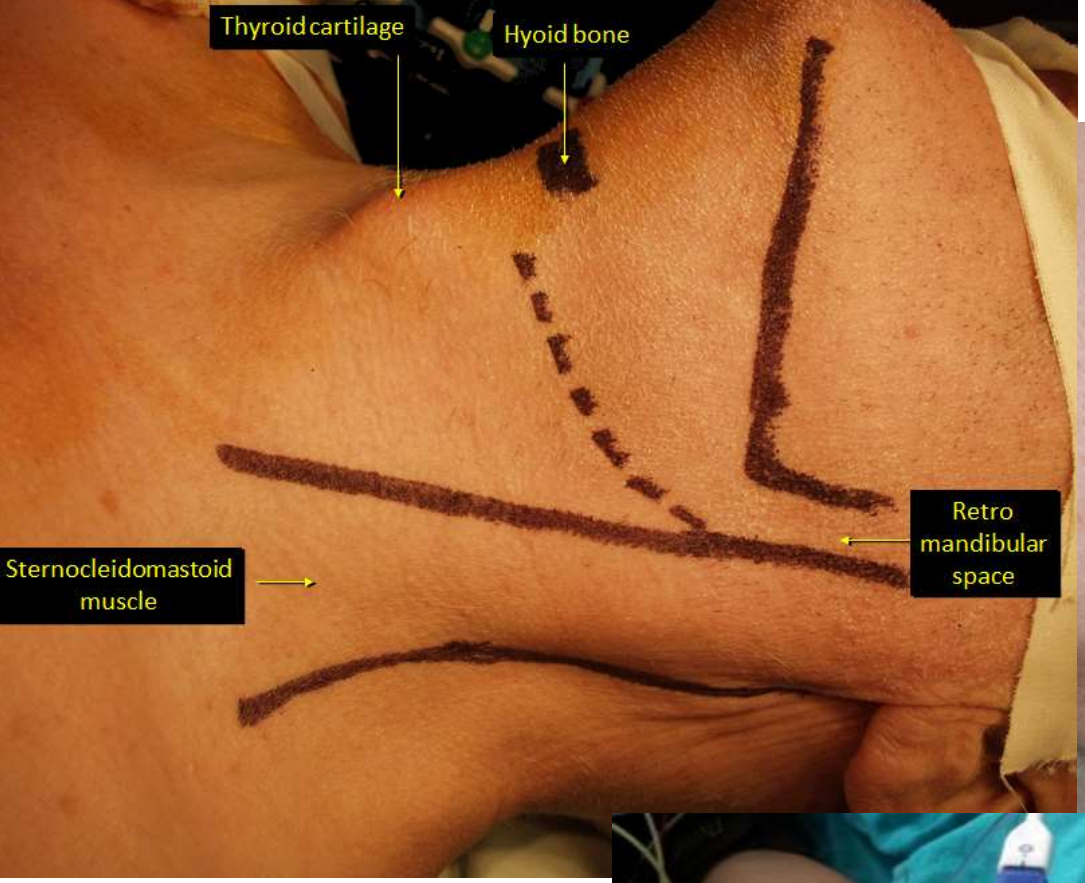
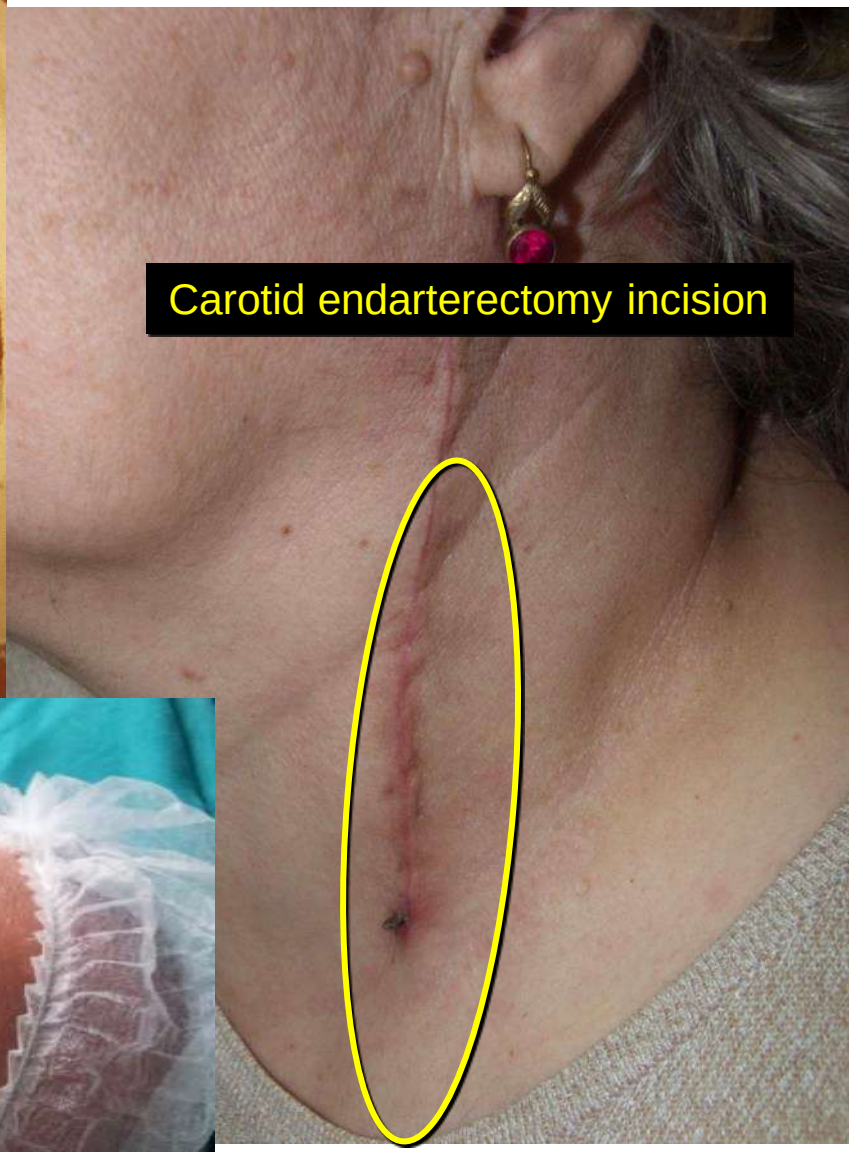
University Emergency Hospital Bucharest
Cardiovascular Department

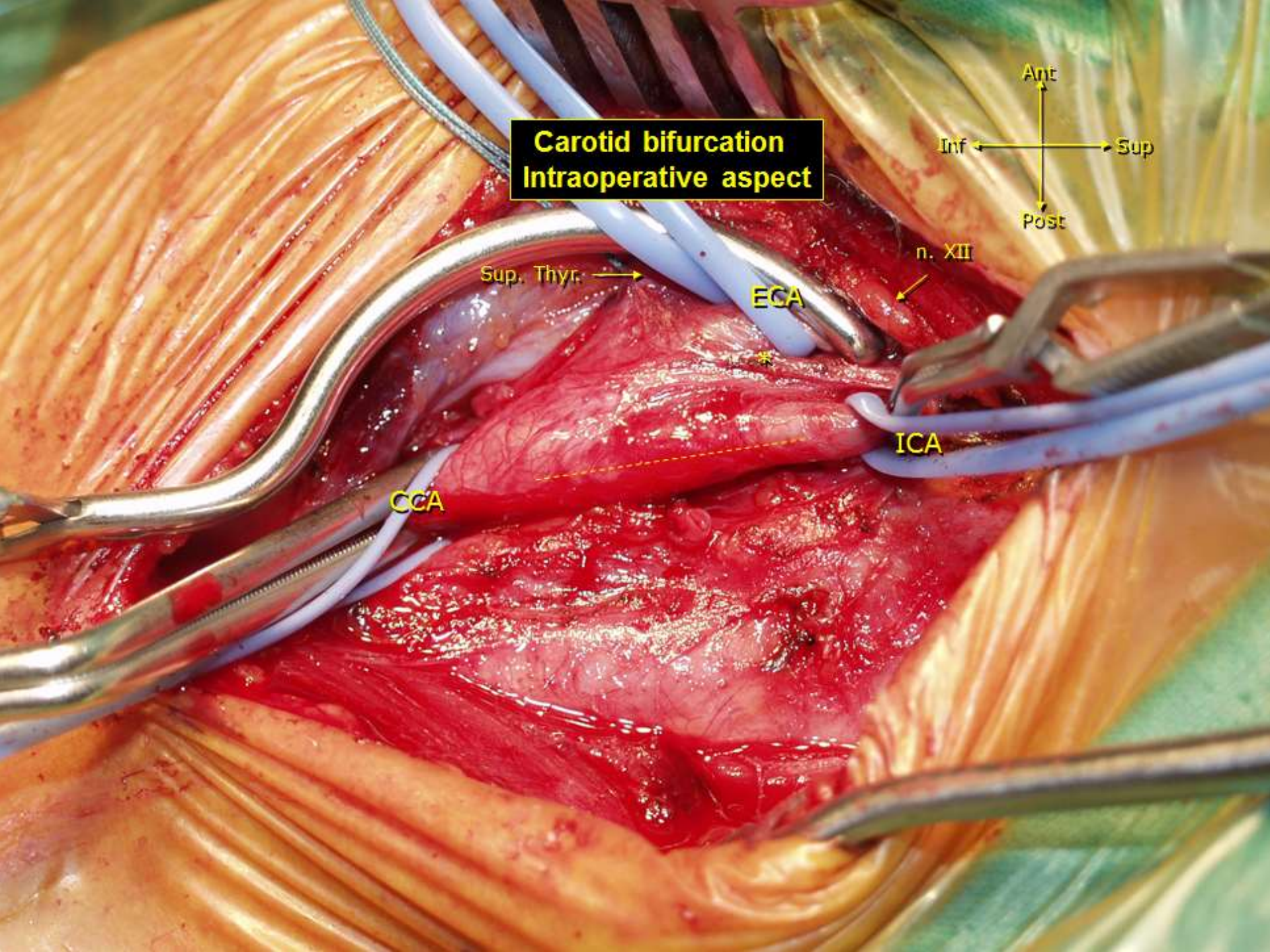
- Locoregional Anesthesia - Cervical Plexus Block

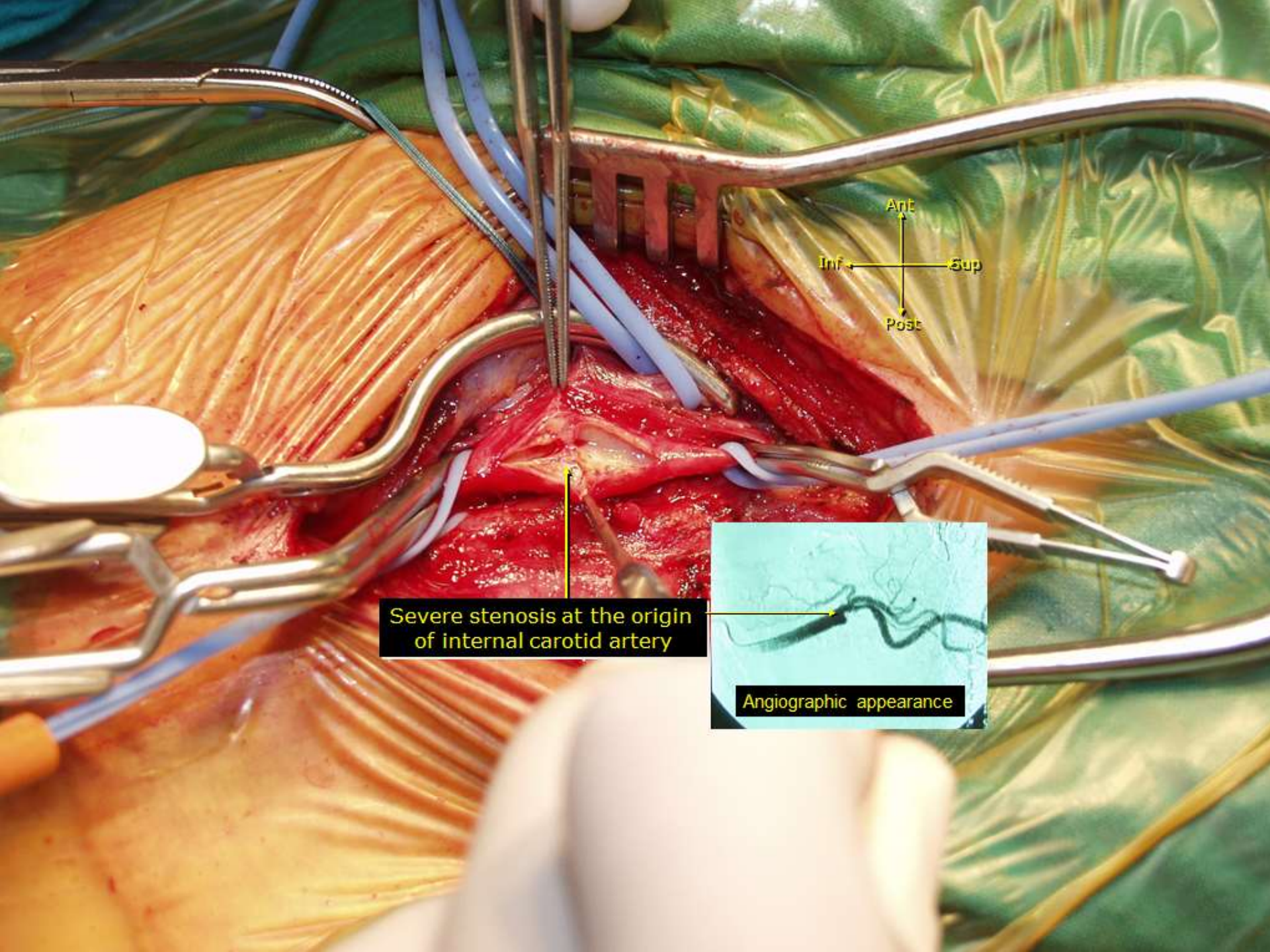
- Monitorizare intraoperatorie clinica + INVOS

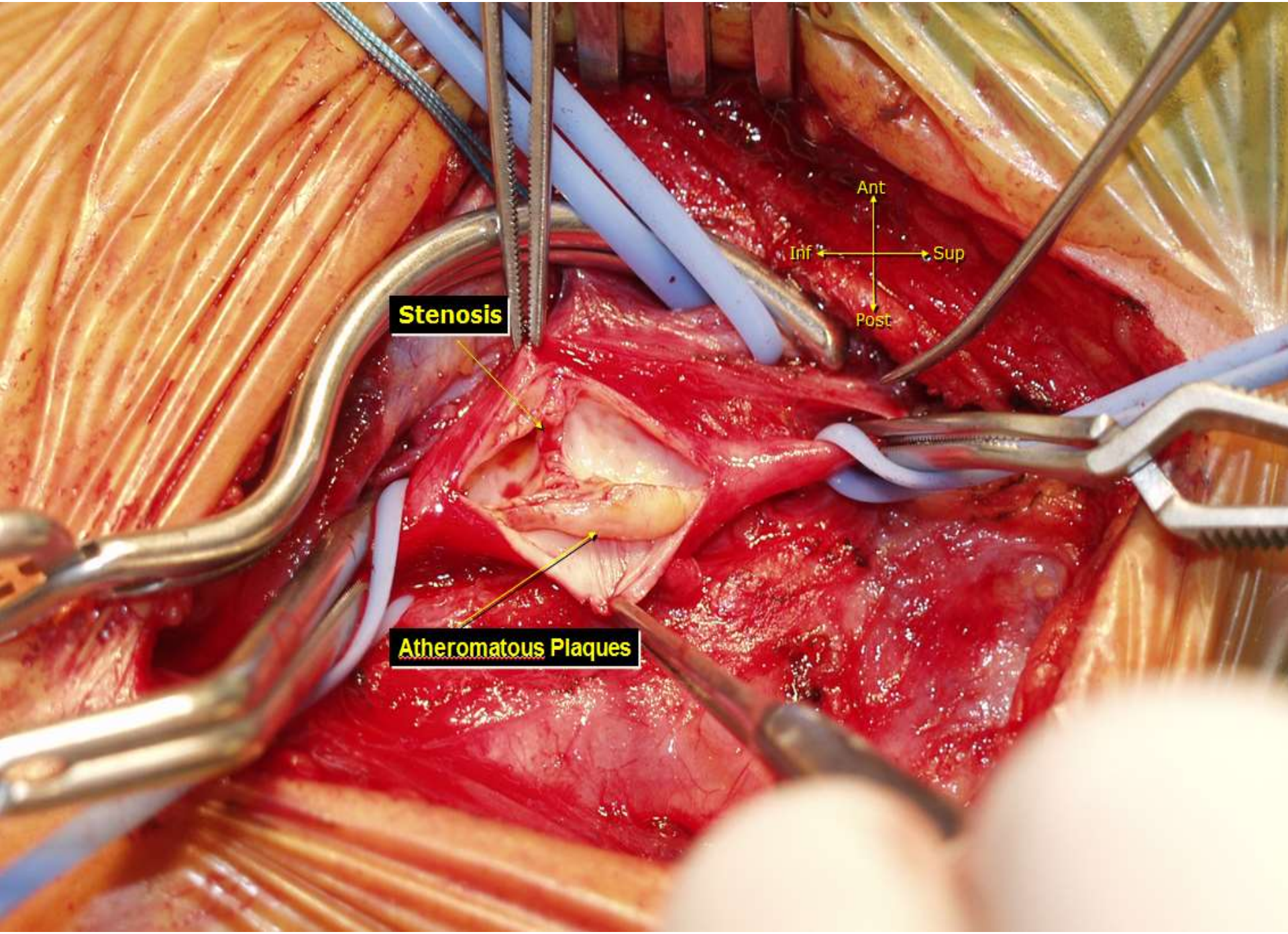


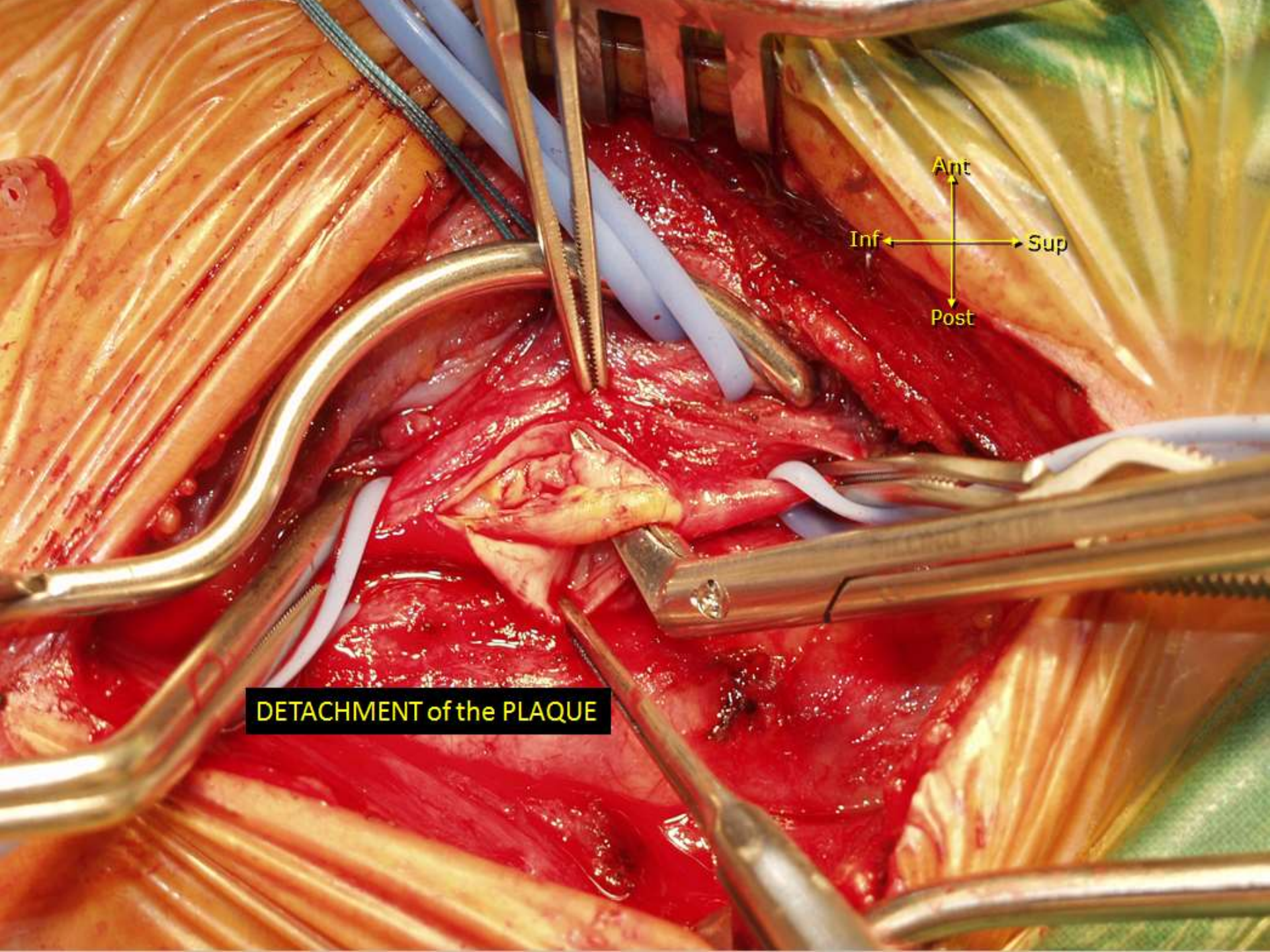


INVOS monitor with awake patient

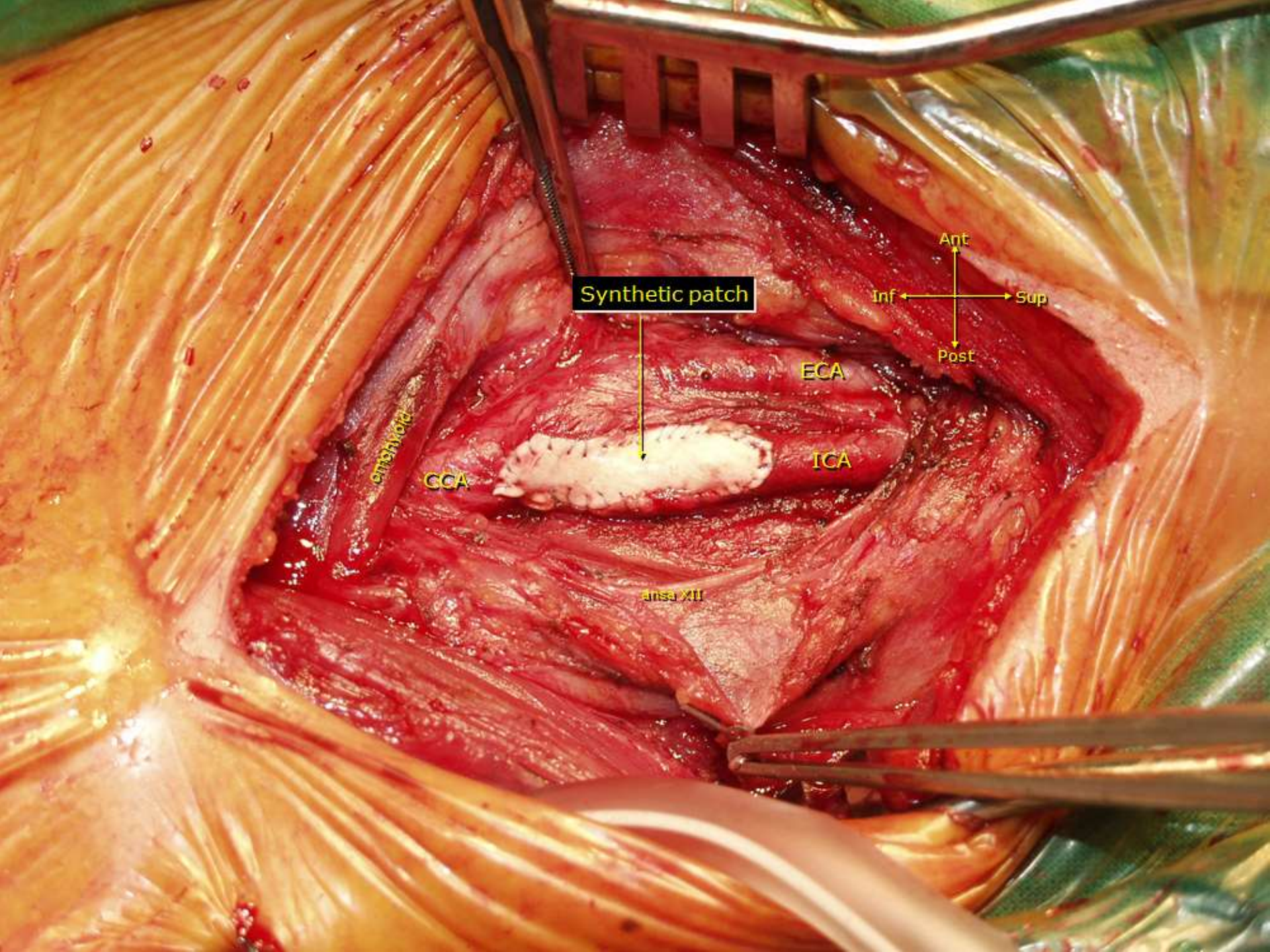

Carotid bifurcation
Intraoperative aspect
Ant
Inf
Sup
Post
n. XII
Sup. Thyr.
ECA
ICA
CCA


Ant
Inf
Sup
Post
Severe stenosis at the origin of internal carotid artery
Angiographic appearance


Ant
Inf
Sup
Post
Stenosis
Atheromatous Plaques


Ant
Inf
Sup
Post
DETACHMENT of the PLAQUE


Ant
Inf
Sup
Post
Appearance after removal of plaque


Synthetic patch
Ant
Inf
Sup
Post
ECA
ICA
CCA
ansa XII

ATHEROMATOUS PLAQUES AFTER THE EXCISION

DATA

	Total	Without shunt	With shunt	General anesthesia	Cervical block plexus
2006	7	5	2	3	4
2007	25	21	6	21	4
2008	74	68	6	74	0
2009	102	92	10	33	69
2010	91	82	9	12	79
2011	105	94	11	2	103
2012	120	108	12	11	109
2013	50	41	9	10	40
Total	574	511	65	166	408
Percent		89%	11%	28,90%	71,10%

DATA

	Complications (number)	Complications (percent)	Locoregional anesthesia complications	Death
2006	0	0	0	0
2007	1	4%	0	0
2008	3	4,05%	0	2
2009	8	7,80%	0	4
2010	2	2,10%	1	0
2011	3	2,80%	0	0
2012	4	3,30%	2	0
2013	1	2%	1	0
Total	22		4	6
Percent		3,80%	0,90%	1,04%

Carotid Endarterectomy complications:

- Hemorrhagic Stroke – 5 patients
- Ischemic Stroke – 5 patients
- Transient ischemic attack – 1 patient
- Cardiac complication – 3 patients
- Neck hematoma – 4 patients
- Shunt related injuries – 2 patients (carotid disection and embolic stroke)
- Nerve Injury (hypoglossal nerve) – 2 patients

Cervical Plexus Block complications:

- Seizures – 3 patients
- Apnea – 1 patient

Conclusions

- Cerebral monitoring system used in carotid endarterectomy must detect early and exact appearance of cerebral ischemia
- No single monitoring method provides 100% sensitivity and 100% specificity compared with awake patient monitoring
- Don’t forget the baseline
- Using two types of monitoring decreases the rate of false positives and fals negatives results.

An experienced surgeon and an experienced anesthesist